Human Health and Ecological Risk Assessment for the Use of Wildlife Damage Management Methods by USDA-APHIS-Wildlife Services

Chapter XII

Use of Lead in Wildlife Damage Management

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USE OF LEAD IN WILDLIFE DAMAGE MANAGEMENT

EXECUTIVE SUMMARY

Lead is a chemical element that has a variety of usages and is used in ammunition (shot, bullets, or pellets) and fishing sinkers. The USDA-APHIS-Wildlife Services (WS) Program uses lead ammunition for aerial and ground shooting in certain Wildlife Services (WS) programs, and minimal amounts of fishing sinkers for a fish reduction program on the Columbia River. WS use of lead has declined as non-lead substitutes have become available, researched, and determined to be effective; however, the use of non-lead shot is dependent on availability and whether non-lead ammunition can be safely used to address wildlife damage management actions. Lead ammunition use as a percentage of total ammunition used by WS varies from state to state; however, total lead ammunition use in WS operational activities as a percentage of total lead use from ammunition in the United States is very low (~0.002%). The use of lead ammunition and weights in WS is expected to continue to decline. A need for additional investigation into the use of non-lead ammunition is noted (APHIS 2012, Caudell et al. 2012).

Risk to human health from lead ammunition (e.g., through consumption of carcasses) is minimized by training WS personnel and the WS carcass disposal policy. In addition, most wildlife damage management conducted for animals such as deer, swine, rabbits, or migratory game birds (e.g., ducks and native doves) that have the highest likelihood of being consumed are conducted mostly on private or secured public lands (e.g., airports), where public access is restricted.

Ecological impacts to aquatic resources are also expected to be minimal based on the low potential for exposure to most aquatic biota. In terrestrial systems the greatest potential for exposure and risk is to nontarget vertebrates that consume lead ammunition fragments inadvertently from the ground or from scavenging carcasses. Risks to nontarget animals are reduced when carcasses are removed and when non-lead ammunition can be used. Lead ammunition degrades slowly in terrestrial and aquatic environments. Its environmental fate once it degrades suggests that the small amounts of lead that may be present in the environment as a result of WS activities would not have an adverse impact to soil, air or water quality. Regardless, WS is gravitating towards the use of non-lead ammunition and fishing sinkers in wildlife damage management and remains committed to working with the U.S. Fish Wildlife Service, other federal agencies, and state agencies to proactively manage lead exposure to fish and wildlife.

Table of Contents

1 INTRODUCTION

This human health and ecological risk assessment provides a qualitative evaluation of potential risks and hazards to human health, the environment, and nontarget fish and wildlife as a result of exposure to lead from the proposed use of lead ammunition (i.e., shot, bullets, or pellets) for aerial or ground-based shooting and fishing weights (sinkers) for fishing by the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Wildlife Services (WS) Program. This risk assessment provides: (a) problem formulation to identify hazards and evaluate potential exposures by identifying possible exposed populations and exposure pathways; (b) a dose-response assessment; and (c) a risk characterization which combines information from the exposure and toxicity assessments to assess the potential for adverse human health and ecological risks. A discussion of the uncertainties associated with the risk assessment and cumulative effects is also included.

The methods used to assess human health effects follow regulatory guidance and methods, and conform to other Federal agencies guidance, such as the National Research Council (1983) and U.S. Environmental Protection Agency (USEPA), Office of Pesticide Programs (USEPA 1989, 2017c). The methods used to assess the ecological risk to nontarget species generally follow USEPA (1989, 2017c) ecological risk assessment methods. The nonchemical or non-lead hazards from aerial or ground-based shooting are evaluated separately in other risk assessments including “The Use of Aircraft in Wildlife Damage Management by WS” and “The Use of Firearms in Wildlife Damage Management by WS.”

WS uses lead, as well as non-lead, ammunition in wildlife damage management (WDM) including ground-based, aerial and harassment shooting, and shooting to euthanize animals caught in nonlethal snares and traps. WS selects ammunition types based on availability, relevant laws and regulations, and the practical, humane, effective, and environmentally safe ammunition for each specific project and location. Additionally, WS uses minor amounts of lead in a northern pikeminnow reduction project in the form of lead sinkers and some of these weights are lost while fishing.

1.1 Use Pattern of Lead

Firearm use is tracked in the WS Management Information System (MIS[1]) for many WS WDM operations. However, the MIS does not track the type of firearm or ammunition used during WDM operations, the number of shots fired, or all firearm usage. Therefore, lead usage is unknown, but it can be estimated based on conservative assumptions. In general, the typical use pattern of firearms for different WDM operations is similar. For example, the vast majority of birds are taken with shotguns, large mammals with rifles, and small mammals with .22 caliber rifles. Air rifles (pneumatics) are tracked separately in the MIS and are used mostly for small mammals and birds. Animals caught in other WDM methods such as cage and foothold traps, and cable restraints are generally euthanized with a gunshot to the brain, typically accomplished with a .22 caliber pistol. The amount of lead varies considerably with the type of ammunition used, the WDM operation being conducted, and legal requirements (e.g., migratory bird permits require the use of lead-free shot); most shotgun use is conducted with lead-free ammunition.

[1] MIS - Computer-based Management Information System used for tracking APHIS-WS WDM activities nationwide. MIS reports will not be referenced in the text or Literature Cited Section because MIS reports are not kept on file. A database is kept that allows queries to be made to retrieve the information needed.

From FY11[2] to FY15, WS used several types of firearms, pneumatics, and fishing that used lead in WDM as the primary method or possibly to euthanize animals caught with other methods (Table 1). Firearms[3] used by WS included shotguns and rifles from the ground and air, and pistols and pneumatics from the ground. If the primary method was a firearm or pneumatics, it was recorded as "firearm" or "pneumatics" in the MIS. However, many animals are taken with other WDM methods such as foothold and cage traps and euthanized with firearms, but the firearm use is not recorded. Additionally, WS conducts a fishing program for northern pikeminnows that uses lead "sinkers" that can be lost; the amount of lead for this is not included in Table 1 but estimated from purchases by the supervisor of the program. Table 1 gives a breakdown of the animals taken with the different methods.

Table 1. The annual average number of target and nontarget animals taken with the variety of firearms used by WS during WDM from FY11 thru FY15.

ANNUAL AVERAGE SPECIES TAKEN WITH FIREARMS			
	TARGET		NONTARGET
Method	**Killed**	**Dispersed**	**Killed**
Firearm Was Method of Take or Harassment[1]			
Shotgun from Ground (12 gauge shot)	317,303	4,338,717	0
Shotgun from Air (12 gauge shot)[1]	41,747	0	0
Rifle (large caliber bullets)	29,189	1,490	0.2
Rifle (.22 caliber bullets)	35,026	8,329	0.4
Pneumatic Rifle (pellets)	29,287	124,729	0
Method of Take Was Traps or Snares, and Animals Possibly Euthanized with Firearms[2]			
Large Animal (large caliber rifle/pistol)	15,083	-	127
Small Animal (.22 caliber rifle/pistol)	51,234	-	1,186
TOTAL	**522,955**	**4,473,265**	**1,314**

1=Addressed in Use of Firearms, Aircraft, and Dogs Risk Assessments; 2=Addressed in Use of Cage Traps, Foothold Traps, and Cable Restraints Risk Assessments, but does not include animals euthanized with euthanasia drugs.

WS has no way to determine the exact amount of lead that was used conducting WDM due to how that type of information is collected, but it can be estimated. All of the WS State Programs were asked the composition of ammunition used for various WDM activities in their state. It was determined that most shotgun use from the ground used lead-free shot, whereas most was lead-based for aerial hunting (safety factor – ricochet is a problem for aircraft); rifle and pistol ammunition, including pellets from air rifles, varied, but more was lead-based. It was assumed that 2 shots were fired for each animal taken with ground-based shooting and 3 shots for those taken with shooting from aircraft, regardless of the firearm type used. It was assumed that only one shot was taken to euthanize an animal caught with another method such as a foothold trap. For dispersal, it was assumed that one shot was fired for every 100 flocking birds hazed, 10 for loosely flocking birds and herding mammals, and 1 shot for solitary mammals and birds, and all reptiles. These are inherently conservative as these assumptions likely overestimate the number of shots fired (e.g., shooting small flocking birds with shotguns often results in many being taken with a single shot, most animals on the ground are taken with a single shot, and many animals caught in some WDM devices such as neck snares are taken lethally and are not euthanized with a firearm). Weights of ammunition varies, but a standard weight of 1.2 ounces of lead for each shotgun shell, 0.3 ounces for each large caliber rifle bullet, 0.1 ounce for each .22 caliber bullet, and 0.03 ounces for each pellet. It was assumed that most birds were taken with shotguns, large mammals (average adults 20 pounds or more) were taken with large caliber rifles, small mammals, reptiles, amphibians, and birds at night (with spotlights/night vision) were taken with

[2] FY11 equals the federal Fiscal Year 2011 which is October 1, 2010-September 30, 2011 (the year is denoted by FY11, FY12, and so on and is the federal Fiscal Year for 2011, 2012, and so on.

