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

Chapter XXIII

Carcass Disposal in Wildlife Damage Management

August 2022

Peer Reviewed Final
May 2023

CARCASS DISPOSAL IN WILDLIFE DAMAGE MANAGEMENT

EXECUTIVE SUMMARY

USDA APHIS Wildlife Services (WS) uses various carcass disposal methods as part of its wildlife damage management activities, including disposing of carcasses during disease outbreaks. Federal and state regulations and internal USDA APHIS WS policies provide the requirements for proper carcass disposal to reduce environmental and human health impacts.

WS uses various carcass disposal methods, including leaving carcasses in the field, burial, open-air burning, composting, rendering, landfill, incineration, and tissue digestion. Some carcasses may also be donated for human consumption where appropriate and in compliance with federal and state regulations. APHIS WS disposes of carcasses more commonly as a result of wildlife damage management activities compared to disease outbreaks. WS leaves most carcasses in the field since most animals taken using lethal methods are individually taken or taken in small numbers and do not pose a threat to wildlife or humans. This method ensures disease is not moved off-site if a local outbreak is occurring. If an animal is diseased, it is turned over to the Health Department or disposed of appropriately to eliminate disease transmission to other wildlife.

As carcasses degrade, bodily fluids consisting of natural and anthropogenic chemical and biological leachate, and hazardous gases may be released into the environment. As a result, carcasses must be effectively managed to minimize the risk to human health and the environment. In addition, specific processes used to manage carcasses may also result in air emissions, liquid effluent, or solid byproducts that pose a risk to human health, animal health, and the environment.

The risk of carcass disposal to human health varies based on the number of animals being disposed of and whether a disease is a concern. The risk to human health from carcass disposal is generally low for all methods when following applicable federal and state regulations and APHIS WS policies. WS personnel are at the greatest risk from handling carcasses either from onsite disposal or from transporting carcasses to other sites for disposal. WS has two directives related to carcass disposal. WS policies and compliance with applicable federal and state regulations reduce the risk to WS employees and the public.

Risk to ecological resources also varies based on the number of animals being disposed of and the method being employed for disposal. Decomposition products produced during carcass disposal can also pose a risk to ecological resources through air, soil, and water exposure. Leaving carcasses on-site in the field results in a greater potential for exposure to scavengers compared to the other disposal options, such as burial, rendering, incineration, and tissue digestion, where no exposure to scavengers would be expected. Animals that WS euthanizes with drugs can pose secondary hazards to scavengers. Disposal of animals euthanized with drugs is dictated by applicable federal and state regulations, drug label instructions, or lacking such guidelines, by deep burial, incineration, or at a landfill approved for such disposal. These would also apply in cases of carcass disposal where zoonotic disease or chemical contaminants are a concern. WS uses disposal options to reduce the risks to scavengers and other ecological resources through compliance with federal and state regulations and WS policies.

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1 INTRODUCTION

The U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Wildlife Services (WS) Program conducts wildlife damage management (WDM) and other related wildlife management activities that result in carcasses of animals. WS uses a variety of WDM methods that lethally take wildlife that may be left in the field (carrion), used for human consumption, rendered, taken to landfills, buried, incinerated, put into a waste digester, composted, or used as bait. Carcasses, especially in large numbers, can present potential risks to humans, domestic animals, wildlife, and the environment. As carcasses degrade, bodily fluids consisting of natural and anthropogenic chemical and biological leachate and hazardous gases may be released into the environment. As a result, carcasses must be effectively managed to minimize this potential. In addition, specific processes used to manage the carcasses may result in air emissions, liquid effluent, or solid byproducts that pose a risk to human health, animal health, and the environment and must be considered. This human health and ecological risk assessment provides a qualitative evaluation of potential risks and hazards to human health and the environment from exposure to carcasses taken by WS.

WS complies with all applicable regulations and policies for carcass disposal activities. WS policies regarding the disposition of wildlife carcasses are outlined in WS Directive 2.515 Disposal of Wildlife and WS Directive 2.510[1]: Fur, Other Animal Parts, and Edible Meat Carcasses and USDA-APHIS Standard Operating Procedures for disposal (APHIS 2014, 2016, 2021). Management of carcasses taken in WDM mostly depends on the method used to take the animal (e.g., toxicant, euthanasia drugs, traps, and firearms) and the number of animals taken and carried out according to the WDM operational plan. Carcass retrieval is often necessary for zoonotic disease management, ecological, environmental, scientific, or public sensitivity purposes. In these instances, WS personnel make reasonable efforts to retrieve and dispose of wildlife carcasses that result from WS WDM activities. WS personnel comply with procedures outlined in the WS Field Operations Manual for the Use of Immobilization and Euthanizing Drugs and WS Directive 2.430 Controlled Chemical Immobilization and Euthanizing Agents. Animals euthanized with drugs that may pose secondary hazards to scavengers must be disposed of according to federal, state, county, and local regulations, drug label instructions, or lacking such guidelines by deep burial, incineration, or at a landfill approved for such disposal. WS is also guided by carcass management as conducted by APHIS Veterinary Services (VS) for livestock and poultry disease outbreaks and discussed in APHIS (2016).

1.1 Carcass Disposal Methods

Several carcass disposal options are considered for different WDM operations based on the type of project. If no known problem exists, such as a disease, carcasses may be left in the field to decompose or be removed for disposal. If an animal is taken with toxicants or drugs with potential secondary hazards or succumbs to a disease or environmental contaminant that could affect humans or wildlife, they are generally removed from the project site and managed with any number of disposal methods (APHIS 2016, 2021). Depending on the circumstances, the carcass may need to be decontaminated prior to removal, including being bagged, especially if an external contaminant or disease is present that can affect people, wildlife, or the environment. Depopulation in an area for disease suppression, such as a herd of captive white-tailed deer[2] with chronic wasting disease or brucellosis, may require an increased level of carcass management

[1] All WS Policy Directives referenced in this document can be found under Wildlife Damage – WS Program Directives @ http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/wildlifedamage.

[2] See the Introduction to Risk Assessments – Chapter I for scientific names. These are only given if not used in that Section

procedures to ensure that disease does not spread or odor does not become an issue (Mukhtar et al. 2012). WS conducts many WDM projects that result in carcasses but conducts few projects specifically for animal disease annually.

On-site disposal options include leaving carcasses in the field, unlined and lined burial, open-air burning, mobile incineration, and composting (APHIS 2016). Off-site disposal includes taking to unlined and lined burial sites, centralized composting, rendering, landfills, and fixed-facility incineration. Still, it can create additional concerns due to the potential for the transport vehicle to accidentally leach infection or be involved in an accident on the way to the disposal facility (Center for Food Security and Public Health 2014, APHIS 2016).

After removing contaminated carcasses from an animal health disease site, decontaminating equipment, materials, and premises may be required to prevent or mitigate the spread of contaminants (APHIS 2018). Decontamination is the inactivation or reduction of contaminants by physical, chemical, or other methods to meet a cleanup goal. Cleaning and disinfecting are part of the decontamination process. USEPA (2022a, b) has the authority to regulate pesticides, specifically disinfectants. USEPA defines disinfectants as pesticides that are used to kill or inactivate disease-producing micro-organisms on inanimate objects.

All disposals will be made in a manner consistent with federal, state, county, and local regulations. All methods listed below are approved for the disposal of wildlife carcasses or parts thereof unless otherwise prohibited (APHIS 2021).

1.1.1 Carcasses Left in Field

WS personnel often leave carcasses in the field, which become carrion (Figure 1). Carrion provides food or nutrient resources for various scavengers, including invertebrates, vertebrates, and plants (Barton et al. 2012, Barton and Bump 2019). Carrion represents only a minimal portion of detritus in most ecosystems because plant litter is usually in much greater quantity (e.g., Parmenter and MacMahon 2009), but its role in nutrient cycling and community dynamics is disproportionate as carrion is nutrient-rich and decomposes much faster (Swift et al. 1979, Moore et al. 2004, Parmenter and MacMahon 2009, Barton and Bump 2019). Carrion forms a ‘‘cadaver decomposition island” with distinct biological and chemical activity hotspots (Carter et al. 2007, Barton et al. 2012). As a result of being a draw to scavengers, especially birds, cadaver decomposition islands can also influence seed dispersal from birds flying to and from them (Steyaert et al. 2018).

Figure 1. Carcasses left in field provide feed for diurnal and nocturnal scavengers, and invertebrates.

WS leaves most carcasses in the field since most animals killed in WDM are taken individually or in small numbers and do not pose a threat to wildlife, humans, or the environment. For animals trapped in larger groups in cage or corral traps (e.g., feral swine), WS scatters the carcasses in the area surrounding the trap site to minimize any potential environmental risks associated with a concentration of carcasses in one spot. This method aims to limit pathogen dissemination off-site if a local outbreak is occurring. If a known diseased animal is encountered, it is turned over to the Health Department or disposed of appropriately so it will not transmit the disease to other wildlife.

1.1.2 Human Consumption

WS may donate meat for human and non-human consumption, which can provide a source of nutrition for people and animals. Typically, WS takes animal carcasses to a meat processor as soon as possible after a WDM operation to minimize spoilage; some animals may be transported and euthanized with carbon dioxide at the processor. Meat processors are contacted beforehand, and arrangements are made for the drop-off. Processors prepare the meat (Figure 2) and give it to designated recipients. WS has stopped donating meat of some species, particularly feral swine, due to the number and high prevalence of diseases found in their populations.

Figure 2. Preparing venison cuts for packaging.

With changes in the global economy, people throughout North America and elsewhere are taking advantage of locally available food sources such as wildlife. Many of these communities have limited access to sufficient food due to limited resources. When examining the environmental contaminant concentration risks to humans, the greatest at-risk groups rely on "*traditional food systems*" for most of their diet. Traditional food systems refer to food species available to a particular culture from natural resources and their accepted usage patterns (Kuhnlein and Chan 2000). These groups are typically indigenous peoples in ecological settings of Alaska and other areas of the United States, Canada, Greenland, and northern Europe, and less frequently, people that primarily practice subsistence lifestyles (Kuhnlein and Chan 2000). To a lesser extent, sportsmen who harvest wildlife supplement their diets from wildlife sources.

If the consumption of a food resource such as wildlife does not pose a life-threatening risk, it is not governed by food industry regulations. Ultimately, the decision to harvest and consume these items is the responsibility of the harvester and consumer. Often, consumption advisories are issued based on the contaminate residue limits, and consumers should remain vigilant in ensuring these recommendations are not exceeded.

1.1.3 Unlined and Lined Burial

Unlined burial involves excavating a pit in the earth (Figure 3), placing the carcasses in the pit, and backfilling with the excavated material. This action is referred to as trench burial when a long narrow pit (trench) is dug versus a large circular hole. Burial pits are typically dug at a single, central location on the premises but typically involve a single large animal or several animals where a cull occurred. However, trench burials may also be constructed with multiple trenches at the affected premises when the numbers of animals are high. Carcasses from multiple premises may also be gathered and buried at a single centralized location. The landowner or land manager typically conducts carcass burial. Larger, existing burial trenches are sometimes excavated by livestock managers for routine livestock carcass disposal programs. Carcasses exude leachate that

Figure 3. Unlined burial pit for livestock carcasses (Unknown source).

can contaminate soil and groundwater, predominantly permeable soils such as sandy loam in unlined burial pits.

Lined burial pits are used to control leachate from carcasses. Lining materials such as compacted clay liner systems or synthetic liners in pits are a barrier for vertical movement of leachate and control flow to reduce soil and groundwater contamination (Kim and Pramanik 2015). In lined systems, leachate can be pumped for treatment to control potential contaminants in soil and groundwater effectively (Albano et al. 2011).

State and local laws and regulations may apply to unlined and lined burial sites, and permits may be necessary to conduct such activities. For example, states require varying depths, which may be 3 to 10 feet deep depending on the state and cover material such as soil or carbon source. Generally, burial pits are not allowed on a slope greater than 5%. The primary resources required for burial sites include the appropriate area to store accumulated carcasses awaiting burial temporarily, the appropriate area to bury carcasses, moving and excavation equipment, and equipment fuel. Land use at these sites may be impacted or lost for several years. Uncontrolled gases, leachate from carcasses, and exhaust from excavation equipment are byproducts of unlined burial. Gases and leachate are more controlled in lined burial systems. Assessing how much leachate will affect groundwater quality by volume and concentration in the watershed is important. It is most likely to occur from leachate produced in unlined burial sites. It should be noted that livestock producers prefer to use licensed collector services for carcasses rather than burial because of the ease and potential for site contamination (Freedman and Fleming 2003).

Currently, WS buries feral swine carcasses in relatively few states, including Alabama, Arkansas, Florida, New York, and the territory of Puerto Rico. In most states with large feral swine populations, including Texas, California, Hawaii, and Oklahoma, WS does not bury carcasses on site.

1.1.4 Open-Air Burning

For open-air burning in fields, carcasses are placed on combustible heaps, known as pyres, and burned to ash (Figure 4). Open-air burning typically occurs where mass animal health emergencies have occurred (e.g., on the affected premises). As with unlined burial, state, and local laws and regulations may apply and require permits, such as one from a local Fire Marshall. In some areas burning may be restricted or banned. Resources required for open-air burning include the appropriate area to store accumulated carcasses awaiting to be burned temporarily, the appropriate area to burn the carcasses, the necessary equipment and equipment fuel, and fuel and combustibles to set and maintain the fire. Machinery is necessary to dig a shallow trench to build the pyre and move the carcasses onto the pyre. A mixture of fuels, such as straw or hay, untreated timbers, kindling wood, and coal or diesel fuel, are required to ignite the pyres and raise the temperatures to the degree necessary for carcass incineration. Fully burned carcasses produce solid waste byproducts, bone, and ash, typically free of pathogens except for prions (Ellis 2001) and decaying

Figure 4. A pyre and smoke rising from a pyre during open-air burning of livestock (picture source Ledingham, S., n.d.)

material that could attract disease vectors (APHIS 2014, 2018). However, other outputs include potentially high levels of air pollution, large amounts of potentially contaminated ash (dioxins, heavy metals), leachate, and unwanted heat. WS generally avoids the use of open burning due to potential fire hazards except when regulations require this method, and it can be conducted safely (WS Directive 2.515).

1.1.5 Composting and Above Ground Burial

Composting is a decomposition process that takes place in the presence of oxygen from the air and relies on naturally occurring microbes, including bacteria and fungi, that aid in the process (Kalbasi-Ashtari et al. 2005, Auvermann et al. 2006, Rahman et al. 2009). Carcasses are combined with organic matter either directly on the ground or on a protective barrier such as plastic or cement that lies on the ground. Above ground burial has been shown to be very effective, with minimal potential to contaminate groundwater (Figure 5). Windrow composting is when the carbon-rich organic matter and carcasses are piled in long rows. Carcass composting can occur on the affected premises or at a centralized location away from the affected premises.

Figure 5. Carcass compost piles (picture source Severidt, J.A. et al. 2002).