[3] The MIS does not separate the types of firearms used (i.e., shotgun, large or small caliber rifle) and whether or not an animal is subsequently euthanized with a firearm such as a small caliber pistol if taken with another method such as a cage or foothold trap.

.22 caliber rifles. Animals in traps were taken with .22 caliber pistols or rifles, except large mammals (40 pounds or greater) were assumed to be shot with large caliber rifles or pistols. For the sake of the estimate, it was assumed that all carcasses were left in the field, thus the lead would be available in the environment. These estimate parameters provided weights for all WDM activities and an estimate of the lead used.

Based on the above assumptions, WS used an estimated average of 11,080 lb. (5.6 tons[4]) of lead annually from FY11 to FY15 (Table 2). This average is minimal when compared to the U.S. use of lead from ammunition, shot and bullets (0.002% of other use in U.S.), based on USGS (2011) data. Conservative WS lead use in each individual state varied (Table 2) with most use in Texas (2,743 lbs.), Oklahoma (1,881 lbs.), and Wyoming (996 lbs.) and least in Washington, D.C. (0 lbs.), Delaware (0 lbs.), and New Hampshire (0.2 lbs.).

Table 2. The estimated average annual use of lead by WS in wildlife damage management from FY11 to FY15.

State	Total lb.	State	Total lb.	State	Total lb.	State	Total lb.
AK	3.5	**ID**	89.4	**NC**	68.3	**RI**	49.7
AL	274.9	**IL**	106.4	**ND**	361.3	**SC**	24.8
AR	2.8	**IN**	1.9	**NE**	25.4	**SD**	1.0
AZ	10.7	**KS**	277.1	**NH**	0.2	**TN**	97.4
CA	229.1	**KY**	73.5	**NJ**	2.2	**TX**	2743.0
CO	462.8	**LA**	310.6	**NM**	384.3	**UT**	461.3
CT	31.6	**MA**	46.1	**NV**	21.1	**VA**	208.0
DC DE	0	**MD**	4.0	**NY**	11.8	**VI**	7.3
FL	43.2	**ME**	3.7	**OH**	51.3	**VT**	1.2
GA	40.2	**MI**	6.1	**OK**	1,881.1	**WA***	221.5
GB	4.1	**MN**	21.1	**OR**	321.7	**WI**	7.0
GU	6.5	**MO**	28.9	**PA**	39.2	**WV**	5.2
HI	61.9	**MS**	14.6	**PR**	33.5	**WY**	996.3
IA	11.1	**MT**	889.3	**WS Total**		**11,080.2 lb.**	

*Includes 150 lbs. of lead sinkers conservatively estimated to be used annually in a fish removal program on the Columbia River since this was an unknown but tracked more precisely in FY16 with 118 pounds lead sinkers used.

To put this into perspective at the landscape scale, WS worked on an average of 18.7 million acres annually in Texas for FY11 to FY15 (31.7 million acres for the cumulative time period from FY11 through FY15[5]). Thus, WS added an estimated average of 67 mg lead/acre for WDM activities annually; WS worked on an average of 11.1% of the land area in Texas (18.9% of the state was worked from FY11 to FY15 cumulatively or 196 mg/acre for the 5-year period). In Oklahoma from FY11 to FY15, WS worked on an average of 7.0% of the land area and averaged 282 mg/acre for WDM activities annually (19.7% of the state was worked cumulatively from FY11 to FY15 or 501 mg/acre for a 5-year period).

2 PROBLEM FORMULATION

WS uses firearms in WDM activities and uses the best ammunition available for a specific firearm, especially since WDM activities require accuracy and precise shot placement, especially in certain locations and areas such as suburban and airport settings, rocky terrain where aerial shooting is involved, or when shooting from greater distances and in relatively populous or otherwise sensitive settings. Lighter non-lead bullets can reduce accuracy when discharged through rifle

[4] The actual amount of pure lead used would be estimated to be 5.5 tons since shot, bullets, and pellets are actually alloys with shot and pellets about 97% lead and rifle bullets about 90% lead.

[5] During this time, WS conducted WDM on many of the same properties, thus the cumulative total is a fraction of the total if added for 5 years.

barrels that have twist rates designed for conventional lead-based bullets. Non-lead rifle ammunition can also result in "non-frangible bullet pass-through," resulting in failure of the bullet to convey its full energy to the target animal. In addition to the increased risk of hitting an unintended target, non-frangible bullet pass-through also increases the likelihood that the target animal will not be fatally wounded and, thus, would not be as humane as conventional bullets (APHIS 2012, Caudell et al. 2009, 2012). As new lead-free ammunition becomes commercially available, WS personnel assess the effectiveness of the ammunition as applicable; the WS Firearms Committee sends out memoranda regarding new information on lead substitutes as it becomes available.

WS uses non-lead ammunition to mitigate or minimize the effects of lead ammunition on the environment, wildlife, and public health in compliance with Federal and State regulations. Most often, WS uses steel or other non-lead shot to remove birds since most Migratory Bird Treaty Act permitted activities typically require its use, especially on waterfowl production and wintering areas, wetlands, U.S. Fish and Wildlife Service refuges, and National Park Service lands. Non-lead shot, bullets, and pellets may also be required in some areas to prevent ingestion by threatened and endangered species such as the California condors (*Gymnogyps californianus*) during carcass consumption. WS, however, uses non-lead shot for a variety of WDM activities. WS observations of non-lead ammunition for WDM in terms of safety and performance suggest that lead ammunition likely remains the best alternative under certain circumstances, but not always (APHIS 2012). For example, while shooting from an aircraft, steel shot is more likely to ricochet off hard surfaces, and WS aircraft, personnel, or other unintended targets can be struck, thus, presenting unacceptable risk to human safety (APHIS 2012); ricochets have damaged WS aircraft. However, further research is called for in order to take advantage of non-lead types to the greatest extent possible (APHIS 2012, Caudell et al. 2012), as many seem to perform as well as lead for many applications (Knott et al. 2009, McCann et al. 2016).

2.1 Chemical Description and Product Use

Lead ammunition includes lead shot, bullets, and pellets. An average lead shot contains 97% metallic lead, 2.5% antimony, and 0.5% arsenic, a lead pellet contains up to 97% metallic lead, 2% antimony, 0.5% arsenic, 0.5% nickel, and jacketed bullets contain up to 90% metallic lead, 9% copper, and 1% zinc (Tanskanen et al. 1991, Scheuhammer and Norris 1995, Scheetz and Rimstidt 2009). The amount of lead varies in ammunition based on the type of firearm and size of the shell, shot, bullet, or pellet. More specifically, the amount of lead for shotguns varies with the gauge, the length of the shell used, and the shot size, and for rifles, pistols, and air guns, the caliber, the type of bullet or pellet, and the grains (weight) of the bullet or pellet used.

WS uses ground and aerial shooting in various WDM activities throughout the United States and these typically occur over a wide geographic area; for example, in Texas from FY11 to FY15, WS worked on an annual average of almost 19 million acres and cumulatively in the five-year period on 32 million acres. Shooting may include the use of various caliber and gauges in rifles, pistols, air guns and shotguns, depending on the target animal and other site-specific conditions. In all situations, WS aims to use the fewest number of shots on targeted animals for humaneness reasons and to limit environmental lead and non-lead ammunition. Lead ammunition use by WS in WDM activities is minimal compared to lead use at firing ranges and in recreational hunting and fishing.

2.2 Physical and Chemical Properties

Lead, CAS Number 7439-92-1, is an odorless, bluish-white, silvery, or gray naturally occurring metal. The molecular weight is 207.2 (National Institutes of Health 2016). Melting point is 327.4°C. The boiling point is 1740°C. Vapor pressure is 1.77 mm Hg at 1000°C. Lead is very resistant to corrosion and copper adds more resistance to corrosive properties. It is insoluble in water but dissolves slowly in water containing a weak acid (National Institutes of Health 2016).

2.3 Environmental Fate

The environmental fate of lead is the process by which lead shot, bullets, or pellets move or are transformed in the environment. The environmental fate processes include: 1) mobility, persistence, and degradation in soil, 2) movement to air, 3) migration potential to groundwater and surface water, and 4) plant uptake.

Although well-trained and tested for proficiency, WS personnel at times contribute to the release of intact lead ammunition into the environment when shots are missed, if a shot passes through a target animal, or when a target animal decomposes in the field. Environmental lead ammunition is insoluble under some conditions, but minor amounts of weathering occurs when lead ammunition comes into contact with soil (USEPA 2005).

In the environment, intact lead shots oxidize to form a crust containing lead carbonates (hydrocerussite ($Pb_3(CO_3)2(OH)_2$), cerussite ($Pb\ CO_3$), and lead sulfates (e.g., anglesite ($Pb\ SO_4$)). The oxidation rate depends on oxidation/reduction potential, ionic strength, pH, oxygen content of the soil, and the presence of compounds (e.g., phosphate) that may inhibit oxidation. The dissolution of lead compounds in the crust material releases lead to the environment (USEPA 2003). The bioavailability of lead sulfates and lead carbonates in soil varies from less than 25% (lead sulfates) to more than 75% (lead carbonates). The relative amount of these compounds in soil determines the overall bioavailability of lead. The speciation of lead in soil is dependent upon the equilibrium of the redox potential (eH), soil pH, and the amount of carbonate and sulfate present in soil. Lead sulfate is the dominant form of lead at a low pH (<5.3), carbonates are the dominant form at a pH between 5.3 and 8.5, and lead hydroxides are dominant at a high pH (>8.5) (USEPA 2003).

In the absence of other environmental factors, lead released to soil usually binds to soil particles and remains immobile in the top 6 inches of the surface soil (Cullen et al. 1996, Hue 2002). Wind and rain influence the transport of lead in surface soil. Lead in dry surface soil can move to air by wind through dust and particulates. Rainfall increases the mobility of lead in soil through dissolution or erosive transport. The smaller particles are more susceptible to transport by erosion and runoff to surface water, and the higher surface area of smaller particles increases the rate of dissolution and leaching into the surrounding soil and surface water (Massachusetts Department of Environmental Protection 2009).

Other environmental factors that affect the solubility of lead compounds from lead shots into the soil and within the soil matrix itself include pH, the presence of carbonate, sulfate, sulfide, phosphate, and chloride, content of organic matter, and soil type. Lead mobility under neutral and basic conditions is low. At a low pH (4-6), lead becomes more soluble and leaching from soil to groundwater can occur. The presence of carbonate, sulfate, sulfide, phosphate, and chloride in soil form lead compounds with varying solubility in water. High organic carbon content in the soil can reduce conditions favorable to the formation of lead sulfides, which are relatively insoluble and immobile. High clay and organic carbon soil reduce the transport of dissolved lead through absorptive process, which inhibits lead's transport from soil to surface water and groundwater (Agency for Toxic Substances and Disease Registry (ATSDR) 2007). Lead may also migrate down the soil profile in alkaline soils containing high amounts of organic matter (Cao 2003). Phosphate sources [$NaH2(PO4)3$, commercial superphosphate and phosphate rock] were determined to be effective at mitigating lead in the soil and human population near mining and smelting areas by reducing solubility by 92% (Sergio et al. 2008).

Water pH, hardness, and oxidation reduction conditions affect the solubility of lead. Dissolved lead concentrations increase when water pH decreases. Dissolved lead precipitates out of solution when raising the water pH, particularly between pH 7.5 and 9.5. However, lead solubility increases at a pH above 9.5 (ATSDR 2007).

The bioavailability of lead in soil for plant uptake generally is limited because of the strong adsorption of lead to soil particles especially in the presence of high organic matter. A significant soil-metal fraction renders lead insoluble and largely unavailable for phytoremediation or plant uptake (Miller et al. 2008). Consequently, the uptake of lead by plants is not a significant fate pathway (Pourrut et al. 2011).

2.4 Hazard Identification

Lead can cause a variety of adverse health effects in humans, including death, and can potentially affect any system or organ in the body depending upon the level and duration of exposure (ATSDR 2007). Lead affects the neurological, cardiovascular, renal, immune, hematological, reproductive, and developmental systems. Lead can also affect other systems including hepatic, gastrointestinal, musculoskeletal, respiratory, and endocrine systems (USEPA 2017a). These effects are the focus of this section and are discussed separately in the subsections below.

Exposure to lead, even low concentrations, can be seriously damaging to the health of children because the child's body absorbs lead more efficiently (Rosen and Sorell 1978 cited in Scheetz and Rimstidt 2009). In addition, children typically have higher intake rates (per unit body weight) for environmental media (such as soil, dust, food, water, air, and paint) than adults, since they are more likely to play in dirt and put their hands and other objects in their mouths. Children tend to absorb a higher fraction of ingested lead from the gastrointestinal tract than adults and are more susceptible to the adverse neurological and developmental effects of lead. Nutritional deficiencies of iron or calcium, which are common in children, may facilitate lead absorption and exacerbate its toxic effects (ATSDR 2007).

2.4.1 Toxicokinetics

Humans can absorb inorganic lead from environmental exposure into the bloodstream via inhalation (30% to 50% of the inhaled dose), oral (8% to 15% of the ingested dose), and dermal (very limited) exposure routes. The dermal route is much less efficient than the inhalation and oral routes for inorganic lead. Small submicron size lead particles can be almost completely absorbed through the respiratory tract, whereas larger particles may be swallowed. The extent and rate of absorption of lead through the gastrointestinal tract varies among individuals and the physiochemical characteristics of the medium ingested. Children can absorb 40–50% of an oral dose of water-soluble lead compared to 3–10% for adults. After gastrointestinal absorption approximately 94% of the total body burden of lead distributes into the bones in adults, but only approximately 73% in children. Once adsorbed into the human body, lead in blood is primarily taken into the red blood cells. Lead distributed to blood plasma, the nervous system, and soft tissues can be redistributed and bioaccumulate in bones (National Toxicology Program 2016, USEPA 2017a, U.S. National Library of Medicine 2017). Metabolism of inorganic lead occurs through formation of complexes with a variety of protein and non-protein ligands. Lead can be transferred from the mother to the fetus and from the mother to infants via maternal milk. Lead excretion is primarily through urine and feces with minor routes from other sources such as sweat, saliva, hair, nails, and breast milk. The elimination half-lives for inorganic lead in blood and bone are approximately 30 days and 27 years, respectively (ATSDR 2007).

2.4.2 General Lead Poisoning Effects

Lead poisoning has no unique symptoms. Lead can affect numerous organs and systems in the human body with children, especially those six years and younger being the most susceptible. Early symptoms from lead exposure may include persistent fatigue, irritability, loss of appetite, stomach discomfort or constipation, reduced attention span, and insomnia. Prolonged lead poisoning in adults may cause poor muscle coordination, nerve damage to the sensory organs and nerves controlling the body, increased blood pressure, decreased kidney function, hearing and vision impairment, reproductive problems (e.g., decreased sperm count), and adversely affect fetal development (such as reduced growth of the fetus and premature birth) at relatively low exposure levels. Prolonged lead poisoning in children may cause damage to the brain and nervous system, behavioral and learning problems, anemia, liver and kidney damage, hearing loss, lower IQ and hyperactivity, developmental delays, and seizures, coma, and death in extreme cases (USEPA 2013, 2017a, b).

Due to public health and environmental concerns regarding lead, a substantial amount of published information is available on its toxicity including several reviews (ATSDR 2007, National Institutes of Health 2016, USEPA 2017a, b, U.S. National Library of Medicine 2017). USEPA (2013) published an integrated science assessment for lead, providing a comprehensive review on the health effects of lead. The assessment evaluated the available epidemiological and toxicological studies and made causal determinations for the relationship between exposure to lead and health effects. The information below summarizes the major health effects of lead on neurological, cardiovascular, renal, immune, hematological, reproductive and developmental systems and the effects of lead on them, based on the USEPA (2013) integrated science assessment. Other metals in ammunition pellets and shot (antimony (being replaced by calcium), arsenic, and nickel) and bullets (copper and zinc) are not evaluated in this risk assessment because the impacts from the small amounts (0.5%-9%, see Section 2.1) of these naturally occurring metals are expected to be minimal.

2.4.3 Lead Effects on Neurological Systems

Lead exposure can cause a range of nervous system effects. In children, extensive epidemiological and toxicology studies show that lead exposure can impair cognitive, auditory, motor, and visual functions as well as alter externalizing and internalizing behaviors. Children ages 4 to 11 years with mean blood lead levels between 2 and 8 micrograms/deciliter (µg/dL) had lower full-scale intelligence quotient (FSIQ), executive function, and academic performance and achievement. Children ages 2 to 17 years experienced reduced neurocognitive levels in FSIQ, infant mental development, memory, learning, and executive function at blood lead levels of 5-10 µg/dL. In juvenile animals, dietary exposure resulting in blood lead levels of 10-25 µg/dL caused a decrease in learning, memory, and executive functions.

Effects on externalizing behaviors in children include two groups: 1) attention decreases, impulsivity, hyperactivity, and attention-deficit hyperactivity disorder (ADHD); and 2) conduct disorders that included aggression, delinquency, and criminal offenses. Children between the ages of 3 and 13 years of age had observable externalizing behavioral changes at mean blood lead levels of 7 to 14 μg/dL (and greater) including conduct disorders leading to a higher likelihood of criminal offenses later in their early adulthood (ages 19-24 years old). Animal studies also show increases in impulsivity or impaired response inhibition with relevant post-weaning and lifetime lead exposures that resulted in blood lead levels of 11 to 30 μg/dL. Effects on internalizing behaviors include withdrawn behavior and symptoms of depression, fearfulness, and anxiety. Parent and teacher ratings of internalizing behaviors in children ages 8-13 years were reported to be higher in children with a higher lifetime average blood (mean: ~14 μg/dL) or childhood tooth (from ages 6-8) lead levels.