Resources required for composting include the appropriate area to store accumulated carcasses waiting to be composted temporarily, the proper area to compost, composting equipment and amendments, and generally, a carbon source such as wood chips and water (Brinton 2000). Composting equipment includes machinery to lift, mix, move, or grind and churn composting piles and instruments for monitoring the composting piles' physical (temperature) and chemical (pH) properties. A front-end loader can be used to move carcasses and turn the pile every 3 to 6 months (Auvermann et al. 2006) and load the final compost into a spreader truck. Effective carcass composting requires layers of carbon sources and bulking agents, adequate aeration, and water (Dougherty 1999, Kalbasi-Ashtari et al. 2005). Carbon source bulking agents (also referred to as amendments) provide the necessary nutrients for decay. These include spent horse bedding (horse manure and pinewood shavings), wood chips, refuse pellets, rotting hay bales, peanut shells, or tree trimmings.

Compost piles are sometimes placed directly on bare ground, but a barrier may be placed between the ground and the piles to help contain leachate. Impermeable barriers can be made of polyvinyl chloride (PVC), plastic, concrete, or asphalt (Rahman et al. 2009). A layer of biodegradable carbon sources (e.g., straw, sawdust, corn stalks, and yard waste) may also be placed beneath carcasses to act as a sorbent and biofilter layer to capture and assist in degrading pollutants). Composting has the potential to produce a valuable stabilized organic residue that is a dark brown to black soil called humus. Humus, which contains primarily nonpathogenic bacteria and plant nutrients, may be spread over the land as a soil additive (Mukhtar et al. 2004) if harmful pathogens are absent. Incompletely degraded humus (which still contains pathogens) or compost made from contaminated animals should not be sold as a commodity and should be disposed of as solid waste. In addition to humus, composting produces water vapor, carbon dioxide, heat, and leachate. The compost area is temporarily lost to production or other activities during composting. Composting should always be performed in a controlled manner and accomplished by trained and experienced personnel where possible. While composting is effective at degrading many disease agents, the process may not be as good as other methods because harmful byproducts could potentially move into the environment where they could be a risk to people unless containment measures are employed.

WS does not typically establish new compost sites for its projects but may take advantage of compost piles established by producers to dispose of carcasses from their livestock operations. Composting would only be conducted in coordination with land management agencies and landowners and in compliance with federal, state, territorial, tribal, county, and local regulations and in accordance with APHIS-WS Directive 2.515 and where facilities already exist.

1.1.6 Rendering

Rendering is a physical and chemical transformation of animal products using a variety of equipment and processes (Meeker 2009). Rendering factories (Figure 6) convert meat-packing plant waste, kitchen grease, and livestock and wildlife carcasses into industrial fats and oils for products such as tallow for soap and various other products such as fertilizer. All rendering processes require the application of heat, the extraction of moisture, and the separation of fat (Meeker 2009). If a carcass is in an advanced decomposition stage, removing the hides and cleaning carcasses becomes more difficult, and decay results in poor-quality end products (Auvermann et al. 2004). Thus, carcasses should be rendered in the early stages of decomposition if the byproducts are to be marketed. Livestock and wildlife carcasses (raw materials) are ground into consistent particle sizes and put into a cooking vessel. Depending on the system and materials, it is heated with steam to temperatures of 240 to 290 °F for 40 to 90 minutes. The melted fat is then separated from the protein and bone solids with a press, removing a large portion of the moisture. Lastly, the protein, minerals, and some residual fats are further processed with continued grinding removing additional moisture, and the products are transferred for storage or shipment (Meeker 2009). Rendering facilities are typically equipped with scrubbers to control emissions of odors and air toxins and wastewater treatment systems to meet discharge permit requirements for the generated wastewater. Compared to digestion and composting, rendering produces 25% as much carbon dioxide, a greenhouse gas, and is considered to have better environmental sustainability (Gooding and Meeker 2016).

Figure 6. Fishmeal rendering plant (picture source asthaiworks.com, ASTW 2020).

Resources required for rendering include transportation equipment, fuel to move the carcasses offsite, and a rendering facility that will accept the carcasses. An appropriate area to store accumulated carcasses temporarily may also be needed. The final byproducts of carcass rendering are free of most pathogens and unpleasant odors, provided the proper processing conditions are used (Sindt 2006). Rendering byproducts from processing carcasses generated by diseased animals are generally not sold for human or animal use. The three primary byproducts from the rendering of carcasses are carcass meal (solid proteins), melted fat or tallow, and water (Auvermann et al. 2004, Sindt 2006). Wastewater created during the process must be disposed of properly, typically under a wastewater discharge permit (USEPA 2022e). The capacity of each rendering plant varies (Auvermann et al. 2004), but industry reports show that typical rendering operations can process 1 million pounds of raw materials in a 24-hour period (Sindt 2006).

Rendering cannot be used for animals killed with lead ammunition, and the availability of independent rendering plants may be limited. Due to the remote operational locations of WS WDM activities, rendering may be precluded as a method of carcass disposal. WS used rendering frequently in the past when they were more commonplace and accessible, but they do not use them as regularly today.

1.1.7 Landfill

Figure 7. Typical landfill, which must be certified to accept animal carcasses.

In the United States, landfills (Figure 7) are highly regulated engineered structures containing solid waste. The Resource Conservation and Recovery Act (RCRA), which amended the Solid Waste Disposal Act, created standards for waste generation, treatment, storage, and disposal. It essentially banned open dumps (40 CFR §§ 258.1(g), 258.1(h)). USEPA (2022f) is responsible for compliance monitoring and enforcement activities under RCRA. Disposal of animal carcasses is allowed in landfills if the facilities have been approved to accept this type of waste. Poultry carcasses taken by WS and other APHIS personnel were placed in landfills during the 2002, 2016, and 2022 avian influenza outbreaks in several states, the 2002 exotic Newcastle disease outbreak in California, and, more recently, the 2022 avian influenza outbreak. The primary resources required for a landfill include the appropriate area to store accumulated carcasses awaiting burial, a landfill that accepts the carcasses, and equipment and fuel for transportation (Chang et al. 2008). While leachate and gases are produced in landfills, they must be collected and contained in accordance with USEPA (2022f) regulatory requirements to protect the surrounding environment. USEPA requires facilities to follow design and operating standards, groundwater monitoring programs, and corrective action measures. The primary features are composite liners, leachate containment, and gas collection systems. The requirement for at least daily cover with earthen materials (or an approved alternative) is specifically designed to control disease vectors, odors, blowing litter, and scavenging (40 CFR § 258.21(a) and (b)). In addition to USEPA (2022f) regulations, landfill operators must also meet State and local landfill regulations.

Potential risks to public health from decomposing animal carcasses in landfills can influence an operator's decision regarding whether to accept carcass material, even if the landfill is permitted to receive carcasses. Some landfill owners refused to accept carcasses for burial from the 2001 foot-and-mouth disease outbreak in the United Kingdom (Nutsch and Spire 2004) and deer and elk in Wisconsin from a chronic wasting disease (CWD) outbreak.

Landfills treat byproducts of decomposition, such as leachate, prior to release into the environment. Landfills may recover byproducts of decomposition, such as methane and carbon dioxide (biogas), for use as an energy source (USEPA 2022c) or release gases into the environment in a controlled manner. Federal or State regulations require most large landfills to capture landfill gas and combust it by flaring or treating it so it can be used in a landfill gas energy system (USEPA 2022c). Flaring will burn the gas with no energy recovered, while harnessing the power of landfill gas will reduce greenhouse gas emissions, offset the use of nonrenewable energy resources, improve local air quality, and provide revenue for landfills (USEPA 2022c). Recovered methane can be sold directly to an end user as natural gas fuel (USEPA 2022c). The availability of preexisting landfills is an advantage when other options fail, particularly if the landfill can receive a relatively large quantity of carcasses. Previously approved Subtitle D landfills allow a rapid response to situations where large numbers of animals are culled if the site already has the needed environmental protection features. Animal carcasses would typically be categorized as nonhazardous waste. RCRA Subtitle D regulates the management of nonhazardous solid wastes (USEPA 2022f). Under Subtitle D, permitting and monitoring municipal and nonhazardous waste landfills are the responsibility of States. Carcass disposal at landfills would occur in Type 1 facilities. Type 1 facilities are required to meet RCRA Subtitle D requirements, as well as other applicable federal and state regulations. These types of facilities can accept most types of carcasses and are designed to manage leachate and gases that are a result of the degradation of organic material, such as those associated with carcass disposal. It must be noted that many landfills have contractual obligations to accept waste from other sources, and these landfills may not have the available additional capacity to accept large quantities of animal carcasses.

1.1.8 Incinerator

Incineration is a waste treatment process that ignites waste materials, combusts the organic portion of the materials, and captures the inorganic portion of the materials either as fly ash or flue-ash, which is a fine particle residue that rises with gases generated during and after combustion, or bottom ash, which is the larger, noncombustible residue that falls to the bottom of a furnace. Fixed-facility incineration (Figure 8, top) occurs at facilities that are dedicated to this purpose, as opposed to semi-movable incinerators on skids (Figure 8, middle) and mobile incinerators on trailers (Figure 8, bottom), which are transported to various sites. Fixed-facility incinerators include small on-farm incinerators, small and large municipal and hazardous waste incineration facilities, crematories, and power plant incinerators. Several smaller incinerators are made to fit on trailers that can be moved to the location of a carcass and incinerate on-site.

Unlike open-air burning, fixed-facility incinerator processes and locations are highly controlled (Kastner and Phebus 2004). New incinerators are particularly efficient at burning carcasses under USEPA (2022e) established emission standards of the Clean Air Act, which have limits on pollutants released into the environment. Many fixed-facility incinerators are equipped with flue gas-cleaning equipment that captures fly ash and air toxins from the incineration process, such as acid gases. The United

Figure 8. A fixed-facility incinerator, a semi-mobile incinerator on a skid, and a mobile incinerator (picture source matthewsenvironmental solutions.com 2020).

Kingdom disposed of many infected animals during bovine spongiform encephalitis (BSE), “mad cow” disease, outbreak by using fixed-facility incinerators (Kastner and Phebus 2004) and any could be used for CWD in deer. BSE and CWD are prion-based diseases; prions are abnormal folding proteins that affect mammals. Resources required for incineration include the appropriate area to temporarily store accumulated carcasses awaiting incineration, an incinerator that can accept the carcasses, and equipment and fuel for transportation. Typically, diesel, natural gas, or propane fuel is needed to ignite the high-water content carcasses. Incineration produces ash, air emissions, and heat. Burning waste materials to ash requires sustained high temperatures, generally over 1562.0 ºF (850 C). Facilities accepting solid wastes do not necessarily accept animal carcasses (USEPA 2021a, 2022e). The capacity or productivity of incineration plants (volume of incinerated wastes produced per time unit) varies with the available type, size, and number of equipment and other resource factors. Some plants can treat more than 100,000 tons of waste per year. WS does not anticipate using this method very often, but it may be used in some states. Backyard poultry flock producers in the 2022 avian influenza outbreak used this method for a small number of premises.

1.1.9 Alkaline Hydrolysis Tissue Digester

With the appearance of a massive pressure cooker on wheels, alkaline hydrolysis tissue digesters convert carcasses to a sterile slurry and crushable bone and teeth with no pathogens that can be safely disposed of in a sanitary sewer. Digesters degrade tissues and proteins quickly, including prions. The carcass is placed in a pressure vessel that is filled with a mixture of water and sodium or potassium hydroxide and heated to a temperature around 320°F for four to six hours under an elevated pressure, which prevents boiling and effectively breaks a carcass down into its chemical components. A lower temperature of 208°F and pressure may be used but for 14 to 16 hours. The mixture starts at a strongly basic pH level of approximately 14 that drops to 11 by the end; the final pH level depends on the total operation time and the amount of fat in the body. Alkaline hydrolysis tissue digesters that have an 8-foot diameter are large enough to accept cattle carcasses. Digesters are the best method to dispose of carcasses with pathogens such as CWD, whereas other disposal methods may not ensure 100% devitalization of the pathogen. Digester availability limits their use, but these are becoming more available for use.

Figure 9. Tissue digesters.

1.1.10 Anaerobic Biodigester

Another digester is an anaerobic biodigester, which uses anaerobic microbes to break down organic matter in the absence of oxygen. The output is principally methane gas along with carbon dioxide. Methane can be captured and used for heating and electricity. The process is similar to composting except that the gases are captured and can be used for power. The byproducts can be used as fertilizer. Temperatures range from 86º to 100º for mesophilic digesters (intermediate temperature environment) and 122º to 140º for thermophilic digesters (high-temperature environment), and generally have particular microorganisms that thrive in these temperature ranges (USEPA 2021c). Thermophilic digesters are generally used to destroy most pathogens.
Carcasses are ground, then placed in a digester, and decomposed by various fermentative anaerobic bacteria (USEPA 2021b). For example, in lactic acid fermentation, ground carcasses are mixed in tanks with lactic acid bacteria and fermentable carbohydrates such as whey or corn.

Biogas is generated, mostly methane and carbon dioxide, with small amounts of water vapor and other gases. Carbon dioxide and other gases can be removed, leaving only methane. In addition, digestate, a wet mixture that is usually separated into a solid and a liquid, is left. Recovering methane from biogas can be a cost-effective source of renewable energy. Digestate is nutrient-rich and can be used as fertilizers for crops if temperatures are consistently high enough to deactivate pathogens. Otherwise, digestate can be stored in vented vats and transported to a rendering facility (USEPA 2021b). Anaerobic digestion can sometimes be slow, approximately 7 to 10 days to complete, and the capacity is limited to the digester size. Thus, the method is appropriate for the disposal of a set tonnage of carcasses. These are becoming more popular as a disposal method, but still are not used very frequently.

1.2 Use Pattern

WS conducts WDM with a variety of methods to protect agriculture, property, natural resources, and human and animal health and safety throughout the United States. WS lethal take is recorded in the computer-based Management Information System (MIS[3]). The methods used by WS have been discussed in other risk assessments, and the disposition of carcasses was minimally discussed in "The Use of DRC-1339 in Wildlife Damage Management" risk assessment. WS NEPA documents often include some discussion on carcass management, and for feral swine specifically, carcass management was discussed in APHIS (2015). From FY11[4] to FY15 and FY16 to FY20, WS killed an estimated average of 3,966,168 and 2,585,469 target and nontarget vertebrates annually, respectively, for species with at least an average annual take (rounded) of one or more, or more than two in five years. WS WDM involved 465 species, 5 subspecies, and 3 "unknown" groups (bats, turtles, and fish)[5] (Table 1 and Appendix A). The total take would have resulted in an estimated annual average of 5,873 and 9,288 tons of carcasses, respectively. The primary difference was a significant increase in the annual average feral swine taken, rising from 33,000 in FY11-FY15 to 79,000 in FY16-FY20, respectively, which would make an estimated increase of 3,400 tons of carcasses per year. The National Feral Swine Program is expected to continue to increase take until feral swine are eradicated in many states; this will increase take for some time. It should be noted that about 46% of the take was from invasive species from FY11 to FY20.

From FY11-FY20, the highest annual average lethal take involved European starlings (37%), brown-headed cowbirds (16%), red-winged blackbirds (14%), black-tailed prairie dogs (6%), coyotes (2%), and feral swine (2%) (Appendix A). The highest tonnage of carcasses from FY11 to FY20, though, was estimated to be from feral swine (55%), coyotes (13%), white-tailed deer (8%), beaver (7%), black-tailed prairie dogs (3%), and raccoons (2%). By group, hoofed mammals accounted for 4,874 tons (64%), predators 1,302 tons (17%), and rodents and rabbits 880 tons (12%) (Table 1 and Appendix A). WS take represents only a small portion of wildlife taken in the United States. To give context, white-tailed deer harvested by hunters annually averaged 6.1 million deer and 1.3 million struck by cars (Quality Deer Management Association (QDMA) 2019), resulting in 648,000 tons of carcasses. Waterfowl harvest averaged 17 million birds annually from FY11-FY20, resulting in 21,000 tons of carcasses (USFWS 2012, 2014, 2016, 2018, 2020). The meat, fur, or other parts are often consumed or used. Thus, not all of this represents carcasses

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[3] The MIS is used for tracking WDM activities. Throughout the text, data for a year (e.g., FY11 to FY15) will be given and is from the MIS. MIS reports are not 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.

[4] 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).

[5] The Management information System (MIS) has several groups of species such as bats (all) or turtles (other) that are used and it could not be determined what the species was.

left in the field, but it estimates the amount taken for context. For example, a deer carcass averages about 47% meat by weight, 13% bones, 9% hide, 5% blood, and 26% other (Pennsylvania Game Commission 2020), depending on what is kept (typically meat, hide, and bones) an annual average of about a third was likely left in the field from FY11-FY20 (Table 1) or 214,000 tons from white-tailed deer harvest alone, which is 28 times higher than the total weight of all animals that WS takes. Scavengers consume those portions of the carcasses left in the field.

Table 1. The estimated annual average lethal take of target and nontarget animals in WDM by WS and tonnage of their carcasses from FY11 to FY15 and FY16 to FY20. For comparison, white-tailed deer harvested by hunters and killed in collisions with vehicles from insurance claims (QDMA 2019) and waterfowl harvested by hunters (USFWS 2012, 2014, 2016, 2018, 2020). Species taken by WS and harvested by hunters are given in Appendix A and discussed in Chapter 1: An Introduction to WS Methods Risk Assessments[6].

Whole Carcass Weight (Tonnage) of Wildlife Taken by WS for FY11-FY15 and FY16-FY20 and Sportsmen Harvest/Vehicle Kills for Context and Comparison					
WS Lethal Take	**From Appendix 1**	**FY11-FY15**		**FY16-FY20**	
Group	**Species Included**	**# Killed**	**Carcass (Ton)**	**# Killed**	**Carcass (Ton)**
Predators	27 Sp., 3 Ssp.	106,793	1,383	93,681	1,222
Hoofed Mammals	18 Species.	39,179	3,011	87,436	6,736
Rodents and Rabbits	82 Species	387,366	893	368,971	867
Other Mammals	17 Sp., 1 Group	884	6	670	4
Landbirds	148 Sp., 1 Ssp.	3,274,616	305	1,882,214	200
Waterbirds	131 Sp., 1 Ssp.	84,658	208	70,177	178
Reptile/Amphibian/Fish	42 Sp., 2 Group	72,672	67	82,320	81
Total	**465 sp., 5 ssp., 3**	**3,966,168**	**5,873**	**2,585,469**	**9,288**
Private Harvest and Vehicle Killed Weight		**FY11-FY15**		**FY16-FY20**	
How Taken	**Species**	**# Killed**	**Carcass (Ton)**	**Take**	**Carcass (Ton)**
Sport Harvest/Vehicle	White-tailed Deer	7,200,000	630,000	7,600,000	665,000
Sport Harvest	Waterfowl (35 sp.)	17,846,014	22,515	15,841,817	20,156
Total	**36 species**	**25,046,014**	**652,571**	**23,041,817**	**685,156**

Sp. = species; Ssp. = subspecies

The majority of mammals taken by WS are taken individually and left as carrion to decompose in the field or scavenged[7]. Many birds are collected and disposed of at local landfills. Culls to minimize disease spread when a herd has become infected with a disease such as CWD or brucellosis in a captive herd of white-tailed deer are disposed of by the most appropriate method, including incinerators and digesters. WS donates approximately 2% of wildlife meat taken in WDM for human and animal consumption(Table 2).

Table 2. The estimated annual average tonnage of meat donated by WS to qualifying organizations and individuals from FY18-FY21.

Annual Average Meat Donated by WS for FY18-FY21						
Consumption Type	**Meat (lbs.)**					**Total**
	Venison	**Swine**	**Bear**	**Goose**	**Other**	
Human	253,342	N/A	12,175	10,956	900	**277,373**
Animal	11,802	5,175	44	11,007	5,079	**33,107**
Total	**265,144**	**5,175**	**12,219**	**21,963**	**5,979**	**310,480**
Tons	**132.6**	**2.6**	**6.1**	**11.0**	**3.0**	**155**

FY18 was the first year that WS recorded the amount of meat donated nationally (most states collected this information earlier but it was incomplete nationally). For FY18-FY21, WS donated

[6] The Introduction is found at https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/programs/nepa/ct-ws-risk_assessments

[7] WS and the MIS does not track carcass disposition, so WS does not have disposition numbers.

an average of 155 tons (310,480 pounds) of meat annually (Table 2). Feral swine were regularly donated prior to 2010, but WS ceased feral swine donations for human consumption due to the number and severity of pathogens that could be transmitted to people, as determined by testing. It should be noted that sportsmen donated 1,400 tons (2.8 million pounds) of cervid, antelope, waterfowl, and pheasant meat in 2010 and that some states give income tax credits for donating meat (Congressional Sportsmen's Foundation 2022).

Table 3. The average annual disease tests submitted by WS operational personnel from FY17-FY19 as reported in the MIS and seropositive rate (have had the virus but may not be shedding) from any source. Rabies surveillance collections included an average of 8,466 brainstems collected in the eastern U.S. (for raccoon rabies variant), with 221 of these positive for the rabies virus. Some collections were from years other than FY17-FY19, where data were not available yet from testing, but the year is noted below. One highly pathogenic avian influenza was found in FY17 in a mallard[8].

DISEASE	Predator	Hoofed Mammal	Rodent & Rabbit	Bats	Bird	Turtle	TOTAL	% Sero Pos
VIRUS								
Rabies	18,840	12	143	174	-	-	**19,169**	**2%**
Avian Flu	2	-	19	-	10,652	-	**10,673**	**~13%**
Pseudorabies	5	1,861	-	-	-	-	**1,866**	**20%***
Hog Cholera	1	1,829	-	-	-	-	**1,830**	**0%**
West Nile Virus	2	311	-	-	84	592	**989**	**na**
Epizootic Hemorrhagic		227	-	-	-	-	**227**	**^**
Avian Paramyxovirus	-	-	-	-	162	-	**162**	**16%+**
Exotic Newcastle	-	-	-	-	152	-	**152**	**na**
Other Viral[1]	1	42	-	-	78	-	**121**	**N/A**
BACTERIA								
Plague	2,004	97	127	-	-	-	**2,228**	**27%**
Swine Brucellosis	1	2,132	-	-	-	-	**2,133**	**6.3%***
Tularemia	1,499	117	204	-	-	-	**1,820**	**0.7%**
Leptospirosis	622	118	-	-	-	-	**740**	**3.6%****
Salmonella	-	-	-	-	206	-	**206**	**8%#**
Tuberculosis[3]	2	95	-	-	40	-	**137**	**na**
Other Bacterial[4]	1	10	-	-	40	-	**51**	**N/A**
OTHER								
Unspecified Disease	223	1,452	19	-	302	-	**1,996**	**N/A**
Prion	-	564	-	-	-	-	**564**	**na**
Roundworms	302	-	64	-	25	-	**391**	**na**
Toxoplasmosis	5	53	-	-	79	-	**137**	**13%**
Other Parasite/Insect Vector[5]	78	72	4	-	-	-	**154**	**N/A**
Environmental (Lead)	-	-	-	-	51	-	**51**	**na**
TOTAL	**23,588**	**8,992**	**580**	**174**	**11,871**	**592**	**45,797**	**N/A**

[1] Other virus = Adenovirus, African swine fever (0%), avian bornavirus, canine parvovirus, equine encephalitis, hepatitis E, porcine epidemic diarrhea, swine influenza (7%), swine vesicular disease, viral encephalitis, and Wellfleet Bay virus; [2] Swine and bovine brucellosis; [3] Avian and bovine tuberculosis; [4] Other bacteria = Anthrax, avian cholera, bluetongue, botulism, bovine brucellosis, chlamydiosis, ehrlichiosis, *Escherichia coli*, and typhus; [5] Other Parasite/Invertebrate = Canine heartworm, echinococcosis, giardiasis, mites, neosporosis, Rocky Mountain spotted fever, trichinellosis (14% FY14-FY16), tapeworms, and ticks; ^ vector-borne and not presented on the carcass; + FY13 - 3,826 samples
NWRC surveillance ann. avg. FY17-FY19 - * 3,190 feral swine, ** 308 feral swine between, # – 388 gamebird intestinal samples, tularemia 168/23,426 in FY12

A primary concern of carcass disposal is the presence of disease pathogens. Zoonotic agents may be bacterial, viral, parasitic, or fungal or involve unconventional agents, such as prions

[8] In FY22, an HPAI outbreak occurred and hundreds of wild birds (e.g., waterbirds, raptors, and passerines) and a few mammals (e.g., fox, coyote, raccoons, and seals) were collected that tested positive for HPAI

(World Health Organization 2013). WS operations collect samples for disease testing, which is recorded in the MIS. In addition, the WS National Wildlife Research Center (NWRC) also collects samples in coordination with other programs in APHIS and other organizations, but this is not recorded in the MIS. From FY17 to FY19, WS collected an annual average of 45,797 samples to test for the presence of viral and bacterial diseases, parasite vectors of disease, and environmental contaminants (Table 3). The WS National Feral Swine Damage Management Program tested about 3,000 feral swine annually for several diseases, but these are not included in Table 3. The percentage of positive animals for disease varied greatly by region. It should be noted that some pathogens are alive only while the host is alive or are transmitted by vectors and not a problem in the carcass, but depending on the pathogen can persist for days or months in the carcass.

2 HAZARDS

2.1 Human Health and Safety Hazards

Hazards to human health and safety associated with carcass disposal primarily involve zoonotic disease, secondary hazards from drugs and toxicants (if these were used in the WDM project to kill or euthanize the animals), natural and artificial chemical and biological leachate from bodily fluids exuded during decomposition, and hazardous or odoriferous gases released during decomposition. The potential for people to consume contaminated or diseased animal meat is also a concern. Additionally, the movement or lifting of carcasses for disposal, especially heavier animals, could cause low back strains or other injuries to WS personnel.

Disease exposure is a primary concern for people that handle carcasses, including WS personnel. Carcasses from culls involving many animals for disease containment from WDM operations, though relatively infrequent, are collected and managed with one or more disposal methods discussed in Section 1.1. Most times, the animal owner may be responsible for the disposal of animals where their animals, such as captive cervids, are being culled for a disease. If carcasses are collected and transported to a disposal site and potentially have a contagious pathogenic disease, APHIS (2014, 2020) decontamination standard operating procedures (SOPs) for equipment and clothing are used to minimize the spread of the disease-causing agents during carcass management activities and allow personnel to work safely. The use of disinfectants and decontamination of personal protective equipment (PPE) is designed to reduce the risk of human infections by zoonotic pathogens and minimize the risk of transporting the disease agent to other locations (USEPA 2022g). For these reasons, cleaning and disinfecting actions of environmental surfaces and PPE during a response are considered a critical part of carcass handling, transport, and disposal policies. Decontamination procedures depend on the pathogen and follow guidelines presented in the Codes of Federal Regulations Title 9. Typical decontamination requires a disinfectant such as 2% chlorine solution applied to dry surfaces at room temperature. For more hardy pathogens such as prions that cause transmissible spongiform encephalopathies (e.g., CWD or scrapie), a 1-molar solution of sodium hydroxide at room temperature for at least 1 hour is applied to disinfect surfaces. Some disinfecting activities on the premises of a disease outbreak require that a State or APHIS employee supervise it.

According to the Centers for Disease Control (CDC 2022b), approximately 75 percent of new emerging human infectious diseases are of animal origin, and approximately 60 percent of all human pathogens are zoonotic. Fortunately, the primary diseases that cause mass animal emergencies, which can be foreign or endemic to the United States, are diseases such as foot-and-mouth disease and classical and African swine fever, which are not public health concerns because humans, for the most part, are not susceptible to these infections (Center for Food

Security and Public Health 2020). However, humans are susceptible to some zoonoses that can be transmitted from animal carcasses, such as avian influenza, this virus causes conjunctivitis or mild respiratory disease, but some viral strains, such as Asian lineage H5N1 (HPAI), cause severe disease and death. Brucellosis (*Brucella* spp.) bacteria causes an acute febrile illness in humans from cattle, bison, elk, and swine with nonspecific flu-like symptoms such as fever, headache, malaise, back pain, drenching sweats, myalgia, and generalized aches. Anthrax (spore-forming bacteria *Bacillus anthracis*) causes severe illness in humans affecting the gastrointestinal and respiratory tracts from direct contact with infected animals or animal parts such as blood, wool, or hide via a break, through an abrasion in the skin or from biting flies. Bovine spongiform encephalopathy (prion-based disease from consumption of contaminated meat) causes a spongy degeneration of the brain (WHO 2013, Center for Food Security and Public Health 2020).

As carcasses degrade, leachate is released into the environment and can directly affect the health of humans in the area. Leachate samples collected from a closed, covered, 5- to 15-year-old landfill had normal microbial flora of *Aeronomas hydrophila, A. sobria* (can cause gastroenteritis), *Bacillus thuringiensis*, *Brevundimonas diminuta*, *Chryseobacterium indologenes*, *Corynebacterium lucuronolyticum*, *Nocardia otitidiscaviarum*, and *Pseudomonas aeruginosa* and *P. putida* (Davis-Hoover et al. 2006). The leachate supported the survival of inoculated *Bacillus anthracis* (anthrax) cultures for 24 weeks, *Clostridium botulinum* (responsible for foodborne botulism) for 22 weeks, and non-spore-forming *Yersinia pestis* (plague) and *Francisella tularensis* (tularemia) for less than 7 weeks (Davis-Hoover et al. 2006). The ability of pathogen populations to survive in leachate demonstrates the need for leachate movement to be controlled but suggests minimal durations for severe pathogen risk from disposal that generates leachate. Concentrations of *Escherichia coli* (strains can cause gastroenteritis, urinary tract infections, and other animal and human diseases) and *Cryptosporidium* spp. (microscopic parasite causes diarrhea) in ground and surface waters were affected to a greater extent by excretion from live animals than from the burial of a small number of carcasses (Gwyther et al. 2011).