Other nervous system effects in children include a decrease in auditory and motor, and possibly visual function. Increased hearing thresholds were reported at ages 4-19 years with median blood lead levels of 8 μg/dL. Decreases in fine and gross motor function were reported in children ages 4-17 years with lifetime average blood lead levels ranging from 4.8 to 12 μg/dL. In addition, some studies indicate negative effect on visual function; however, the available epidemiologic and toxicological studies are insufficient or inconsistent.

In adults, lead exposure impairs cognitive function and can cause psychopathological effects. Declines in cognitive function (executive function, visuospatial skills, learning and memory) were reported in adults over the age of 50 years who, over a two-year period, had higher baseline bone lead levels. In lead-exposed workers with blood lead levels in the range of 14 to 89 μg/dL, epidemiologic studies showed reductions in memory, attention, reaction time, and reasoning. Non-occupational exposed studies with adults (examining bone lead levels and concurrent blood lead levels) suggested there is an influence of past or cumulative lead exposures on current cognitive function, indicating a long-term impact.

Adults with higher concurrent blood or tibia lead levels self-reported symptoms of depression and anxiety. Epidemiologic studies also indicate that decreases in auditory function is associated with higher tibia lead level. Amyotrophic lateral sclerosis, Parkinson's disease, and essential tremors were also reported to be associated with lead exposure. In addition, some studies indicate effects on visual function decreases; however, the available epidemiologic and toxicological studies are insufficient or inconsistent.

2.4.4 Lead Effects on Cardiovascular System

Both epidemiologic and animal toxicological studies show that increased lead exposure is associated with increased cardiovascular effects, in particular, blood pressure and incidence of arterial hypertension. Other effects of lead on the cardiovascular system include altered vascular reactivity and cardiac function, atherosclerosis, and increased cardiovascular mortality. Experimental animal studies show mean blood lead levels of 10 μg/dL or greater caused an increase in blood pressure. Epidemiologic studies also demonstrated associations of blood and bone lead levels with other cardiovascular diseases (CVD), such as ischemic heart, cerebrovascular, and peripheral vascular diseases, and CVD-related mortality in adults. In addition, cardiovascular effects can arise secondarily to lead-induced renal injury as the cardiovascular and renal systems are intimately connected.

2.4.5 Lead Effects on Renal System

Epidemiologic and toxicological studies indicate that lead exposure is associated with reduced kidney function and chronic kidney disease among adults (with mean blood lead levels between

20 and 30 μg/dL) through mechanisms such as reduced glomerular filtration rate and creatinine clearance, and increased serum creatinine. Long-term lead exposure is associated with pathological changes in the renal system such as proximal tubule cytomegaly, renal cell death, mitochondrial dysfunction, aminoaciduria, increased electrolyte excretion, adenosine-triphosphase dysfunction, oxidant redox imbalance, and altered nitric oxide homeostasis with ensuing elevated blood pressure are known as well. Longitudinal studies show lead-related reductions of renal function in populations with mean blood lead levels between 7 and 9 μg/dL. Animal toxicological studies provide clear evidence for lead-induced kidney dysfunction at blood lead levels 30 μg/dL and greater. Kidney dysfunction evidence in animals at blood lead levels less than 20 μg/dL is not available.

2.4.6 Lead Effects on Immune System

Epidemiologic and toxicological studies show an increase in allergic and inflammatory conditions and decreased immune resistance resulting from lead exposure. Prospective studies in children (ages 1-5 years) indicate associations of asthma and allergy with prenatal cord and childhood blood lead levels. Epidemiologic studies show children with concurrent blood lead levels 10 μg/dL and above had an increased level of immunoglobulin E (IgE) antibody, which plays a crucial role in the allergic response, and increased asthma prevalence. Evidence of lead-induced increases in T helper cells (Th2) cytokine production and inflammation in animals also support lead-associated increases in asthma, allergies, and IgE antibodies. Although toxicological or epidemiologic evidence does not clearly identify a critical life stage or duration of lead exposure associated with allergic and inflammatory conditions, the evidence points to an influence of gestational and cumulative lead exposures.

Evidence for lead-induced decreased immune resistance is mainly from animal toxicological studies. Dietary lead exposure (blood lead levels of 7-25 μg/dL) in rodents resulted in increased susceptibility to bacterial infection and suppressed delayed type hypersensitivity. Evidence of suppressed production of T helper cells (Th1) cytokines and decreased macrophage function in animals also provides support to lead-induced decreased immune resistance.

2.4.7 Lead Effects on Hematological System

Animal toxicological and epidemiologic studies show effects including decreased red blood cell (RBC) survival and function and altered heme synthesis resulting from lead exposure. Human exposure resulting in blood lead levels between 2 and 7 μg/dL resulted in altered hematological parameters; oxidative stress; increased cytotoxicity in RBC precursor cells; and changes to the mode of action endpoints such as decreased intracellular calcium concentrations, decreased adenosine-triphosphate activity, and increased phosphatidylserine expression. Effects related to altered heme synthesis from relevant lead exposures (e.g., blood lead levels of 6.5 μg/dL) include decreased activities of delta-aminolevulinic acid dehydratase (ALAD) and ferrochelatase, and decreased levels of hemoglobin.

2.4.8 Lead Effects on Reproductive and Developmental System

Epidemiologic and toxicological studies show lead's negative effects on male and female development and reproductive function. Developmental effects include delayed pubertal onset in cross-sectional epidemiologic studies of girls (ages 6-18 years) and boys (ages 8-15 years) with concurrent blood lead levels from 1.2-9.5 μg/dL. Experimental animal studies indicate delayed pubertal onset in female pups with blood lead levels of 1.3-13 μg/dL and delayed male sexual maturity at blood lead levels of 34 μg/dL. In addition, studies suggest that lead may affect birth outcomes (e.g., low birth weight/fetal growth, and spontaneous abortion) and female reproductive function (e.g., hormone level, and placental pathology). However, the overall evidence is inconsistent.

2.4.9 Carcinogenicity and Mutagenicity of Lead

Concerns have been expressed that lead and lead compounds are likely or potential human carcinogens (National Toxicology Program 2003, 2016, International Agency for Research on Cancer 1998, 2006, 2017, USEPA 2013). The International Agency for Research on Cancer (1998, 2006, 2017) classified inorganic lead compounds as probable human carcinogens (Group 2A of the International Agency for Research on Cancer classification) based on limited human evidence and sufficient animal evidence. USEPA (2013) classified lead as a "probable human carcinogen" (B2 of the USEPA classification) based on sufficient cancer evidence from cancer studies in experimental animals (rodents) but inadequate cancer evidence from epidemiologic studies in humans. Chronic human epidemiologic studies showed limited evidence of increased risks of lung and stomach cancers, although concerns about confounding from arsenic exposure was raised (ATSDR 2007). In addition, weak evidence for an association with kidney cancer and gliomas has been noted (Steenland and Boffetta 2000 *as cited in* ATSDR 2007).

Lead is a clastogen (causing disruption or breakage of chromosomes). Studies conducted on workers exposed to lead showed an increase in chromosomal aberrations, and micronuclei and sister chromatid exchanges in peripheral blood cells (Minozzo et al. 2004, ATSDR 2007). However, studies on sister chromatid exchange and genetic studies on humans environmentally exposed to lead, together with *in vitro* mutagenicity studies in microorganisms, do not show the same results (National Toxicology Program 2016). Thus, workers in enclosed areas appear to be exposed to lead differently than those exposed to lead environmentally.

3 DOSE-RESPONSE ASSESSMENT

3.1 Human Health Dose-Response Assessment

Dose-response assessments evaluate the dose levels (toxicity criteria) for potential human health effects from exposure to potentially harmful substances.

USEPA (2013) concluded it was inappropriate to develop an oral reference dose for inorganic lead given that the impacts to children can occur at blood lead levels too low for a threshold[6]. Adverse effects in adults associated with bone lead concentrations exceeding 10 μg/g include cardiovascular, renal, and neurobehavioral effects. Adverse effects at a blood lead concentration less than 10 μg/dL include delayed and impaired development of the nervous system, delayed sexual maturation, neurobehavioral effects, increased blood pressure, depressed renal glomerular filtration rate, and inhibition of pathways in heme synthesis. Delay or impairment of neurological and sexual development occurred in children during pre- and post-natal development; and cognitive deficits, hypertension, and depressed glomerular filtration rate occurred in adults older than 60 years or postmenopausal (ATSDR 2007). USEPA (2013) uses blood lead concentration as a biomarker to regulate lead exposure. The Centers for Disease

[6] The maximum level set for children in USEPA (2013) was based on data from Lanphear et al. (2005), with some data points being erroneous. USEPA (2014) reanalyzed the conclusions of USEPA (2013) for children and determined they were still valid.

Control and Prevention (2012, 2017) uses a reference level of 5 μg/dL for lead exposure in children.

USEPA (2013) has established a hazard standard of 400 ppm lead in residential soil in children's play areas or an average of 1,200 ppm lead in soil in the rest of a residential yard. Lead present at or above these levels is considered to be a hazard in the areas described. The sources for lead in residential soil are either naturally occurring or man-made sources such as automobile or industrial emissions.

3.2 Ecological Effects Analysis

This section of the risk assessment discusses available ecological lead effects data for terrestrial and aquatic biota from ammunition but should not be considered an exhaustive review.

3.2.1 Aquatic Effects Analysis

The toxicity of lead to aquatic resources such as invertebrates and vertebrates is dependent upon the species tested, endpoint and threshold evaluated, and water chemistry. Lead can occur in various forms in aquatic systems based on water and sediment chemistry parameters that can significantly alter the toxicity to nontarget species. Water hardness, pH, and temperature are just a few of the water quality parameters that can impact the toxicity of lead to aquatic biota. Lead will also partition to sediment where sediment chemistry parameters such as acid-volatile sulfide levels, organic matter and redox potential all impact the bioavailability and toxicity of lead to aquatic invertebrates and vertebrates. Lead can bioconcentrate in aquatic organisms, especially filter feeders and algae, but has not been reported to bioaccumulate (Eisler 1988).[7]

<u>3.2.1.1 Aquatic Vertebrates and Invertebrates</u>

Lethal and sublethal lead effects have been noted in aquatic invertebrates, including physiological and biochemical functions that can lead to reduced reproduction and growth, and the inability to avoid predators and forage for prey items (Eisler 1988, Rattner et al. 2008). Freshwater cladocerans and amphipods appear to be the more sensitive group of aquatic invertebrates to the effects of lead based on available literature (Eisler 1988, USEPA 2006, 2013). Adverse effects to fish occur at concentrations ranging from 3.5 to 29,000 micrograms per liter (μg/L), with cold water species such as the rainbow trout being one of the more sensitive species to the effects of lead (Eisler 1988, USEPA 2006, 2017a). The range of toxicity values for fish are within the range of toxicity values that have been reported for amphibians (Eisler 1988, USEPA 2006, 2017a). Median lethality for amphibians range in the low part per million to greater than 12,500 μg/L in pore water, or interstitial sediment water, for the northern leopard frog (*Lithobates pipiens*) with no observable effect concentrations reported as low as 10.0 μg/L (Eisler 1988, Chen et al. 2006).

<u>3.2.1.2 Aquatic Plants</u>

The reported median effect concentrations for duckweed (*Lemna minor*) during a seven-day exposure was 5,500 μg/L and several wetland plants have been shown to have impacts on growth at dissolved lead concentrations of 20,000 μg/L. Aquatic macrophytes are less sensitive to the impacts of lead compared to freshwater and marine algae, and algae and diatoms showed that

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[7] Bioconcentration is the accumulation of a chemical such as lead in or on an organism solely in water or the concentration of a chemical exceeding that of water as a result of exposure in water whereas bioaccumulation is the accumulation of substances such as lead in an organism and is not lost at a rate faster than via catabolism and excretion. Biomagnification is the accumulation of a chemical in an organism as a result of feeding on plants and animals that have taken up the chemical already and retain the chemical, thus the concentration is taken in at even a greater rate.

growth was impacted at lead concentrations as low as 5.1 µg/L, and up to and greater than 1,000 µg/L (Eisler 1988, USEPA 2017a).

3.2.2 Terrestrial Effects Analysis

3.2.2.1 Mammals

The effect of lead on wild and domestic mammals is similar to the types of impacts discussed in the hazard characterization section of this risk assessment (Section 2.4). An extensive amount of literature exists regarding impacts to standard laboratory test mammals and livestock with less data available for wild mammals. Wild mammal studies focus on body burdens of lead for mammals that forage in areas contaminated by lead from industrial practices. These studies have revealed lead body burdens that have the potential for adverse effects to a variety of small and large mammal species (Rattner et al. 2008). The potential for effects to wild and domestic mammals from WS activities would be the greatest for mammals that scavenge carcasses containing lead ammunition.

3.2.2.2 Birds

Bird sensitivity to lead from exposure to ammunition such as lead shot, bullets or bullet fragments, and lead tackle is well documented. Clinical signs of lead poisoning in birds are observed when blood lead concentrations reach 20 to 50 µg/dL while severe clinical signs are observed at concentrations exceeding 100 µg/dL. Clinical signs of lead poisoning include wing droop, anemia and weakness in affected birds (Rattner et al. 2008). The effects of the ingestion of lead shot have been noted in various avian species. Pain et al. (2009) documented impacts to 33 raptor species and 30 other species including ground nesting birds, cranes, and upland game birds. In fact, as few as 10 pellets can result in lethal and sublethal impacts to large raptor species such as the bald eagle (Eisler 1988). Lead impacts from spent ammunition have also been noted in numerous waterfowl species (Tranel and Kimmel 2009). Lethal and sublethal effects can occur at relatively small doses of lead from ammunition. An individual lead pellet has been shown to result in lead toxicosis in waterfowl and ground nesting birds. It should be noted that lead fishing tackle is also a risk factor for 75 bird species (USEPA 1994); it is the leading cause of mortality for common loons (Grade et al. 2018).

Sublethal impacts to birds are similar to those observed in mammals and other vertebrates. Depending on the dose and exposure time lead can exert deleterious effects on a range of physiological and biochemical functions. Reproductive impacts include effects to the testes, sperm count, eggshell thickness, reduced hatching as well as numerous embryo-related impacts in various avian test species. Other physiological impacts include ALAD inhibition, immune suppression, and impacts to the central nervous system among other effects. Behavioral effects including depressed locomotion, impaired ability to thermoregulate, diminished migratory movement, and reduced ability to avoid predation were also noted in a variety of test species (Burger 1995).

3.2.2.3 Reptiles and Amphibians (Terrestrial)

Effects from lead shot have been observed in reptiles, especially from chronic exposures. Lance et al. (2006) reported reproductive impacts to captive American alligator that were fed nutria containing lead shot. This supports previous work regarding the detection of lead in captive alligators that were related to ingestion of nutria containing lead shot (Camus 1998). Lead blood levels of 280 µg/dL with no apparent lead toxicosis suggests that reptiles may be less sensitive to the effects of lead than other vertebrates. Hammerton et al. (2003) made similar observations with estuarine crocodiles (*Crocodylus porosus*) that had high lead blood levels from consuming prey contaminated with lead ammunition.

3.2.2.4 Terrestrial Invertebrates and Microorganisms

A majority of the published literature regarding lead and terrestrial invertebrates focuses on the potential residues that could occur in these organisms in areas that are adjacent to industries related to lead use or production. USEPA (2005) established ecological soil screening levels (Eco-SSL) that can be used as an effect threshold based on the available toxicity data. The Eco-SSL in this case was based on the geometric mean of the maximum allowable toxicant concentration (MATC) using the collembolan (*Folsomia candida*) and reproduction as the endpoint. The value estimated from these studies was 1,700 mg/kg dry weight (dw). Soil pH ranged from 4.5 to 6.0 with an organic matter content of 10% in all studies

Other toxicity studies assessing lead effects to nematodes and earthworms did not meet the criteria for estimating the Eco-SSL but still provided information regarding lead sensitivity for other soil borne terrestrial invertebrates. In these studies, median lethality values for the nematode (*Caenorhabditis elegans*) ranged from 11.6 to 1,434 mg/kg dw with higher toxicity at lower pH and organic matter values. Median lethality for the earthworm (*Eisenia fetida*) was reported at 3,716 mg/kg dw with reproductive effects noted between 1,629 and 1,940 mg/kg dw.

3.2.2.5 Terrestrial Plants

Lead has been shown to inhibit photosynthesis, impact water adsorption and affect various metabolic processes in various monocot and dicot species (Sharma and Dubey 2005). USEPA (2005) has established an Eco-SSL of 120 mg/kg dw based on the geometric mean of the MATC for growth in studies using loblolly pine (*Pinus taeda*) red maple (*Acer rubrum*), berseem clover (*Trifolium alexandrium*) and ryegrass (*Lolium rigidum*). The Eco-SSL was based on impacts to growth in each terrestrial plant species with ryegrass being the most sensitive (MATC = 22 mg/kg dw) and berseem clover the least sensitive (MATC = 316 mg/kg dw). NOEC and LOEC values for various other terrestrial plants including other crops and tree species have values at, or exceeding, the Eco-SSL established for terrestrial plants (Demayo et al. 1982, USEPA 2005).

4 EXPOSURE ASSESSMENT

4.1 Human Health Exposure Assessment

This exposure assessment estimates the potential for human lead exposure from WS activities. Identified lead exposure pathways are reported to include inhalation from shooting-related activities, and exposure from consuming meat from animals killed with lead ammunition.