Improper carcass management can contaminate water supplies with biological or chemical agents, representing a health risk to human populations using the contaminated water for drinking, bathing, and cleaning. Existing laws and practices are designed to minimize impacts on water resources and decrease the likelihood of human exposure to contaminated water. Transient wildlife may disseminate contaminants from carcass piles or contaminated water to nearby people. Biological agents may become wind- or water-borne and place human populations at risk from nearby carcasses, making it prudent to require some level of carcass management activities for these areas. The risks rise with the number and size of carcasses being disposed of. The human health and safety risks of each disposal method arise from exposure to pathogens, workplace hazards associated with the equipment, and hazardous materials used or produced during processing. Each disposal method is associated with the production of some level of noise, either through the equipment as it operates or during the loading and offloading of carcasses. During normal operations for routine mortalities, these noise levels are expected to be within existing standards for occupational exposure.

Human health risks also include the potential for psychological distress arising from the sight of animal remains or coping with extremely unpleasant odors. Odors permeate most carcass management operations, primarily the smell of decaying animals that is revulsive to most people. To a certain extent, the human nose becomes desensitized during extended exposure to any smell, and, therefore, acute distress is likely to be felt by workers only from time to time. Passersby are likely to avoid the smells by leaving the area and closing vehicle windows. People residing downwind from a carcass management operation are those most likely to avoid periodic wafting odors.

Site safety is a key factor in preventing disease and contamination. If carcasses are contaminated with a contagious pathogen, the carcass management site may need biosecurity practices as part of the security system. If carcasses are contaminated with a non-infectious agent, the site may not need strict security and biosecurity measures. It should be noted that anthrax is rare in the U.S. because of the yearly vaccination of livestock in areas where it has been previously detected (CDC 2022b). Therefore, it is typically not a threat. Cleaning and disinfection at a site after carcass disposal include using physical or chemical processes to reduce, remove, inactivate, or destroy pathogenic microorganisms (APHIS 2020). Cleaning and disinfection procedures are crucial in controlling the spread or transfer of microorganisms between animals, locations, or people. The potential for the spread or transfer of microorganisms can occur from the direct or indirect contamination of equipment, facilities, vehicles, people, and the movement of animals or animal products. Cleaning and disinfection processes vary: many factors affect the efficacy of the process, including the method or product selected, the organism involved, and several other environmental factors, such as temperature, organic load, or water hardness. Procedures vary depending on the situation. No single method is adequate for all situations.

People can be exposed to pathogens or environmental contaminants from consuming wildlife meat. While most wildlife are healthy, pathogens and contaminants can be in the meat of some animals. Thus, preparation is critical to reducing most pathogens, but contaminants, such as mercury, remain. Proper preparation includes using clean surfaces and utensils, washing hands before and after cutting and handling meats, and cooking meats thoroughly. A few pollutants that do not break down in the environment can be consumed or absorbed by fish and wildlife and accumulate in the food chain, which in turn may be eaten by people. Many researchers have attempted to study the effects of chronic low-dose exposure to meat contaminants among human populations, but results remain controversial due to inconsistent findings because of confounding variables such as malnutrition, smoking, substance abuse, genetics, supplement use, medications, and pre-existing health conditions. Risk determinations for human populations from wildlife meat consumption are not static due to changing environmental contaminant levels, consequences of their use, and health effects. Health departments and other agencies often publish advisories or guidelines regarding high contaminant levels and are typically based on maximum residue limits or tolerable intakes and estimated consumption levels (Kuhnlein and Chan 2000).

Secondary hazards could occur in humans that consume found carcasses killed in WDM by toxicants and drugs. Secondary hazards of chemicals used in WDM are addressed in other risk assessments [9] for the use of toxicants, drugs, and environmental contaminants such as bromethalin, sodium pentobarbital, and lead. This scenario is not likely because carcasses found dead will not likely be consumed by people who chance upon them.

Injuries moving carcasses occur, especially for large animals such as deer and bears. WS personnel sustain injuries from moving carcasses, such as muscle pulls, slip-and-falls, abrasions, and cuts. Cuts that occur while dressing carcasses are especially concerning when the animal has a disease that can be transferred to humans. Blood-to-blood contact (septicemic transmission) is especially concerning for bacterial infections and toxins.

[9] WS methods risk assessments are at https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/programs/nepa/ct-ws-risk_assessments for toxicants, immobilization and euthanasia drugs, and lead.

2.2 Environmental Hazards

Similar to human hazards, environmental hazards associated with carcass management primarily involve wildlife disease, secondary hazards to wildlife from drugs and toxicants if these were the WDM methods used to take the animals, naturally and unnaturally occurring biological (e.g., *Aeronomas hydrophila* and *Francisella tularensis)* and chemical (e.g., rodenticides and euthanasia drugs) leachate components from bodily fluids, and hazardous gases (e.g., methane and carbon dioxide) released during decomposition.

APHIS responds to new animal disease outbreaks and is concerned about disease transmission from carcasses to healthy animals. For example, should an outbreak of African swine fever occur in the United States, APHIS would work closely with other federal and state agencies and the swine industry to take actions to protect the nation's pigs. African swine fever is a highly contagious and deadly viral disease affecting domestic and wild pigs of all ages. There is no evidence the virus is transmissible from pigs to humans. No treatment or vaccine is available for this disease. The only way to stop this disease is to depopulate all affected or exposed domestic and feral swine. APHIS is actively preparing to respond if African swine fever is detected in the U.S. In FY22, an outbreak occurred on the Island of Hispaniola, and APHIS is actively removing feral swine and sampling them on the neighboring island of Puerto Rico. Minimizing risks from feral swine carcasses on the landscape is necessary for response planning and preparedness. During outbreaks that potentially involve livestock, APHIS Veterinary Services becomes involved and works with the appropriate state agency to determine the disposal method and where this will occur according to state laws. APHIS provides technical information, but the states and the landowner, if it involves captive wildlife for slaughter, would conduct the disposal.

Bowden et al. (2023) determined that applying hydrated lime, a disinfectant, to feral swine carcasses, in a control operation where carcasses must be left in the field, even temporarily, could reduce carcass disruption via scavenging (Figure 10). The addition of hydrated lime to a carcass creates a sterile crust on feral swine but does not disinfect the entire carcass. Scavengers, including turkey vultures, corvids, and coyotes, visited hydrated lime-treated carcasses. Preliminary research suggests that applying hydrated lime to carcasses may be a partial solution to leaving carcasses in the field. However, further study is needed to determine if scavengers could transfer the disease. Hydrated lime could also be used for other contagious disease outbreaks.

Figure 10. Turkey vultures attempting to scavenge a feral swine carcass covered with hydrated lime.

Secondary hazards could occur for wildlife that consumes carcasses killed with the use of some toxicants and drugs; these risks are addressed in separate risk assessments for the individual take methods, as given in footnote number 9. Depending on the method used to take wildlife, some risks of secondary poisoning could be higher. Although many chemical methods WS uses can potentially be a secondary hazard, the risk of exposure to toxic levels is minimal.

3 EXPOSURE AND RISKS

3.1 Human Health and Safety Exposure and Risks

Human exposure and risk to carcasses are greatest for those who handle and dispose of the carcasses. Where carcasses are left in the field, the public can be exposed. However, the majority of carcasses are on private lands where the public has little access. The various carcass disposal methods can potentially pose risks to human health and safety at various levels and for a broader range of people. Proper carcass disposal management with mitigation as necessary can minimize or nullify human health and safety risks.

3.1.1 Disease

Wildlife can potentially carry several zoonotic diseases that are a risk to people, and WS surveils the prevalence of many of these diseases (Table 3). WS conducts disease surveillance by collecting samples from an animal population which may require taking the animal (e.g., testing for rabies in raccoons) or collecting samples from an animal taken for another purpose (e.g., removing birds from an airport). In these situations, WS personnel are the population at risk of exposure to the disease when they collect the sample. However, WS personnel wear personal protective equipment such as gloves and face masks and use appropriate restraining devices to prevent zoonotic pathogens from entering their skin through wounds or bites from the restrained animal. WS personnel are trained in using sharp tools such as scalpels and needles used during sample collection and follow proper disposal protocols for sharp implements, as discussed in WS (2018).

During a mass animal health emergency involving a disease outbreak, WS personnel, along with veterinarians or livestock owners, may be exposed to the pathogen. APHIS (2021) carcass management protocols and safeguards may provide some protection to non-APHIS staff assisting in a mass outbreak, but WS does not have the authority to impose its safeguards on others.

Virulent diseases can spread to people from contaminated people, their clothing, PPE, or other equipment used to handle carcasses. Before leaving an infected site, WS mitigates these risks by cleaning and disinfecting clothing, PPE, and equipment, including trailer beds, trucks, backhoes, cutting implements, and hoists. APHIS (2020) and USEPA (2022a, b) provide information for various disinfectants that are appropriate to use against animal disease causative agents. Label directions are followed for disposal of items that cannot be adequately disinfected, such as some masks. The additional pathogen dissemination risk associated with transportation may be minimized by proper decontamination procedures and practices, including at vehicle accident sites along the transport route. For example, particles contaminated with pathogens may become airborne and then deposited on surfaces and equipment during infected carcasses' loading, transport, and off-loading (Center for Food Security and Public Health 2020). Thorough cleaning and disinfection with approved disinfectants of the transport vehicles after loading and unloading reduce these risks. Carcasses may need to be bagged for transport to avoid dispersal of pathogens. Insecticides may need to be used around carcasses to prevent the spread of disease from vectors such as biting flies and midges (Baird and Savell 2004).

Wildlife meat in the U.S. could be a potential source of pathogens. WS donates meat for human consumption (Table 2). WS personnel appropriately dispose of individuals that appear sick (lethargic, poor condition, abnormal growths, or other maladies). Meat processors can further cull animals with abnormal organs (spots on the liver, foul-smelling meat, or growths on internal organs). Many pathogens are minimized through proper handling and killed by cooking meats thoroughly, to 160 ºF for ground meat and 145 ºF for steaks. WS cannot guarantee any meat is disease-free, but if cooked appropriately, risks are minimal.

Carcass management can be a direct exposure risk to humans through pathogens such as tuberculosis, plague, and brucellosis. Carcasses turned over to processors for human consumption have the potential to spread disease or contaminants to people who process and consume the meat. Another example is that risks can be related to the process itself, such as working around heavy equipment used for handling carcasses, heat-related injuries related to burning, incineration, and rendering, or risks of chemical exposure from disinfection. Failure to properly manage carcasses when in large numbers also creates the potential for indirect exposure to risks. Disease and contaminants can be transferred from flies landing on carcasses or leachate and then directly landing on humans. If left unabated, vectors such as fleas and rats can spread pathogens or contaminants to humans from decomposing carcasses. Leachate runoff without mitigation can also spread disease and contaminants.

The risk of contracting a zoonotic disease, being exposed to harmful chemicals, or suffering an injury varies with carcass management methods and the number of carcasses at a site. The least potential risk posed by carcass management methods is leaving carcasses in the field when few are taken, taking carcasses to a landfill, rendering facility, incinerator, or digester, and using lined burial or composting with leachate and gas mitigation. Disposal methods that have more potential to be harmful to people but still minimally are open-air burning, unlined burial, and lined burial or composting without leachate and gas mitigation. Impacts on people are expected to be least when carcasses are left in the field or disposed of at regulated facilities, including rendering facilities, fixed-facility incinerators, landfills, and digesters, but transportation of the carcasses to these places could be a concern. This is especially true when the number of carcasses weighs many tons and when a known live contagious pathogen is potentially in the carcass. Byproducts of degrading carcasses, such as leachate that can potentially contain biological and chemical agents, are better contained within these controlled facilities than other methods. Regulated facilities with higher control in their processing are better able to destroy disease agents and destroy or capture potentially toxic residues and byproducts. Newer designs of disposal methods with enhanced containment of byproducts and better processing procedures have reduced the risks to humans. Overall, risks are minimal from decomposing carcasses, but WS personnel are mindful of this potential.

3.1.2 Cleaning and Disinfectants

Cleaning involves the removal of visible organic and inorganic matter (e.g., soil, dirt, debris, salts, oils, blood) from objects or surfaces where carcasses or animal parts have been. When done appropriately, cleaning alone can remove a large percentage of microorganisms (APHIS 2018, USEPA). This step also helps improve disinfection efficacy since many chemical disinfectants have reduced effectiveness in the presence of organic material. The cleaning process should be conducted before applying all EPA-registered disinfectants. Cleaning is broken down into steps dry clean, wash, rinse, and dry (APHIS 2018, USEPA 2022a, g).

Disinfectants are chemical agents that inactivate or destroy microorganisms on surfaces (APHIS 2020). Disinfection may not kill all microorganisms, such as bacterial spores resistant to these chemicals. Disinfectants include soaps and detergents, oxidizing agents, alkalis, acids, aldehydes, phenols, bleaches, and possibly insecticides[10] (Baird and Savell 2004). The use of

[10] Baird and Savell (2004) consider insecticides as a disinfectant by minimizing vectors that spread disease from contaminated carcasses.

any specific disinfectant depends on the type of disease outbreak that resulted in the need for carcass management (Mukhtar et al. 2012). When specific data is unavailable, USEPA (2022a, b) sometimes uses an organism hierarchy to identify effective products for use on emerging pathogens. Chemical disinfectants can inactivate most vegetative bacteria and enveloped viruses. Fungal spores and non-enveloped viruses generally are less susceptible to chemical disinfectants. Mycobacteria, bacterial endospores, and protozoal oocysts are highly resistant to most disinfectants (Favero and Bond 2000). Prions, the cause of transmissible spongiform encephalopathy, are exceptionally resistant to chemical inactivation. Newer model incinerators and digesters are best for destroying these proteins rather than disinfectants; APHIS SOPs discuss cleaning and disinfection in APHIS (2018). Some diseases, such as vesicular stomatitis, can be minimized using insecticides, stopping insect vectors that spread the disease from contaminated carcasses. Most diseases can be minimized by appropriate disinfection, vector management, or using the most appropriate carcass management method.

Disinfectant manufacturers typically must register their pathogen pesticide products with USEPA (2022a, b) and are required to provide data showing that the product performs as claimed. Labels appearing on the product containers, as well as any associated labeling, are approved by USEPA (2022a, b) under the Federal Insecticide, Fungicide, Rodenticide Act of 1947 (FIFRA), as amended (7 U.S.C. §§ 136-136y). It is unlawful to use a registered pesticide product in a manner inconsistent with its labeling (FIFRA section 12(a)(2)(G)). If a microorganism claim appears on the label, applicators may use the product according to label directions. If a claim for a particular microorganism does not appear on the label, which could be anticipated with new animal diseases arising, but all other use directions are followed and, among other things, the use site is the same as it is on the label, a disinfectant may still be used under a FIFRA section 2(ee) exemption. However, applicators are advised to check with USEPA to confirm this. Applicators may also apply to USEPA (2022a) for use exemptions that are not approved on the label through a FIFRA section 18 emergency exemption request.