Handling and firing bullets are sources of lead exposure mainly through inhalation of airborne particles. The National Research Council (2012) evaluated the potential health risks to United States Department of Defense firing-range personnel from recurrent lead exposure. This evaluation indicated that airborne particulates and re-suspension of settled lead dust during range maintenance and cleaning are major sources of exposure for firing ranges. In WS programs, lead exposure from inhalation of lead fumes and dust during firing is commensurate with normal shooting practices (mostly outdoors plus indoor calibration activities). Exposure to lead from accidental exposure such as shooting oneself or cleaning firearms is not expected due to rigorous training requirements (WS Directive 2.165, WS Firearm Use and Safety) and the use of protective equipment such as gloves. Shooting glasses and hearing protection are also required during shooting to prevent eye injury from debris and hot gas, and to prevent permanent hearing damage from noise.

The potential for the public to come into direct contact with lead such as shot, bullets, and pellets that remain intact after discharge will be low because bullets and shots fired will remain in the targeted animal. APHIS WS expects a minimal occurrence that WS personnel would miss the target animal or that a shot would pass through the target animal.

Regular consumption of game meat harvested with lead ammunition, especially those harvested with highly fragmented bullets such as high-powered, soft-point or rapid expanding ballistic tip lead bullets, may cause increases in blood lead levels compared to background levels, particularly in children (Johansen 2004, Kosnett 2009, Tranel and Kimmel 2009). Rapid expanding ballistic tip bullets had the highest fragmentation rate compared with the shotgun slug and muzzleloader bullet, with an average of 141 lead fragments per carcass and an average maximum distance of 11 inches from the wound channel (Cornicelli and Grund 2009). Other studies show that humans can be exposed to bioavailable lead from bullet fragments through consumption of deer killed with standard lead-based rifle bullets and processed under normal procedures (Hunt et al. 2009, Pain et al. 2010). When lead shot is used in WS programs, potential dietary exposure among the public is unlikely as most carcasses are disposed of properly. WS participates in meat donation programs such as "Sportsmen Against Hunger" whereby meat is donated under WS Policy 2.510 (Fur, Other Animal Parts, and Edible Meat, 10/08/2003). However, only meat that is processed professionally or by the recipient is donated. Hematomas tend to be cut out to avoid lead fragments and foul-tasting meat. Donated meat such as deer is almost always from head or neck shots, thereby, reducing the chance of contaminating meat with lead. Feral swine are not donated due to FDA rules and regulations. Recreational hunters tend to aim behind the shoulder of an animal, where bullets that fragment often deposit lead into muscle tissue. In contrast, WS deer removals using firearms ideally involve fatal shots to the head or upper neck to incapacitate and kill an animal immediately unless long-ranges are involved, reducing the risk of lead introduction to parts of the animal used for edible meat.

A complete exposure pathway is not identified for soil, groundwater, and surface water media or plant uptake because the amount of lead from ammunition directly released onto soil is minimal. The small amount of lead released to soil tends to stay in soil based on the environmental fate of lead. A standard measurement for soil weight per acre is an "acre furrow slice" which is 2 million pounds of soil in the top 6.7 inches of an acre of land (actually 2,024,458 lb. or 918,279 kg), and the soil where released lead would be immobilized (Cullen et al. 1996, Hue 2002). Thus, for Texas, it was determined that WS distributed 67 mg per acre of lead using the annual average for FY11 to FY15 or 196 mg per acre for FY11 to FY15 for the cumulative area worked from FY11 to FY15 and the total pounds used during this time. To be conservative, it is assumed that all the lead would remain in the top inch of soil where the lead would be deposited. The weight of one inch of soil over an acre is estimated at 302,158 lb. (137,056 kg). Thus, in the top inch of soil, WS added 0.0005 mg/kg (= ppm) lead for the annual average from FY11 to FY15 or 0.0014 ppm for the cumulative total from FY11 to FY15. In 100 years, WS would add 0.05 ppm at the annual average in Texas. In Oklahoma, where calculations were higher, it was determined that WS distributed 282 mg per acre of lead for an annual average for FY11 to FY15 or 501 mg per acre for the cumulative total lead used from FY11 to FY15. WS added 0.0021 ppm using the annual average or .0037 for the five-year cumulative total. The estimated lead distribution conservatively represents the potential lead concentration released to soil from WS activities. The natural background levels of lead in soil range between 50 parts per million (ppm) to 400 ppm (USEPA 2017a). The estimated lead use by APHIS WS contributes a small amount yearly (24,000 times less) to the lowest natural background concentration of 50 ppm in Oklahoma. USEPA (2017a) set the lead hazard standard for residential soil in children play areas at 400 ppm, thus WS adds an insignificant amount of lead to the soil. In fact, the amount of lead distributed by WS is likely six times less than that estimated or 144,000 times less than the natural background level of lead.

4.2 Ecological Exposure Assessment

4.2.1 Aquatic Exposure Assessment

Lead shot or bullets, or fragments may be transported to aquatic ecosystems via runoff from soil, from an animal being fatally wounded in an aquatic environment, or directly from ammunition being discharged into aquatic areas. These circumstances are expected to result in minimal loading of lead in aquatic environments since large numbers of shot, bullets, and fragments would not be expected for most WS programs. In addition, bioavailability would be very low under these conditions.

WS uses a variety of ammunition in its various programs so the amount of lead that could be discharged from a specific firearm is variable. As a conservative estimate of lead loading into aquatic environments a large caliber rifle (.30-06) was assumed to be used with a 220-grain bullet which is considered a heavier grain bullet for that type of rifle for the majority of species taken (these are typically used for very large animals and predators). Generally, 150-160 grain bullets are used for large animals such as black bears and 110-125 grain bullets for coyotes and deer. Assuming a shallow water body of one foot deep by one acre and all of the lead from a bullet being discharged into the water body, this would result in a lead concentration of approximately 10 µg/L. The assumptions are that the shot or bullet is 90% lead, all of the lead would become soluble, and instantaneously dissolve equally throughout the body of water. In reality aquatic residues would be orders of magnitude less since the bullet would erode slowly over time in aquatic environments and be subject to binding in sediment and organic matter in the water column. The estimated residue is not meant to serve as a benchmark concentration, but to illustrate that lead residues in aquatic environments from WS activities would be expected to be very low. Lead from spent ammunition that would occur in runoff from soil would also be extremely low. Degradation rates for lead pellets and bullets to more soluble or bioavailable forms in soil is variable depending on soil type and other site-specific factors, but half-lives for pellets ranged from 40 to 70 years (Jorgensen and Willems 1987). In addition, the amount of lead that becomes soluble in soil is usually very small (0.1-2.0%) (USEPA 2005).

4.2.2 Terrestrial Exposure Assessment

Exposure to terrestrial vertebrates, primarily birds and mammals, could occur from dietary exposure through the ingestion of soil or carcasses that contain spent lead ammunition. Dietary exposure from the consumption of water is not expected to be a significant pathway of exposure since lead pellets and bullets degrade slowly over time and the amount of lead that would be available is negligible compared to ingestion from soil or sediment used as grit in some bird species or scavenging of carcasses killed with firearms by vertebrates. Dietary lead exposure to terrestrial vertebrates from the consumption of plants or prey would also not be considered a potential exposure pathway. Lead uptake in plants and various prey items have been shown to occur; however, the low amounts of lead ammunition that are being used by WS and the lack of bioavailability to plants and other prey items suggest this exposure pathway to terrestrial vertebrates is negligible.

Terrestrial plants and soil-borne invertebrates could potentially be exposed to lead directly. Potential soil-lead levels (0.0021 mg/kg) are anticipated to be very low based on historical use estimated for the WS Oklahoma program, a program with the highest lead use per acre. This amount would actually be less since only a small fraction of the lead would be bioavailable and lead that is released would bind in the top 6 inches of soil. Only a small fraction of lead is water soluble in soil due to slow degradation and, therefore, the quantities available for uptake into plants or that could impact soil invertebrates would be negligible to nonexistent.

5 RISK CHARACTERIZATION

This section qualitatively characterizes risks associated with adverse human health and fish and wildlife. Under the anticipated uses, lead from bullets, shot, or pellets should pose minimal risk to human health and most nontarget organisms. Risk is further reduced in WS operations that are able to use non-lead ammunition. The use of non-lead ammunition is expected to increase over time further reducing risk to human health and the environment.

5.1 Human Health

WS uses lead shot, bullets, or pellets in aerial or ground-based shooting over relatively wide areas in mostly remote locations. Although potentially toxic to humans, it is highly unlikely that adverse health effects as a result of WS activities involving lead will occur. Approximately 5.5 tons (5.0 metric tons) of lead are released to the environment per year in all states during WS activities. Over the landscape, this is minor.

Lead exposure and risk to human health from WS activities is not expected to result in significant risk to any subgroups of human populations (such as WS personnel, and the public including children, and hunters). There is potential for exposure and risk to WS personnel who handle lead ammunition. However, exposure and risk are expected to be low since firing occurs almost always outdoors reducing inhalation exposure from lead fumes and dust that may occur during firing. In addition, APHIS policies and practices for WS personnel handling firearms reduce the potential for lead exposure as well as from injuries related to the discharging of firearms (WS Directive 2.165). Subgroups of the public that could be exposed to lead ammunition from WS activities are people who may consume some of the animals that are donated or have been wounded or shot by WS personnel. Carcasses from ground or aerial shooting will be collected, when feasible, and then disposed of and not available for human consumption.

Small numbers of game animals that are mortally wounded but are not collected by WS personnel may be available for human consumption. However, this is not expected to be a significant risk to people for several reasons, including: (1) The goal of WS personnel conducting direct lethal control is to kill target animals with minimal wounding; (2) WS personnel typically make lethal shots to the head and neck region of an animal during WS WDM activities, which is generally not the part of a game animal (e.g. deer) that is harvested for meat and reduces the potential for lead exposure from meat; (3) WS employees and meat processor remove hematomas caused by bullets, shot, pellets, or fragments and remove them during preparation, if meat is to be donated for consumption; (4) carcasses found in the field are not fit for human consumption in a relatively short time, dependent on temperature; and (5) the potential for lead exposure is null in cases where WS uses non-lead ammunition. Therefore, the low potential for lead exposure from activities related to WS activities is expected to result in negligible risk to human health.

5.2 Ecological Risks

5.2.1 Aquatic

Risk to aquatic ecosystems is expected to be minimal based on the available toxicity data for lead, the potential exposure pathways, and environmental fate for lead. Risk to aquatic ecosystems including fish, amphibians, invertebrates and plants may occur primarily as lead ammunition either degrades in soil and is transported via runoff or is directly deposited. Lead levels estimated from WS activities based on conservative assumptions of exposure would not exceed toxicity levels for aquatic nontarget organisms. In addition, lead levels would not exceed acute or chronic aquatic life criteria under the Clean Water Act that vary based on water hardness (USEPA 1985). Ingestion of lead shot, bullets or associated fragments is not considered a significant risk to fish and amphibians (Rattner et al. 2008). In addition, risk to aquatic ecosystems is further reduced as WS transitions to non-lead shot and bullets. The current use of non-lead ammunition varies between states within WS, but approximately 64% of the state WS programs use less than 20% lead ammunition. Lead use in WS is expected to continue to decline.

5.2.2 Terrestrial

Exposure and risk to nontarget mammals and birds will be greatest for those that consume animal carcasses killed with lead ammunition. However, the potential for lead exposure and risk to these types of scavengers will be reduced in instances where carcasses are removed by WS. There is also the potential for lead exposure and risk to nontarget mammals and birds that may consume soil that could contain lead fragments or pellets. Risk would be greatest for birds that consume soil for grit to aid in digestion. The use of non-lead ammunition and pellets within the WS program will remove the risk of lead exposure through these two exposure pathways.

Risk to terrestrial plants and soil-borne invertebrates is expected to be negligible based on the use pattern for lead by WS, the environmental fate of lead ammunition and pellets, and the effects data for these two nontarget groups. The potential concentration of lead in soil from the use of lead ammunition by WS in its Texas program (see section 4.1), is 6.7×10^{-5} mg/kg. The Eco-SSLs for terrestrial plants and invertebrates were 120 and 1700 mg/kg dw. Effect values for terrestrial plants and invertebrates were seven to eight orders of magnitude above the soil residue value estimated in Texas suggesting wide margins of safety. Lead concentrations could be higher within a given acre since lead ammunition and pellets are not evenly distributed within an acre; however, even in concentrated areas the levels would still be well below effect thresholds. In addition, these values assumed that all of the lead in the acre is available for uptake by plants and invertebrates which would not be the case due to the slow degradation and environmental fate of lead in soil.

6 UNCERTAINTIES AND CUMULATIVE IMPACTS

This section qualitatively discusses the potential uncertainties with this risk evaluation and the cumulative effects associated with additional lead exposures from other sources to human health and environment, and potential cumulative effects from exposure to other stressors. The uncertainties associated with this risk evaluation arise primarily from various parameters (see Section 2.3) associated with the weathering rate of lead shot and potential lead leaching from soil to groundwater, which is qualitatively discussed in this section. These parameters include precipitation, chloride ion concentration, organic matter cover, and pH. However, the transition by WS from lead to non-lead ammunition, which is proactively occurring in many WS State Offices, where feasible, and the low concentrations of lead released by WS into the environment suggest that significant adverse impacts to human health or the environment are unlikely.

WS uses aerial and ground shooting for a range of animal control activities on an annual basis. Minimal repeated exposure of WS personnel to lead during the loading and firing of guns is expected. Lead accumulation in the human body will not occur from repeated use of lead ammunition due to the small amount of lead released to the environment from WS activities. We estimate that it will take approximately 750,000 years of activity of the type and magnitude that WS conducts to release the amount of lead that is equal to the low end of the background lead soil level of 50 mg/kg (Section 4). Risk from lead ammunition use is also extremely low for the general public from WS activities. Sources of lead from firearms, hunting, and shooting activities that are not part of WS activities as well as airborne emissions from metals industries (such as lead smelters and iron and steel production), manufacturing industries, and waste incineration are large sources of lead. The reported lead accumulation rates on individual shooting ranges are between 1.4 to greater than 15 metric tons per year (Rattner et al. 2008). Annual shot deposition in upland fields from hunting may be as much as one million shots per hectare (Schulz et al. 2002). Data shows that U.S. use of lead from ammunition, shot and bullets, was 69,200 metric tons (USGS 2008, 2011). An approximated 3,977 metric tons of lead fishing sinkers are sold in the United States annually (Rattner et al. 2008). Average lead use in WS programs is approximately 5.0 metric tons per year. The amount of lead released into the environment from WS activities is less than 0.01% than just the estimates for lead in ammunition and fishing sinkers, and not including industrial activities. The contribution of lead to the environment from WS is negligible and, therefore, an incrementally negligible addition to the cumulative effects from all sources of lead in the environment.

Cumulative impacts to human health and the environment from WS lead ammunition use will be negligible when considering potential impacts from exposures to other anthropogenic and natural stressors. Lead has wide-ranging effects on most biological systems in humans and nontarget animals, therefore current effects to any biological systems from other contaminants or stressors would be expected to have a cumulative effect when considering lead use in WS programs. Spatial and temporal variability in exposure to different contaminants and stressors, as well as a lack of knowledge about the impacts of multiple stressors, make it difficult to state what types of cumulative impacts could be expected. However, the potential risk to human health and the environment from lead ammunition exposure as a result of WS activities is so low that cumulative impacts to any effects would be incrementally minor when considering exposure to other stressors.

7 SUMMARY

Lead has a variety of industrial and manufacturing usages including uses in ammunition (shot, bullets, or pellets) and fishing sinkers. The WS Program uses lead ammunition for aerial and ground shooting for a variety of programs and minimal amounts of fishing sinkers, but use of lead has declined as non-lead substitutes have become available, researched, and determined to be effective. Lead ammunition use as a percentage of total ammunition used by WS varies from state to state, but the total lead ammunition use in WS operational activities as a percentage of total lead use from ammunition in the United States is very low (~0.002%), and even magnitudes less considering all uses of lead, especially in mining and smelting areas (USEPA 2017a). The use of lead ammunition and weights in WS is expected to continue to decline.

Risk to human health and the environment from lead has been documented in this report. Risk of lead related maladies from ammunition (e.g., through consumption of carcasses) is minimized by training WS personnel (e.g., shot placement) and the WS carcass disposal policy. In addition, most WDM conducted for animals such as deer, swine, rabbits, or migratory game birds (e.g., ducks and native doves) that have the highest likelihood of being consumed are conducted mostly on private or secured public lands (e.g., airports), where public access is restricted. Overall, the risk of lead poisoning from WS use is minimal. WS expects that the potential of lead toxicity from WS use to humans, especially children who are the most sensitive to the effects of lead, and the environment will be negligible. WS anticipates that this risk will continue to decline

Ecological impacts to aquatic resources are also expected to be minimal based on the low potential for exposure to most aquatic biota. In terrestrial systems the greatest potential for exposure and risk is to nontarget vertebrates that consume lead ammunition fragments inadvertently from the ground or from scavenging carcasses. Risks to nontarget animals are reduced when carcasses are removed and when non-lead ammunition can be used. Lead ammunition degrades slowly in terrestrial and aquatic environments. Its environmental fate once it degrades suggests that the small amounts of lead that may be present in the environment as a result of WS activities would not have an adverse impact to soil, air or water quality. Regardless, WS is increasing the use of non-lead ammunition and fishing sinkers in WDM and remains committed to working with the U.S. Fish Wildlife Service, other federal agencies, and state agencies to proactively manage lead exposure to fish and wildlife.