3.1.3 Contaminants

Contaminants could affect human health from being consumed in wildlife meat, the primary concern of their presence. They can also be found in ash or leachate when carcasses are disposed of. Several toxic heavy metals such as arsenic, cadmium, mercury, and lead, and organochlorines enter the food chain from local mineralogy, military sites, mining and smelting sites, agriculture, and industrial areas such as glass, metal and paint manufacturers, lumber and crude oil processors, landfills, and quarries (Tsipoura et al. 2011, Rather et al. 2017). Plants are the base of the food chain, and they can easily absorb toxic substances from the soil and may contaminate leaves, fruits, and vegetables (Peralta-Videa et al. 2009); these, in turn, are eaten by fish and wildlife and go up the food chain. In the case of pesticides, the maximum residue level (MRL) is an important determinant of the risk it poses to human health and determines their use restrictions and allowable levels put on resources. The pesticide residue levels in food are regulated by legislation to minimize its exposure to the consumer (Nasreddine and Parent-Massin 2002). Chemical contaminants are primarily those transported short- and long-range from sites due to geology, including rain runoff and rivers, wind, wildlife, or industrial activities such as the movement of all types of vehicles. Contaminants can accumulate in wildlife and plants depending on multiple factors (pH, temperature, soil type, molecular structure of chemicals, concentration, organic-carbon content, and physiology) and their bioavailability in the soil, sediments, water, and plants. Once an organism ingests a contaminant, it can be subject to bioaccumulation or facilitate the transfer of the compound to other organisms. The degree of bioaccumulation in food webs depends on the number of species it passes through, biomagnification, solubility in lipids or water, and chemical inertness. Biomagnification, the continuous increase in chemical concentrations in a food chain, is highest in fish and marine mammals or seabirds (Kuhnlein and Chan 2000) but occurs in terrestrial birds as well.

Studies examining the effects of chronic low-dose exposure to contaminants among human populations have had inconsistent findings. These results may have been confounded by factors such as malnutrition, smoking, substance abuse, genetics, medications or supplement use, and pre-existing health conditions. Risk determinations for populations are not static due to evolving data on contaminants, the consequences of their use, and their health effects. Published advisories or guidelines are typically based on maximum residue limits or tolerable intakes and estimated consumption levels (Kuhnlein and Chan 2000). Subsequently, consuming food resources more often than the daily allotment or not consuming them in off-seasons when they are not available have not been studied.

Contaminant levels in wildlife meat vary regionally depending on proximity to local conditions, as discussed in Tsipoura et al. (2011). The age, sex, and diet of animals can similarly impact exposure. Like dietary assessments for nutrient intake, human contaminant exposure through food consumption is measured by assessing the level of food intake and the potential contaminant level within the food. Frequently consuming a large quantity of a food source with a low contaminant level could expose the consumer to the same relative risk as consuming a small amount of food with high contaminant levels, especially if it is primarily stored in the fats or lipids of animals. The extent of risk derived from dietary data and dietary standards for contaminants related to contaminate exposure must be carefully considered, especially in situations where meats pose a low risk to the consumer and contribute to the sustainable health of a community.

Wildlife are a food resource for many people, including subsistence hunters and sportsmen that harvest meat and impoverished people with food insecurities given donated meat from WS (Table 2). This meat may potentially contain contaminants. Cultures such as indigenous peoples that rely on wildlife resources and regularly consume meat may refer to dietary intake guidelines published by health organizations such as the Agency for Toxic Substances and Disease Registry, Joint Food and Agricultural Organization, World Health Organization Expert Committee on Food Additives, and USEPA. These dietary standards, including contaminant-intake guidelines, express tolerable intake levels for everyday consumption for a given timeframe (grams or micrograms of contaminant per kilogram of body weight per day) and incorporate safety precautions based on orders of magnitude for contaminant standards.

Table 4 provides the Agency for Toxic Substances and Disease Registry (2022) minimal risk level (MRL) for a few toxic heavy metal contaminants and organochlorines and average levels in meats from studies. It should be noted that contaminant levels in organs such as liver and kidney tissues have been studied, as well as muscle tissues because they are consumed; organs can have higher levels of several contaminants. Some levels found in meat, including organs, could be toxic. Studies used in Table 4 found no toxic levels of contaminants except for lead, but high levels were from a few outliers of the animals collected for the studies (Bruckwicki et al. 2006, Danieli et al. 2012, Hassan et al. 2012, Horak et al. 2014). However, considering the meat from wildlife consumed, exposure risks are minimal. An example of toxicity from Table 4 is if a 110 lb (50 kg) person ate 0.25 pounds (0.11 kg) of goose breast meat a day for 100 days of a year, then they would get 0.1 ng of arsenic, .03 ng cadmium, a day or 0.01 mg/kg in that time. That would be a tenth of the MRL for arsenic.

Sportsmen and indigenous people throughout the United States harvest wildlife, including mammals (deer, elk, moose, antelope, rabbits, bear, and others), birds (waterfowl, gallinaceous birds such as pheasant and grouse, pigeons, and doves), reptiles, amphibians, and fish. The total weight exceeds half a million tons for deer alone in the United States (Appendix A Table A2). Few records of problems have arisen from eating this meat, but it does occur. On the other hand, impoverished people with few food sources could benefit from a nutritious meal, which would benefit their health. Thus, we believe the risks are minimal, especially if the meat is prepared appropriately.

WS donates wildlife meat for consumption to qualifying organizations (Table 2). A concern that has arisen is the potential for meat to be contaminated. Contaminated meat is a risk to people but is considered minimal (Kuhnlein and Chan 2000, QDMA 2019). When the consumption of wildlife does not generally pose a life-threatening risk, it is not governed by food industry regulations. Ultimately, the decision to harvest and consume these items is the responsibility of the harvester or consumer. Often, consumption advisories are issued based on the contaminate residue limits. Consumers should remain vigilant to ensure these recommendations are not exceeded and regularly occur, especially for contaminants such as mercury and lead, for animals from a given area.

Table 4. Examples of dietary intake guidelines for contaminants from the Agency for Toxic Substances and Disease Registry (2022) in meat and the average amount of contaminants present in turkey and urban goose breast meat (Horak et al. 2014), wild boar meat (Danieli et al. 2012), semi-domestic reindeer venison (Hassan et al. 2012), and deer (Bruckwicki et al. 2006). The contaminants given are some that are of greatest concern.

CONTAMINANTS IN MEAT FROM DIFFERENT SOURCES							
Contaminant	**ATSDR MRL**	**Turkey Breast**	**Goose Breast**	**Swine Meat**	**Reindeer Meat**	**WT Deer Meat**	**WT Deer Liver**
	mg/kg	**Amount (ppm)**					
As (Arsenic)	0.1 Int. (15-364 days)	0.04	0.05	na	0.020	<0.2	<0.2
Cd (Cadmium)	0.025 /month	0.005	0.016	0.078	0.002	<0.1	2.6
Pb (Lead)*	0.035**	0.018	0.191	0.124	0.008	0.38 (5.2)	<0.2 (1.9)
Hg (Mercury)	0.3	na	0.154	na	na	<0.1	<0.1
Organochlorines	0.5-1	na	0.0103	na	na	x	x

* Both white-tailed deer and Canada goose studies had individual animals that tested very high, but most were within the safe zone.
** No safe level of lead has been determined for children but has been set at 3.5 µg/dL blood level (0.035 ppm) is with potential effects at ≤ 5µg/dL (CDC 2022a) so this cannot be converted to mg/kg. Background levels in the first 5 cm soil throughout the United States averaged 26 mg/kg (Smith et al. 2013)

Contaminants in Canada goose breast meat from several states were analyzed from urban WS WDM projects where geese were euthanized with carbon dioxide (Horak et al. 2014). “Resident” geese tend to stay within the confines of urban areas for most of the year, where high levels of contaminants may exist. Horak et al. (2014) found higher levels of cadmium and lead than in regular turkey breast meat and somewhat high mercury levels, but this was not available for turkey or was not found (Table 4). Levels of cadmium and mercury were not considered a risk to people (Horak et al. 2014). In the Horak et al. (2014) study, three geese, in particular, had high levels of lead, with one from Virginia having three times the level of any others, which skewed results; it was not determined exactly where these three geese were feeding, but possibly in nearby industrial areas. Geese with high levels of one contaminant usually had high levels of others. Lead concentration studies in urban versus rural areas have typically found that lead levels in urban human populations are generally higher (Cohen et al. 1973, Aelion and Davis 2019). These have been associated with lead paint, leaded gasoline, and continued environmental background to this day. Lead has no biological function and is considered toxic to people and wildlife at certain levels of chronic exposure, mostly from exposure to environmental contamination. When absorbed, lead disrupts various biochemical reactions and cellular structures (Thompson 2012).

It is believed that, in general, goose or other meats donated by WS to the food insecure will have minimal potential to cause long-term effects because the number of geese or other meats donated to an individual person is limited, and the duration of the donations is seasonal. Meat from animals suspected of carrying a zoonotic disease, appearing sick, or having abnormal-looking meat and organs are discarded appropriately. WS does not donate any meat from animals taken with any chemicals and minimally for animals shot with lead. Even with meat cut away from the entrance and exit wounds, bullet or shot fragments can often still be found in the meat as far as 6 inches away (Tsuji et al. 1999, Bellinger et al. 2013). WS attempts to recover animals from operations that have a potential for contaminants that could harm people. Thus, it is believed that the consumption of meat donated by WS will not have more than a minimal effect on people.

3.1.4 Injuries

Injuries to WS personnel from carcass management in the field are mostly associated with moving carcasses. Between FY13 and FY15, WS employees reported an annual average of 2 injuries related to the movement of carcasses (a strained back and sprained wrist), an annual average of 3 tick bites (it is unknown whether these came from carcasses or just from being in the field) and 0.7 average annual injuries from using scalpels to take rabies samples, potentially exposing themselves to the disease. Between FY16 and FY21, WS employees reported an annual average of 2 injuries related to the movement of carcasses resulting in strains and sprains, and an annual average of 16 tick bites (it is unknown whether these came from carcasses or just from being in the field) and 6 average annual injuries from using scalpels or needles to take tissue and blood samples, potentially exposing themselves to zoonotic disease. Additionally, WS employees had an annual average of 31 field injuries from FY13-15 and 5 field injuries from FY16-20 from falls, slips, twists, and repetitive activities that resulted in lacerations, sprains, contusions, strains, compression bruises, and fractures, but the injury report did not associate them with any specific activity such as moving a carcass. Considering the number of employees (~1,900), the claims were relatively few for the number of hours spent afield. Thus, risks are relatively minor to employees.

3.2 Environmental Risks

Carcass management and the various disposal methods have the potential to pose risks to wildlife and the environment (APHIS 2018, USEPA 2022b, d). Carcass management can spread unwanted pathogens to wildlife and livestock. Vehicles loaded with carcasses may pass through other land-use areas, but these areas are only briefly affected unless consequences arise from an accident. The risk of contracting a disease or being exposed to harmful chemicals varies with carcass management methods and is similar to risks discussed in Section 3.1, except pathogens typically spread to the same or similar species in the area. Thus, it is much more important for proper disposal methods to be used. Newer designs of incinerators and digesters are better for some diseases, such as those resulting from prions. Landfill and carcass burial liners that allow the collection of leachate reduce the potential for a large number of buried carcasses to impact water quality in an area.

Environmental components consider a broad range of abiotic and biotic resources. Abiotic resources include soil, air, and water; biotic resources include vegetation and wildlife. Areas potentially affected during the implementation of a carcass management program include agricultural and nonagricultural lands in all States of the United States and its territories.

Impacts on soil, air, and water are expected to be minimized by handling carcasses at regulated facilities, including rendering facilities, fixed-facility incinerators, and landfills. Animals left in the field cause minimal problems if there are few but can be more of a concern when it becomes tons of biomass.

3.2.1 Soils and Vegetation

WS WDM projects that result in carcasses occur at a range of sites on rangelands, grasslands, forests, urban areas, and farms, which often dictate the carcass management choice and location. Most are at remote sites where the public has no or little access. Overall, carcass management locations and facilities where carcasses are disposed of, such as landfills or off-site incinerators, have minimal access by the public. However, roads that lead to offsite disposal facilities could be accessed so carcasses are secured and covered as necessary to prevent the spreading of pathogens or contaminants of concern. During carcass management, land use on a premise may shift from livestock production to a disposal location if onsite burning, burial, or composting occurs. Plant cover reduces erosion and protects the soil against degradation; consequently, the removal of plant cover impacts ecosystem function and future land use (Castillo et al. 1997, Zhao et al. 2011).

Soils are affected by decomposing carcasses. The degree depends on local topography, geography, soil type, and plant cover. Variations in the chemical and physical properties of the soil will impact bioavailability, chemical degradation, and transport of leachate, including chemical contaminants and pathogens from carcasses. Physical impacts on soil during carcass management can occur from digging trenches, removing topsoil, and physically compacting soil using heavy equipment; these activities may increase erosion and decrease soil quality (Engel et al. 2004). Decaying carcasses impact soil quality by releasing chemical contaminants or leachate. Nitrogen and phosphorus from carcass leachate may add minerals and nutrients to the soil that become available for plant growth; however, excessive amounts of these nutrients can negatively affect soil microorganisms and alter normal carbon, nitrogen, and phosphorus cycling. Antibiotics from farmed animals and other chemical contaminants may leach into soil and affect naturally occurring soil microorganisms or become available for plant and animal uptake, which may contaminate the food chain. The impacts on soil and vegetation from leachate are minimal when isolated or a few individuals are left in the field. The impacts on soil and vegetation from leachate increase with a large number of carcasses requiring other disposal methods that collect leachate and protect soil quality.

3.2.2 Air Quality

The release of atmospheric pollutants from carcass management methods varies and may be regulated by federal and state regulations. Many air pollutants associated with large animal operations are also associated with various carcass management practices. Carbon dioxide, ammonia, methane, and other volatile organic carbons are associated with onsite burial, composting, and landfills (Engel et al. 2004, Xu et al. 2007, Hao et al. 2009, Akdeniz et al. 2011, Yuan et al. 2012). Air quality conditions vary across the United States, with urban areas typically experiencing degraded air quality during certain times of the year. Both Federal and State agencies monitor air quality. USEPA (2014) monitors air quality throughout the country at monitoring stations that measure various pollutants (USEPA 2014). USEPA monitoring generates an air quality index (AQI) for a given area that can be used by the public to determine air quality conditions (USEPA 2014). The AQI ranges from 0 to 500, with values below 50 suggesting good air quality with no health impacts. In contrast, values above 300 suggest poor air quality and potential human health impacts on the entire population. A value of 100 is related to the air quality standard for a given pollutant; values between 100 and 150 may result in potential health impacts on the most sensitive populations. An AQI above 150 represents unhealthy conditions for a larger part of the population, with more impacts as the value increases. Values above 200 are considered rare in the United States. Typical AQI values are below 100 throughout the United States but may exceed 100 during various times of the year (USEPA 2014). The AQI is based on four priority pollutants: sulfur dioxide, carbon monoxide, particulate matter, and ozone. Particulate matter is further divided into particles less than 2.5 micrometers (µm) and those less than 10 µm. Other air quality standards are not considered in the estimate of the AQI.