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9.2 Internal Reviewers

USDA APHIS Wildlife Services

Reviewer: Kevin Grant (retired)
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Experience: Twenty-eight years of service in APHIS, Wildlife Services in Oklahoma and Arizona, with seven years as a Wildlife Damage Management Field Specialist with Texas A&M Cooperative Extension Service. Special expertise in the application and supervision of Integrated Wildlife Damage Management techniques for the prevention of damages to resources from predators, rodents, and feral swine.

Reviewer: John Steuber
Position: USDA-APHIS-WS, State Director/Supervisory Wildlife Biologist, Billings, MT
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Reviewer: Michael Yeary
Position: USDA-APHIS-WS, State Director/Supervisory Wildlife Biologist, Lakewood, CO
Education: BS in Wildlife Ecology, Texas A&M University

Experience: Special expertise in wildlife damage management including applying and supervising M-44s and their use. Thirty-eight years of service in APHIS Wildlife Services in TX, KS, CO, and WS Regional Office with experience in a wide variety of programs (livestock, aquaculture, dairy, property, natural resources, and human health and safety protection) including predator, bird, beaver, feral swine, and rodent damage management activities.

9.3 Peer Review

The Office of Management and Budget requires agencies to have peer review guidelines for scientific documents. The APHIS guidelines were followed to have "Use of Lead in Wildlife Damage Management" peer reviewed. WS worked with the Association of Fish and Wildlife Agencies to have experts review the documents.

9.3.1 Peer Reviewers Selected by the Association of Fish and Wildlife Agencies

Alabama Department of Conservation and Natural Resources
Michigan Department of Natural Resources
New York State Department of Environmental Conservation

9.3.2 Comments

Peer reviewers provided editorial comments on the manuscript. These were appreciated and incorporated into the final document. Following are the comments regarding concerns with the risk assessment and a response:

1. **Comment:** The risk assessment for lead fluctuates between statements that lead use by the agency is of such small volume that adverse effects will be negligible, and reiteration of protocols undertaken to mitigate these adverse effects. This could be portrayed as WS being proactive, but several seemingly conflicting and controversial statements jeopardize this effort.

   Response: The risk assessment demonstrates the minimal use of lead by WS but attempts to reduce the use of lead as safe and effective alternatives become available. Thus, while this dichotomy exists, we believe that WS use of lead poses minimal risks, but WS will continue to take measures that reduce the risks associated with lead ammunition use.

2. **Comment:** One significant area of omission in the lead risk assessment is any mention of lead toxicosis and loons. The absence of this particular species was notable because of the abundance of data regarding adverse effects related to lead ingestion, likely from the use of lead sinkers. There was a singular statement that 'an individual lead pellet has been shown to result in lead toxicosis in waterfowl and ground nesting birds' (Section 3.2.2.2); this statement seemingly contradicts other assertions that 'lead from bullets, shot, or pellets should pose minimal risk to most nontarget organisms.

   Response: The risk assessment notes the high toxicity of lead to birds, especially waterfowl. However, a sentence was added specifically for birds in Section 3.2.2.2 regarding lead sinkers which can pose a serious threat to birds. Overall, WS expects that the risks are low to this group of birds because most WS activities involving waterfowl damage management require the use of non-toxic shot. The transport of bullets and pellets to aquatic systems would be negligible based on how WS uses these forms of ammunition and the environmental fate of any lead that may end in the soil or water. On the other hand, sinkers could pose a problem if used in areas frequented by waterbirds where fishing damage management is occurring. Since common loons and other birds are affected by fishing tackle, more information was added in Section 3.2.2.2. It is not anticipated that WS will have much of an effect on them because of the minimal amount of lead weight used annually and the location of such activities. WS has a fishing program for overabundant pikeminnows on the Columbia River in deep waters downstream of dams to protect threatened and endangered salmonids. WS loses an estimated 150 lbs. of sinkers annually in these deep waters that likely become snagged on the bottom of the river. The lead sinkers would be at the bottom of rivers where they will not likely be consumed by birds.

3. **Comment:** The lead risk assessment does a good job of highlighting the uncertainty in lead usage across the agency. However, the document repeatedly mentions a 'conservative estimate' of lead use that likely overestimates the actual amount of lead being used (and judging from the context this is accurate), but the phrase by definition usually refers to a lower than true amount. This may be somewhat confusing to readers.

   Response: We agree with this assertion and attempted to provide an explanation for this use and maybe a better word would be careful or cautious. No matter the word, it is attempting to provide the "worst-case-scenario**"** to ensure that environmental risks and impacts are addressed. Thus, in this risk assessment, it is conservative to provide an overestimate of the use of lead given

4. **Comment:** In my opinion this document heavily overestimates the amount of lead deposited by WS and available for environmental uptake. Estimates provided are very conservative.

   Response: We provide conservative estimates, using exaggerated numbers of more lead than likely used to ensure WS use is under that threshold and to evaluate a worst-case scenario. We see minimal effects from the overestimates, so we know that impacts are even less than those given.

5. **Comment:** The lead risk assessment would better achieve its intended goals of completeness if it improved its focus on the procedures and protocols employed by WS to mitigate any adverse effects of lead usage, rather than rely on questionable mathematical extrapolations or comparisons with other sources of lead to argue the activities pose little to no risk.

   Response: The risk assessment cites and summarizes the relevant procedures and protocols WS has developed related to the use of lead in WDM. The risk assessment also estimated conservative estimates of use as a screening tool to characterize the risk to human health and the environment. The risk assessment cites the applicable protocols throughout the risk assessment. WS recognizes that the estimates are highly conservative and may overestimate actual exposure and risk to human health and the environment; however, this was the intent of this screening level risk assessment.

6. **Comment:** As rightfully described in the lead risk assessment, the use of lead may be necessary in specific situations to ensure humane killing and protect the safety of staff/public. These objectives are of paramount importance and warrant more attention within the document.

   Response: We believe your assessment of the necessity for the use of firearms to humanely euthanize wildlife and protect public safety is correct and a goal of WDM. A discussion of the humaneness was given in the risk assessment introductory chapter for the risk assessments as this is an issue that arises for most methods used in WDM. We also addressed this in the risk assessment "The Use of Firearms in Wildlife Damage Management by WS.": This risk assessment tried to focus on just the issue of lead impacts on people and the environment and did not want to dilute this assessment with additional information that have already been addressed. We appreciate the comment.

7. **Comment** Section 1.1 extrapolates lead contamination on a broad geographic scale to argue the amount of lead deposition is minimal. However, it is unclear if this is an appropriate method of estimation because the activities of the Program are typically clustered on the landscape (as is later pointed out in the document), and focal areas of WDM activities will certainly have higher risks of lead deposition than others.

Response: WS conducts WDM over the landscape by many employees in a state. While WDM may be clustered in some areas, such as at an airport, the general area where WDM is conducted is still of considerable size. The greatest amounts of lead come from aerial work for feral swine and coyotes and activities are conducted much more so over the landscape where animals are found. It is unlikely that animals at this level are found at the same location on a property. Thus, we believe that while we estimated the amount of lead used conservatively (overestimate in this sense), we would have few, if any, areas where the amount of lead used was clustered to the extent that lead deposition would rise to a level of high risk.

8. **Comment:** There were multiple statements that seemingly portrayed the lead use by the agency as not a risk because it is at a smaller scale than other activities, notably that of recreational hunting and fishing (Section 2.1). This could be viewed as an inflammatory redirect or negative commentary on those activities.

   Response: The use of the comparison between recreational activities and WDM activities was meant to give the reader an idea of the extent of lead used by WS in WDM. We did not draw these comparisons to be negative on recreational activities. To the contrary, we believe that it gives readers an idea of the potential extent of risks and we believe it to be minimal.

9. **Comment:** This document contends WS adds an insignificant amount of lead to the soil because the amount distributed is less than 'the lead hazard standard for residential soil in children play areas at 400 ppm' (Section 4.1), but also reminds the reader the USEPA contends 'the impacts to children can occur at blood lead levels too low for a threshold' (Section 3.1).

   Response: We agree with your assessment that acceptable levels of lead for children are likely very low and that we would not want to surpass that level anywhere. USEPA continually modifies acceptable levels of lead in the soil for people, especially children, as the science continually improves our understanding of lead toxicity and safe levels of lead for people. We have evaluated this risk and the potential to add to the lead level to the soil. Even over 100 years, WS would not add 1 ppm lead to the soil. For comparison, the background level, lead already in the soil, is 50 ppm. Thus, we believe that using these levels helps illustrate the risk of WDM activities and the amount of lead that is added to the environment from WDM. We believe that this is a very low level and the risk would be considered minimal. Additionally, many areas where WS conducts WDM are off-limits to the public and, therefore, we believe risks are likely even lower.

Comments received not requiring a response. We appreciate these comments.

1. **Comment:** This review adequately describes the use of lead and techniques that use lead for wildlife damage management.

2. **Comment:** Overall the method risk assessment was complete and thorough in describing methods, consequences and successes.

3. **Comment:** I appreciated the opportunity to review the risk assessment!