USEPA and some state agencies also monitor other pollutants; these may be used to determine if some regions of the United States are within attainment for priority pollutants as defined by the National Ambient Air Quality Standards (NAAQS) in the CAA. Areas in the United States where large numbers of livestock occur are typically rural, where the AQI is below 50, and are considered compliant with air quality standards. However, these areas may contain large, confined animal operations with the potential for localized impacts on air quality. The extent of the impact on air quality from these operations depends on the size and management of the facilities. Releases of pollutants or volatile organic compounds (VOC) from these types of facilities may impact air quality and include odorous compounds, microorganisms, particulate matter, ammonia, nitric oxides, nitrogen oxides, carbon dioxide, methane, and hydrogen sulfide, which are commonly grouped as VOCs (Aneja et al. 2009, Ni et al. 2009, Guerra et al. 2017). Some pollutants are regulated under federal or state law and may be managed through compliance agreements between the source and the applicable regulatory entity. Strategies to abate VOC emissions are ongoing but getting more robust (Guerra et al. 2017). WS may be required to obtain burn permits from the appropriate agencies for disposal operations involving burn piles and incinerator use.

3.2.3 Water Quality

Ground and surface water quality varies across the United States due to various natural and man-made factors. Natural physical and chemical features (e.g., soil type, topography, vegetation type, cover, and mineral levels) can all influence background water quality characteristics for a water body. However, features and activities such as dams, urban development, industrial mining, and agricultural activities can also provide point and non-point sources of contamination that can impact a wide variety of water quality parameters such as pH, temperature, and biological oxygen demand. These and similar features and activities can also introduce natural and anthropogenic stressors into ground and surface water, impacting water quality. Excessive nutrients, pathogens, sediments, and other chemicals can degrade water quality, impacting human and ecological health and the designated use of a specific water body.

Carcasses of animals that die in water due to a WDM action may not be retrieved, which can happen with several species, such as double-crested cormorants, red-winged blackbirds, beavers, nutria, and waterfowl. The Rivers and Harbors Act of 1899, known as the Refuse Act of 1899, as amended (codified at 33 U.S.C. §§ 401–426), makes it unlawful to obstruct navigation or discharge or deposit refuse into navigable waters. Carcasses that die in or fall into the water are not discharged into the water. However, carcasses taken on the ground are not disposed of in U.S. waters by WS. Reasons for water quality impairment vary and generally fall into a category of contamination, but CWA section 303(d) listings for all States show that the primary reasons for impairment (in decreasing order) are pathogens, nutrients, metals, organic enrichment, and sediments. This group represents approximately 38 percent of the total causes for impairment of assessed water bodies in the United States (USEPA 2022h). Within the pathogen group, fecal coliforms and *E. coli* are the primary causal agents for impairment due to pathogens. Nutrient impairment is primarily due to excessive phosphorus and total nitrogen in water. The minimal number of carcasses taken by WS and left in water would not foul the waters of the United States. WS attempts to retrieve diseased animals that have died in water if it is safe and possible to reduce further disease transmission.

Agriculture is the primary cause of impairment to rivers and streams, is the third leading cause of impairment for lakes, and is the second leading cause of impairment for wetlands (Kim and Kim 2012, U.S. Geological Survey 2019, USEPA 2022h). Agriculture includes multiple aspects of the industry, including crop and livestock production. Livestock sources may include grazing, confined animal feeding operations, animal manure, and other activities (U.S. Geological Survey 2019, USEPA 2022h). Several pollutants are identified as threats to ground and surface water as a result of carcass management, including antibiotics, ash, chloride, dioxins, polycyclic aromatic hydrocarbons, and other combustion byproducts, hormones, metals, microorganisms such as pathogens, nitrogen-containing compounds (ammonia and nitrate), oils and grease, pharmaceutical drugs (various veterinary uses such as euthanasia), phosphorous, sulfates, total dissolved solids, and total organic carbon (Ritter and Chirnside 1995. Myers et al. 1999, Engel et al. 2004, Glanville et al. 2006, Pratt and Fonstad 2009, Joung et al. 2013, Yuan et al. 2013). Some of these contaminants are detected in leachate from swine, cattle, and poultry disposal, while the presence of others, such as antibiotics, pathogenic microorganisms, and veterinarian pharmaceuticals, reflect the specific source or industry. Many of these pollutants are also listed as causal agents for impairment under section 303(d) for various water bodies in the United States. Aerial deposition and leaching or runoff may be pathways for pollutants to enter surface and groundwater sources from burning activities (Pollard et al. 2008).

3.2.4 Wildlife

Wildlife may feed on carcasses left in the field. In general, scavenging of carcasses left in the field will have no deleterious effects on wildlife and may benefit wildlife, especially during food-limited times. On the other hand, if pathogens, euthanasia drugs, or chemicals, including lead, are a concern, scavengers may be at risk, and, thus, collecting and conducting the appropriate level of carcass disposal for the particular pathogen, drug, or chemical would be required. Managing carcasses as quickly as allowable decreases the time that scavengers (e.g., raptors, corvids such as ravens, canids, bears, mustelids such as fishers, skunks, and to a lesser extent, cats) can feed on carcasses helping to minimize the transmission of pathogens. Scavengers, such as eagles, quickly locate fresh carcasses, making them susceptible to secondary poisoning when animals are killed with toxins and left uncovered. Animals euthanized with drugs are generally in hand or controlled so they can be immediately gathered. In contrast, those taken with toxicants may die in varied locations depending on the chemical used.

WS has prepared or is preparing chemical risk assessments, including immobilization and euthanasia drugs, for the individual chemical control methods used in WDM. In those risk assessments, WS evaluated the risk of secondary poisoning to nontarget plants and wildlife that feed on treated animals or carcasses in each applicable chemical risk assessment. The risk assessments, for the most part, did not address the disposal of carcasses taken with chemical method, as required by labeling or policy. WS minimizes secondary risks as necessary by collecting target and nontarget animals that are taken using chemical control methods. The labels for chemical control use limit the amount of pesticide that can be used or where it may be used. In many cases, the label requires the collection of any target or nontarget species that succumb to chemical control when secondary hazards are a risk or for other reasons. For example, USFWS and National Euthanasia Registry recommend that animals treated with pentobarbital are either buried or burned shortly after death since this drug, in particular, can have an effect on scavengers (Krueger and Krueger 2002, Lazaroff 2002). Mammals, birds, and other wildlife, such as foxes, bears, coyotes, lynxes, bobcats, and mountain lions, could be affected by the ingestion of pentobarbital (Krueger and Krueger 2002). WS does not anticipate this to be a problem, though, since all animals euthanized are disposed of according to label instructions, mostly taking them to a facility that accepts them and has the animal on hand (e.g., in a cage or foothold trap, a catch-pole, or immobilized).

Lead ammunition is a concern for wildlife. The United States mostly banned the use of leaded paint, gas, and lead pellets for hunting waterfowl in 1991 (Anderson et al. 2000), and these helped reduce environmental lead levels, but lead poisoning remains a hazard to wildlife. Lead use from all sources has been banned in the range of the California condor (*Gymnogyps californianus*). The WS *Use of Lead in Wildlife Damage Management* risk assessment discussed lead risks. It determined that the amount of lead used in WS WDM operations poses minimal risk to humans and the environment.

The final issue related to carcass disposal is the potential for leachate to harm wildlife and ecosystems. Leachate is managed to the greatest extent by the selection of the disposal method, as several methods do not result in leachate

4 UNCERTAINTIES AND CUMULATIVE EFFECTS

A few uncertainties are associated with carcass management and disposal. WS is unable to predict when and where a mass disease outbreak will occur, which could result in the handling and disposal of a large number of carcasses. The disposal methods available to WS are appropriate for the range of animal diseases currently identified in the United States. Current disposal methods and their use may need to be modified if a disease outbreak that can be spread by carcass-based transmission (e.g., African Swine Fever) occurs.

Cumulative impacts are not expected to occur by disposing of wildlife carcasses in WDM. Although the open burning of animal carcasses from a mass disease outbreak could occur in an area where there are other burn activities taking place (controlled burning of a field or forest, wildfire, etc.), the burning of carcasses is controlled, localized and occurs for a short period of time. The "Introduction to Risk Assessments for Methods Used in Wildlife Damage Management"[12] looks at all take from all WDM activities by WS, and none shows a significant level of take for any native species. From a human health perspective, the use of carcass disposal methods in WDM will not have any known cumulative impacts.

5 SUMMARY

WS uses carcass disposal as a component of an integrated approach in WDM. WS works cooperatively with other federal and state natural resource agencies, including other programs in APHIS, to develop standards for disposing of animal carcasses following WDM projects, including mass animal incidences involving pathogens. Federal and state regulations and internal USDA APHIS WS policies provide the requirements for proper carcass disposal to reduce environmental and human health impacts.

The various carcass disposal methods WS uses include leaving carcasses in the field, burial, open-air burning, composting, rendering, landfill, incineration, and tissue digestion. Some carcasses may also be donated for human consumption where appropriate and in compliance with federal and state regulations. Carcass disposal due to wildlife management activities typically results in fewer animals than carcass disposal due to disease outbreaks. However, APHIS WS disposes of carcasses more commonly due to WDM activities than disease outbreaks. WS leaves most carcasses in the field since most animals taken using lethal methods are individually taken or taken in small numbers and do not pose a threat to wildlife or humans. If a local outbreak occurs, this method ensures disease is not moved off-site. If an animal is diseased, it is turned over to the Health Department or disposed of appropriately to eliminate disease transmission to other wildlife.

As carcasses degrade, bodily fluids consisting of natural and anthropogenic chemical and biological leachate, and hazardous gases may be released into the environment. The risk of carcass disposal to human health and the environment varies based on the number of animals being disposed of and whether a disease is of concern. The risk to human health from carcass disposal is generally low for all methods when following applicable federal and state regulations and WS policies. WS personnel are at the greatest risk from handling carcasses, but risks are minimal or nullified if standard operating procedures are followed. Risks to ecological resources are also generally low. Decomposition products from carcass disposal can also pose a risk to ecological resources through air, soil, and water exposure. Leaving carcasses on-site in the field results in a greater potential for exposure to scavengers compared to the other disposal options, such as burial, rendering, incineration, and tissue digestion, where no exposure to scavengers would be expected. Animals euthanized with drugs can pose secondary hazards to scavengers. Disposal is dictated by applicable federal and state regulations, drug label instructions, or lacking such guidelines by deep burial, incineration, or at a landfill approved for such disposal. In cases of carcass disposal where zoonotic disease or chemical contaminants are a concern, WS uses disposal options intended to reduce the risks to scavengers and other ecological resources through compliance with federal and state regulations and WS policies.

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USDA APHIS Wildlife Services

Reviewer: Michael Bodenchuk
Position: USDA APHIS WS, State Director, San Antonio, TX
Education: BS Wildlife Management, New Mexico State University
Experience: Ten years state and private sectors in wildlife management . Thirty-two years USDA APHIS WS in wildlife damage management including conducting and supervising carcass management.

Reviewer: Vienna Brown
Position: USDA APHIS WS National Feral Swine Program, Disease Biologist, Fort Collins, CO
Education: BS Animal Sciences, Colorado State University; MPH Animals, People, and the Environment; University of Colorado, Denver; PhD Microbiology, Colorado State University
Experience: Two years as a post-doc with Department of Homeland Security working on risk assessments at the wildlife-livestock interface. Four years as a staff biologist with the National Feral Swine Damage Management Program as the Disease and Research Components lead.

Reviewer: Brett Dunlap
Position: USDA APHIS WS, State Director, Madison, TN
Education: BS Wildlife & Fisheries Sciences, Texas A&M University; MA Biology, Sam Houston State University
Experience: Thirty-three years with Texas Animal Damage Control and USDA APHIS WS in wildlife damage management including conducting and supervising carcass management.

Reviewer: Shannon Hebert
Position: USDA APHIS WS, Assistant Deputy Director, Environmental Management
Education: BS Animal Science, Virginia Tech; MS Agriculture, Cal Poly, San Luis Obispo
Experience: Thirty-three years in Federal environmental compliance focused on natural resource management, including 27 years with APHIS WS.

Reviewer: Michael Marlow
Position: USDA APHIS WS, National Feral Swine Damage Management Program, Assistant Program Manager
Education: BS Wildlife Ecology, MAg International Agriculture, Oklahoma State University
Experience: Twenty-six years USDA APHIS WS including field operations, disease surveillance, and carcass management.

7.3 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 Carcass Disposal in Wildlife Damage Management" peer reviewed. WS worked with the Association of Fish and Wildlife Agencies to have experts review the documents.

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

Missouri Department of Conservation

Oklahoma Department of Wildlife Conservation

Idaho Department of Fish and Game

7.3.2 Comments

1. The only hazard/risk I did not see, and I could have missed it, was the risk of attack from large carnivores that are looking to feed on disposed carcasses, especially in areas where animals are regularly left in open areas. I know from my time in the mountain west that some grizzly and black bears were frequent areas that animal carcasses were disposed of and in some cases these animals expressed aggressive behaviors towards people that either were dropping off carcasses or with people that were driving or hiking in the area. So that might be something to look into, but again this was not a frequently occurring thing but I think is valid to think to acknowledge given all the other factors that are considered in this document.

   Response: We agree that bears and other large carnivores may be attracted to carcasses left on the landscape. If carcasses are routinely disposed of in the same pit, over time, the area can be an attractant to scavengers. However, WS personnel do not do this. Sander et al. (2002; Selected methods of animal carcass disposal JAVMA 220: 1003-1006) acknowledge that cattle carcasses can attract predators to an area causing increased predation of calves at calving time. WS is not generally involved in cattle removals. Wildlife removed by WS through WDM are taken individually or in small numbers and do not pose a threat to wildlife, humans, or the environment when left on the landscape. Most animals are scavenged relatively quickly by birds (e.g., turkey vultures, eagles). Other wildlife, such as deer, are often donated and not left on the landscape (see Table 2). Feral swine, when trapped in large numbers, are often spread across the landscape, but the location of these carcasses would not put humans or the public in danger. In locations where WS conducts wildlife damage management activities, people would not usually drive or hike, and WS does not generally utilize carcass pits at centralized locations.

Comments received not requiring a response.

1. This document provided an exhaustive review on the subject of carcass disposal in wildlife management. I did not find any sections that warranted changes.
2. Document was reviewed. No edits or comments to be added.
3. The Carcass Disposal in Wildlife Damage Management document to me seem well written and covers a lot of information in a concise manor for just about anyone to be able to read and understand. In Missouri, we do a mix of sending carcasses to dumps, incinerate, or leave in the field when possible. Most of the animals that are disposed of do not pose a threat to human safety and this document does a good job providing context about the potential hazards that could come from utilizing any of these methods.

Appendix A. Average weights of animals lethally taken by WS in wildlife damage management and for comparison weights of animals from sportsmen harvest and vehicular accidents.

WS conducts wildlife damage management (WDM) for many species each year in different projects. Numbers are recorded in the MIS. The use of toxicants needs estimates of the numbers taken but are included and assumptions are given in the risk assessments for those methods. Appendix A - Table A1 (mammalian predators), Table A2 (hoofed mammals), Table A3 (rodents and rabbits), Table A4 (other mammals), Table A5 (landbirds), Table A6 (waterbirds), and Table A7 (reptiles, amphibians, and fish) give the numbers of animals killed by WS and their carcass weights. For comparison to WS take, sportsmen harvest of deer and waterfowl and road killed deer numbers and weight are include in Table A8. Numbers from these tables are summarized in the risk assessment.

Table A1. The annual average number of predators killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

PREDATORS						
Species	**Scientific Name**	**Weight (oz)**	**Annual Avg FY11-**		**Annual Avg FY16-**	
			# Killed	**Total Wt**	**# Killed**	**Total Wt**
Virginia Opossum^	*Didelphis virginiana*	96	2,287	13,722	2,457	14,742
Feral/Free-roaming Cat*	*Felis catus*	240	907	13,605	473	7,905
Bobcat	*Lynx rufus*	288	944	16,992	903	16,254
Mountain Lion	*Puma concolor*	2160	351	47,385	326	44,010
Small Asian Mongoose*	*Herpestes javanicus*	19	2,175	2,583	1,793	2,129
Coyote^#	*Canis latrans*	440	75,077	2,064,618	67,848	1,865,820
Northwestern Gray Wolf	*Canis lupus*	1744	166	18,094	175	19,075
- Mexican Gray Wolf[T&E]	*Canis lupus baileyi*	1080	1	68	1	68
- Great Plains Gray	*Canis lupus nubilus*	1440	213	19,170	188	16,920
- Feral/Free-Roaming	*Canis lupus familiaris*	960	339	20,280	135	8,100
Red Fox^#	*Vulpes vulpes*	240	2,222	33,330	1,540	23,100
Swift Fox	*Vulpes velox*	78	23	112	11	54
Kit Fox	*Vulpes macrotis*	76	13	62	9	43
Arctic Fox^	*Vulpes lagopus*	113	176	1,243	34	240
Common Gray Fox	*Urocyon*	186	1,928	22,413	1,717	19,960
Brown Bear (Grizzly)	*Ursus arctos horribilis*	6800	-	-	2	850
Black Bear	*Ursus americanus*	4000	524	131,000	435	108,750
River Otter	*Lontra canadensis*	336	512	10,752	649	13,629
Fisher	*Martes pennanti*	120	1	7.5	1	7.5
Long-tailed Weasel	*Mustela frenata*	7	8	3.5	4	1.8
Short-tailed Weasel	*Mustela erminea*	4	3	0.5	1	0.2
Mink	*Mustela vison*	28	39	68	16	28
Badger#	*Taxidea taxus*	272	423	7,191	381	6,477
Ringtail	*Bassariscus astutus*	176	2	22	-	-
Raccoon	*Procyon lotor*	400	11,887	297,175	9,609	240,225
Hog-nosed Skunk	*Conepatus leuconotus*	114	6	43	2	14
Hooded Skunk	*Mephitis macroura*	30	9	17	6	11
Striped Skunk#	*Mephitis mephitis*	112	6,543	45,794	4,953	34,671
Eastern Spotted Skunk	*Spilogale putorius*	26	4	6.5	6	10
Western Spotted Skunk	*Spilogale gracilis*	27	10	17	6	10
TOTAL PREDATORS	**27 Sp. + 3 Ssp.**		**106,793**	**2,765,774**	**93,681**	**2,443,105**

* Introduced Species ^ Translocated from former range within North America to areas where invasive

\# Numbers killed were estimated for dens taken (2 for each badger den, 3 for striped skunk, and 4 for coyote, red fox, and opossum)

T&E –Threatened and endangered species (Federal only)

Table A2. The annual average number of hoofed mammals killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

HOOFED MAMMALS						
Species	**Scientific Name**	**Weight (oz)**	**Annual Avg FY11-**		**Annual Avg FY16-**	
			Killed	**Total Wt**	**Killed**	**Total Wt**
Feral Swine*	*Sus scrofa*	2400	32,976	4,946,400	78,648	11,797,200
Collared Peccary	*Pecari tajacu*	752	196	9,212	134	6,298
Moose^	*Alces alces*	17280	2	2,160	1	1,080
Axis Deer*	*Axis axis*	2560	376	60,160	3	480
Fallow Deer	*Dama dama*	2050	-	-	21	2,691
American Elk^	*Cervus canadensis*	9600	2	1200	110	66,000
Red Deer*	*Cervus elaphus*	6040	1	378	2	755
Sika Deer*	*Cervus nippon*	1280	3	240	1	80
Mule Deer	*Odocoileus hemionus*	2800	67	11,725	47	8,225
White-tailed Deer^	*Odocoileus virginianus*	2800	5,474	957,950	8,094	1,416,450
Caribou	*Rangifer tarandus*	4400	3	825	1	275
Philippine (*Sambar*) Deer	*Rusa marianna*	8000	50	25,000	321	160,500
Pronghorn (American	*Antilocapra americana*	1600	4	400	3	300
Nilgai	*Boselaphus*	6260	-	-	5	1,956
Feral Cattle*	*Bos primigenius*	16000	3	3,000	6	6,000
Feral Goat*	*Capra aegagrus hircus*	1920	13	1,560	8	960
Bighorn Sheep	*Ovis canadensis*	2500	6	938	28	4,375
Feral Sheep*	*Ovis aries*	1408	3	264	3	264
TOTAL	**18 Species**		**39,179**	**6,021,412**	**87,436**	**13,473,889**

* Introduced Species ^Introduced populations exist

Table A3. The annual average number of rodents and rabbits killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

RODENTS AND RABBITS						
Species	**Scientific Name**	**Weight (oz)**	**Annual Avg FY11-FY15**		**Annual Avg FY16-FY20**	
			Killed	**Total Wt**	**Killed**	**Total Wt**
Mountain Beaver	Aplodontia rufa	40	109	273	263	658
Western Gray Squirrel	*Sciurus griseus*	20	8	10	15	19
Eastern Gray Squirrel^	*Sciurus carolinensis*	19	145	172	158	188
Eastern Fox Squirrel^	*Sciurus niger*	32	155	310	124	248
Abert’s Squirrel	*Sciurus aberti*	28	-	-	92	161
Red Squirrel	*Tamiasciurus hudsonicus*	8.0	3	1.5	12	6.0
Douglas Squirrel	*Tamiasciurus douglasii*	6.5	12	4.9	-	-
Woodchuck	*Marmota monax*	120	4,869	36,518	1,858	13,935
Yellow-bellied Marmot	*Marmota flaviventris*	120	1,803	13,523	1,373	
Hoary Marmot	*Marmota caligata*	224	1	14	-	-
Black-tailed Prairie Dog	*Cynomys ludovicianus*	40	193,144	482,860	215,843	539,608
Gunnison’s Prairie Dog	*Cynomys gunnisoni*	32	19,160	38,320	9,593	19,186
White-tailed Prairie Dog	*Cynomys leucurus*	32	2,181	4,362	2,504	5,008
California Ground Squirrel	*Otospermophilus beecheyi*	24	9,645	14,468	7,054	10,581
Rock Squirrel	*Otospermophilus*	26	430	699	164	267
White-tailed Antelope	*Ammospermophilus*	2	-	-	1	0.1
Paiute Ground Squirrel	*Urocitellus mollis*	5	832	260	-	-
Richardson’s Ground	*Urocitellus richardsonii*	15	949	890	481	451
Wyoming Ground Squirrel	*Urocitellus elegans*	12	83	62	83	62
Uinta Ground Squirrel	*Urocitellus armatus*	13	95	77	14	11
Belding's Ground Squirrel	*Urocitellus beldingi*	10	4,730	2,956	4,988	3,118
Columbian Ground Squirrel	*Urocitellus columbianus*	20	1,476	1,845	23	29
S. Idaho Ground Squirrel	*Urocitellus endemicus*	10	-	-	39	24
Thirteen-Lined Ground	*Ictidomys tridecemlineatus*	6.5	1,062	431	140	57
Mexican Ground Squirrel	*Ictidomys mexicanus*	9.5	1,487	883	237	141
Round-tailed Ground	*Xerospermophilus*	5.5	7,754	2,665	4,230	1,454

Cliff Chipmunk	*Neotamias dorsalis*	2	-	-	1	0.1
Yellow Pine Chipmunk	*Neotamias amoenus*	2.5	-	-	6	0.9
Eastern Chipmunk	*Tamias striatus*	3.5	21	4.6	35	7.7
Beaver^	*Castor canadensis*	720	24,400	1,098,000	23,462	1,055,790
Ord's Kangaroo Rat	*Dipodomys ordii*	2.0	1,672	209	933	117
Merriam's Kangaroo Rat	*Dipodomys merriami*	1.5	-	-	3	0.3
Yellow-Faced Pocket	*Cratogeomys castanops*	10	3,189	1,993	684	428
Attwater's Pocket Gopher	*Geomys attwateri*	8.5	234	124	-	-
Desert Pocket Gopher	*Geomys arenarius*	8.5	1	0.5	-	-
Knox Jones' Pocket Gopher	*Geomys knoxjonesi*	8.5	9	4.8	2	1.1
Plains Pocket Gopher	*Geomys bursarius*	8.5	1,093	581	108	57
Texas Pocket Gopher	*Geomys personatus*	12	1	0.8	-	-
Botta's Pocket Gopher	*Thomomys bottae*	5.6	5,030	1,761	211	74
Camas Pocket Gopher	*Thomomys bulbivorous*	16	463	463	106	106
Northern Pocket Gopher	*Thomomys talpoides*	3.7	2,847	658	127	29
Western Pocket Gopher	*Thomomys mazama*	3.4	5	1.1	188	40
Arizona Pocket Mouse	*Perognathus amplus*	0.5	-	-	9	0.3
N. Giant (*Gambian*)	*Cricetomys gambianus*	43	2	5.4	-	-
Cactus Deermouse	*Peromyscus eremicus*	1	-	-	19	1.2
California Deermouse	*Peromyscus californicus*	1.6	-	-	2	0.2
Cotton Deemouse	*Peromyscus gossypinus*	1.4	1	0.1	-	
North American Deermouse	*Peromyscus maniculatus*	1.0	211	13	5,527	345
White-footed Deermouse	*Peromyscus leucopus*	0.85	18,720	995	7,307	388
Eastern Woodrat	*Neotoma floridana*	10	2	1.3	1	0.6
Mexican Woodrat	*Neotoma mexicana*	6.5	2	0.8	-	-
White-throated Woodrat	*Neotoma albigula*	7.5	-	-	7	3.3
White-toothed Woodrat	*Neotoma leucodon*	7.5	-	-	24	11
Big-eared Woodrat	*Neotoma macrotis*	11	-	-	9	6.2
Dusky-footed Woodrat	*Neotoma fuscipes*	11	-	-	2	1.4
Bushy-tailed Woodrat	*Neotoma cinerea*	14	8	7.0	2	1.8
Southern Red-backed Vole	*Myodes gapperi*	1	-	-	1	0.1
Sagebrush Vole	*Lemmiscus curtatus*	1.0	576	36	-	-
Gray-tailed Vole	*Microtus canicaudus*	1.8	4,000	450	-	-
Long-tailed Vole	*Microtus longicaudus*	1.7	158	17	-	-
Montane Vole	*Microtus montanus*	2.0	999	125	604	76
Prairie Vole	*Microtus ochrogaster*	1.3	7,095	576	37,105	3,015
Tundra Vole	*Microtus oeconomus*	2.1	-	-	12	1.6
Meadow Vole	*Microtus pennsylvanicus*	1.8	13,414	1,509	12,985	1,461
Woodland (*Pine*) Vole	*Microtus pinetorum*	1.0	4,466	279	11,944	747
Muskrat	*Ondatra zibethicus*	48	2,261		1,199	3,597
House Mouse*	*Mus musculus*	0.8	25,532	1,293	2,156	109
Brown (*Norway*) Rat*	*Rattus norvegicus*	8.5	535	285	988	525
Pacific (*Polynesian*) Rat*	*Rattus exulans*	2.2	2,331	321	54	7.4
Black Rat*	*Rattus rattus*	7.5	6,562	3,076	4,381	2,054
North American Porcupine	*Erethizon dorsatum*	304	243	4,617	165	3,135
Nutria*	*Myocastor coypus*	280	1,981	36,785	1,776	31,080
Desmarest's Hutia	*Capromys pilorides*	288	77	1,386	1	18
North American Pika	*Ochotona princeps*	5.2	-	-	1	0.3
Brush Rabbit	*Sylvilagus bachmani*	24	-	-	1	1.5
Eastern Cottontail^	*Sylvilagus floridanus*	48	1,169	3,507	1,483	4,449
Mountain Cottontail	*Sylvilagus nuttallii*	35	78	171	12	26
Desert Cottontail	*Sylvilagus audubonii*	32	6,232	12,464	3,488	6,976
Swamp Rabbit	*Sylvilagus aquaticus*	77	4	19	19	91
Feral (*European*) Rabbit*	*Oryctolagus cuniculus*	136	46	391	11	94
Snowshoe Hare	*Lepus americanus*	24	-	-	2	3.0
White-tailed Jackrabbit	*Lepus townsendii*	120	44	330	97	728
Black-tailed Jackrabbit^	*Lepus californicus*	80	1,519	7,595	2,422	12,110
TOTAL	**82 Species**		**387,366**	**1,786,309**	**368,971**	**1,733,224**

Table A4. The annual average number of other mammals killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

OTHER MAMMALS				
			Ave Annual FY11-FY15	**FY16-FY20**

Species	Scientific Name	Weight	Killed	Total Wt	Killed	Total Wt
Nine-banded Armadillo	*Dasypus novemcinctus*	200	277	3,463	491	6,138
Patas Monkey*	*Erythrocebus patas*	333	221	4,600	13	271
Rhesus Monkey*	*Macaca mulatta*	233	281	4,092	98	1,427
Elliot's Short-tailed Shrew	*Blarina hylophaga*	0.60	1	0.04	1	0.04
Northern Short-tailed Shrew	*Blarina brevicauda*	0.60	2	0.1	14	0.5
North American Least Shrew	*Cryptotis parva*	0.20	14	0.2	9	0.1
Cinereus (*Masked*) Shrew	*Sorex cinereus*	0.15	4	0.04	8	0.1
Vagrant Shrew	*Sorex vagrans*	0.25	14	0.2	1	0.02
Star-nosed Mole	*Condylura cristata*	2.0	-	-	2	0.3
Eastern Mole	*Scalopus aquaticus*	3.6	17	3.8	7	1.6
Coast Mole	*Scapanus orarius*	2.0	19	2.4	-	-
Townsend's Mole	*Scapanus townsendii*	5.0	17	5.3	2	0.6
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	0.50	3	0.1	5	0.2
Big Brown Bat	*Eptesicus fuscus*	0.50	2	0.1	5	0.2
Eastern (*Tri-colored*) Bat	*Pipistrellus subflavus*	0.17	1	0.01	-	-
Cave Myotis	*Myotis velifer*	0.30	-	-	1	0.02
Little Brown Myotis	*Myotis lucifugus*	0.30	3	0.1	13	0.2
Unidentified Bat	Chiroptera (30 possible	0.25	8	0.1	-	--
TOTAL	**17 sp + 1 group**		**884**	**12,167**	**670**	**7,840**

* Introduced Species

Table A5. The annual average number of landbirds killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

LANDBIRDS						
Species	Scientific Name	Weight (oz)	Ave Annual FY11-FY15		FY16-FY20	
			Killed	Total Wt	Killed	Total Wt
Helmeted Guineafowl*	*Numida meleagris*	48	1	3.0	3	9.0
Northern Bobwhite	*Colinus virginianus*	6	-	-	1	0.4
Gambel's Quail	*Callipepla gambelii*	6	3	1.1	8	3.0
Wild Turkey^	*Meleagris gallopavo*	203	329	4,174	389	4,935
Sharp-tailed Grouse	*Tympanuchus*	30	2	3.8	10	19
Gray Partridge*	*Perdix perdix*	14	4	3.5	2	1.8
Ring-necked Pheasant*	*Phasianus colchicus*	40	953	2,383	125	313
Indian Peafowl*	*Pavo cristatus*	150	13	122	16	150
Gray Francolin*	*Francolinus*	11	2,007	1,380	1,371	943
Black Francolin*	*Francolinus francolinus*	16	1,868	1,868	1,006	1,006
Red Junglefowl*	*Gallus gallus*	32	477	954	-	-
- Feral Domestic Chicken*	*Gallus gallus domesticus*	32	2,547	5,094	2,237	4,474
Chukar*	*Alectoris chukar*	21	4	5.3	8	11
Erckel's Francolin*	*Francolinus erckelii*	46	311	894	187	538
Rock Pigeon*	*Columba livia*	9	94,752	53,298	69,489	39,088
Island Collared Dove*	*Streptopelia bitorquata*	7	156	68	484	212
Eurasian Collared Dove*	*Streptopelia decaocto*	7	3,660	1,601	2,604	1,139
Spotted Dove*	*Streptopelia chinensis*	6	6,617	2,481	3,362	1,261
Zebra Dove*	*Geopelia striata*	1.9	17,096	2,030	11,462	1,361
Common Ground Dove	*Columbina passerina*	1.1	-	-	26	1.8
White-winged Dove	*Zenaida asiatica*	5	104	33	100	31
Zenaida Dove	*Zenaida aurita*	4	-	-	69	17
Mourning Dove^	*Zenaida macroura*	4.2	18,146	4,763	21,495	5,642
Smooth-billed Ani	*Crotophaga ani*	3.7	-	-	1	0.2
Greater Roadrunner	*Geococcyx californianus*	13			5	4.1
Common Nighthawk	*Chordeiles minor*	2.2	68	9.4	78	11
Lesser Nighthawk	*Chordeiles acutipennis*	1.8	-	-	1	0.1
Chimney Swift	*Chaetura pelagica*	0.81	1	0.1	5	0.3
Black Vulture	*Coragyps atratus*	70	4,773	20,882	9,700	42,438
Turkey Vulture	*Cathartes aura*	64	1,541	6,164	1,363	5,452
Osprey	*Pandion haliaetus*	56	66	231	119	417
White-tailed Kite	*Elanus leucurus*	12	1	0.8	-	-
Swallow-tailed Kite	*Elanoides forficatus*	15	-	-	3	2.8
Golden Eagle	*Aquila chrysaetos*	160	2	20	1	10
Northern Harrier	*Circus cyaneus*	15	142	133	123	115
Sharp-shinned Hawk	*Accipiter striatus*	5	6	1.9	11	3.4
Cooper's Hawk	*Accipiter cooperii*	16	42	42	79	79
Bald Eagle	*Haliaeetus leucocephalus*	152	1	9.5	-	-

Mississippi Kite	*Ictinia mississippiensis*	10	91	57	129	81
Harris's Hawk	*Parabuteo unicinctus*	32	1	2.0	-	-
Red-shouldered Hawk	*Buteo lineatus*	22	25	34	46	63
Broad-winged Hawk	*Buteo platypterus*	14	1	0.9	10	8.8
Swainson's Hawk	*Buteo swainsoni*	30	78	146	142	266
Red-tailed Hawk	*Buteo jamaicensis*	38	1,117	2,653	1,669	3,964
Rough-legged Hawk	*Buteo lagopus*	35	42	92	18	39
Ferruginous Hawk	*Buteo regalis*	56	23	81	20	70
Barn Owl^	*Tyto furcata*	16	186	186	284	284
Great Horned Owl	*Bubo virginianus*	50	18	56	40	125
Snowy Owl	*Bubo scandiacus*	64	3	12	1	4
Burrowing Owl	*Athene cunicularia*	5	1	0.3	4	1.3
Barred Owl	*Strix varia*	26	3	4.9	3	4.9
Short-eared Owl	*Asio flammeus*	12	12	9.0	13	9.8
Belted Kingfisher	*Megaceryle alcyon*	5	1	0.3	3	0.9
Acorn Woodpecker	*Melanerpes formicivorus*	2.8	3	0.5	2	0.4
Gila Woodpecker	*Melanerpes uropygialis*	2.3	68	9.8	121	17
Golden-fronted Woodpecker	*Melanerpes aurifrons*	2.9	2	0.4	-	-
Downy Woodpecker	*Picoides pubescens*	0.95	2	0.1	11	0.7
Hairy Woodpecker	*Picoides villosus*	2.3	1	0.1	-	-
Northern Flicker	*Colaptes auratus*	4.6	77	22	44	13
Pileated Woodpecker	*Dryocopus pileatus*	10	1	0.6	-	-
Crested Caracara	*Caracara cheriway*	35	9	20	23	50
American Kestrel	*Falco sparverius*	4.1	490	126	565	145
Merlin	*Falco columbarius*	6.5	9	3.7	15	6.1
Peregrine Falcon	*Falco peregrinus*	26	-	-	1	1.6
Prairie Falcon	*Falco mexicanus*	26	-	-	1	1.6
Monk Parakeet*	*Myiopsitta monachus*	3.5	3	0.7	2	0.4
Rose-ringed Parakeet*	*Psittacula krameri*	4.1	697	179	281	72
Rosy-faced Lovebird	*Agapornis roseicollis*	1	-	-	132	8.3
Western Kingbird	*Tyrannus verticalis*	1.4	346	30	420	37
Eastern Kingbird	*Tyrannus tyrannus*	1.4	38	3.3	116	10
Gray Kingbird	*Tyrannus dominicensis*	1.5	-	-	45	4.2
Scissor-tailed Flycatcher	*Tyrannus forficatus*	1.5	151	14	83	7.8
Eastern Phoebe	*Sayornis phoebe*	0.7	1	0.04	1	0.04
Say's Phoebe	*Sayornis saya*	0.74	1	0.05	4	0.2
Loggerhead Shrike	*Lanius ludovicianus*	1.7	16	1.7	3	0.3
Black Drongo*	*Dicrurus macrocercus*	1.8	-	-	5	0.6
Steller's Jay	*Cyanocitta stelleri*	3.7	47	11	-	--
Blue Jay	*Cyanocitta cristata*	3	1	0.2	5	0.9
California Scrub-Jay>	*Aphelocoma californica*	3	1	0.2	2	0.4
Woodhouse's Scrub-Jay>	*Aphelocoma woodhouseii*	3	-	-	1	0.2
Black-billed Magpie	*Pica hudsonia*	6	371	139	647	247
American Crow	*Corvus brachyrhynchos*	16	11,151	11,151	7,968	7,968
Fish Crow	*Corvus ossifragus*	10	75	47	129	81
Common (*Northern*) Raven	*Corvus corax*	42	9,640	25,305	9,182	24,103
Eurasian Skylark*	*Alauda arvensis or*	1.4	597	52	732	64
Horned Lark	*Eremophila alpestris*	1.1	2,109	145	1,371	94
Bank Swallow (*Sand Martin*)	*Riparia riparia*	0.47	102	3.0	24	0.7
Tree Swallow	*Tachycineta bicolor*	0.7	84	3.7	143	6.3
Violet-green Swallow	*Tachycineta thalassina*	0.49	-	-	1	0.03
Purple Martin	*Progne subis*	2	56	7.0	83	10
Northern Rough-winged	*Stelgidopteryx serripennis*	0.56	4	0.1	5	0.2
Barn Swallow	*Hirundo rustica*	0.67	857	36	1,032	43
Cliff Swallow	*Petrochelidon pyrrhonota*	0.74	2,370	110	1,695	78
Cave Swallow	*Petrochelidon fulva*	0.53	84	2.8	12	0.4
Red-vented Bulbul*	*Pycnonotus cafer*	1.5	1,033	97	531	50
Cedar Waxwing	*Bombycilla cedrorum*	1.1	7	0.5	8	0.6
Gray Catbird	*Dumetella carolinensis*	1.3	1	0.1	1	0.1
Pearly-eyed Thrasher	*Margarops fuscatus*	2.5	-	-	7	1.1
Northern Mockingbird	*Mimus polyglottos*	1.7	74	7.9	105	11
European Starling*	*Sturnus vulgaris*	2.9	1,619,236	293,487	813,198	147,392
Common Myna*	*Acridotheres tristis*	3.7	7,023	1,624	6,150	1,422
Common Hill Myna	*Gracula religiosa*	7.5	-	-	1	0.5
Eastern Bluebird	*Sialia sialis*	1.1	9	0.6	5	0.3
American Robin	*Turdus migratorius*	2.7	272	46	529	89
African Silverbill*	*Euodice cantans*	0.53	353	12	131	4.3
Java Sparrow*	*Padda oryzivora*	0.9	7,335	413	7,023	395
Scaly-breasted Munia*	*Lonchura punctulata*	0.49	19,969	612	12,731	390

Chestnut Munia *	*Lonchura atricapilla*	0.46	26,781	770	17,028	490
Red Avadavat*	*Amandava amandava*	0.25	1,179	18	164	2.6
Common Waxbill*	*Estrilda astrild*	0.28	749	13	114	2.0
House Sparrow*	*Passer domesticus*	1.0	6,760	423	8,584	537
Eurasian Tree Sparrow*	*Passer montanus*	0.8	303	15	2,253	113
American Pipit	*Anthus rubescens*	0.74	19	0.9	26	1.2
Gray-crowned Rosy-Finch	*Leucosticte tephrocotis*	0.91	1	0.1	-	-
House Finch^	*Haemorhous mexicanus*	0.74	3,194	148	1,884	87
Purple Finch	*Haemorhous purpureus*	0.88	1	0.1	2	0.1
Pine Siskin	*Spinus pinus*	0.53	-	-	2	0.1
Lesser Goldfinch	*Spinus psaltria*	0.33	1	0.02	9	0.2
American Goldfinch	*Spinus tristis*	0.46	5	0.1	-	-
Lapland Longspur	*Calcarius lapponicus*	0.95	5	0.3	1	0.1
Snow Bunting	*Plectrophenax nivalis*	1.5	13	1.2	2	0.2
Grasshopper Sparrow	*Ammodramus*	0.6	4	0.2	1	0.04
Lark Bunting	*Calamospiza*	1.3	355	29	95	7.7
Chipping Sparrow	*Spizella passerina*	0.42	-	-	2	0.1
Field Sparrow	*Spizella pusilla*	0.44	3	0.1	7	0.2
Brewer's Sparrow	*Spizella breweri*	0.37	-	-	1	0.02
Fox Sparrow	*Passerella iliaca*	1.1	1	0.1	3	0.2
Dark-eyed Junco	*Junco hyemalis*	0.67	3	0.1	1	0.04
White-crowned Sparrow	*Zonotrichia leucophrys*	1	179	11	29	1.8
Savannah Sparrow	*Passerculus*	0.7	66	2.9	18	0.8
Song Sparrow	*Melospiza melodia*	0.7	-	-	13	0.6
Lincoln's Sparrow	*Melospiza lincolnii*	0.6	4	0.2	-	-
California Towhee	*Melozone crissalis*	1.5	17	1.6	2	0.2
Yellow-headed Blackbird	*Xanthocephalus*	2.3	831	119	787	113
Bobolink	*Dolichonyx oryzivorus*	1.5	5	0.5	8	0.8
Eastern Meadowlark^	*Sturnella magna*	3.4	1,198	255	1,468	312
Western Meadowlark^	*Sturnella neglecta*	3.2	1,013	202	1,081	216
Red-winged Blackbird	*Agelaius phoeniceus*	1.8	476,632	53,621	472,460	53,152
Brown-headed Cowbird	*Molothrus ater*	1.5	765,183	71,736	300,266	28,150
Rusty Blackbird	*Euphagus carolinus*	0.21	-	-	1	0.01
Brewer's Blackbird	*Euphagus cyanocephalus*	2.2	7,560	1,040	768	106
Common Grackle	*Quiscalus quiscula*	4	126,191	31,548	78,525	19,631
Greater Antillean Grackle	*Quiscalus niger*	3	65	12	95	18
Boat-tailed Grackle	*Quiscalus major*	6.1	524	200	236	90
Great-tailed Grackle	*Quiscalus mexicanus*	5.4	9,522	3,214	936	316
Northern Cardinal^	*Cardinalis cardinalis*	1.6	163	16	40	4.0
Dickcissel	*Spiza americana*	0.95	1	0.1	7	0.4
Red-crested Cardinal*	*Paroaria coronata*	1.5	4,006	376	1,465	137
Saffron Finch*	*Sicalis flaveola*	0.63	8	0.3	178	7.0
TOTAL	**148 Spp. + 1 Domestic**		**3,274,616**	**609,489**	**1,882,214**	**400,934**

* Introduced Species ^Some population introduced/invasive

Table A6. The annual average number of waterbirds killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

WATERBIRDS						
Species	**Scientific Name**	**Weight (oz)**	**Annual Avg FY11-FY15**		**Annual Avg FY16-FY20**	
			Killed	**Total Wt**	**Killed**	**Total Wt**
Black-bellied Whistling Duck	*Dendrocygna autumnalis*	29	24	44	44	80
Brant Goose	*Branta bernicla*	50	256	800	106	331
Canada Goose	*Branta canadensis*	157	22,728	223,019	23,509	230,682
Cackling Goose	*Branta hutchinsii*	56	10	35	39	137
Ross's Goose	*Chen rossii*	43	1	2.7	-	-
Snow Goose	*Chen caerulescens*	102	28	179	37	236
Feral Graylag/Swan Goose *	*Anser anser/cygnoides*	110	82	564	37	254
Greater White-fronted Goose	*Anser albifrons*	77	42	202	42	202
Mute Swan*	*Cygnus olor*	352	1,793	39,446	1,309	28,798
Trumpeter Swan[1]	*Cygnus buccinator*	368	1	23	5	115
Tundra Swan	*Cygnus columbianus*	219	1	14	3	41
Egyptian Goose	*Alopochen aegyptiaca*	44	-	-	1	2.8

Feral Domestic Muscovy	*Cairina moschata*	80	34	170	115	575
Wood Duck	*Aix sponsa*	21	35	46	59	77
Cinnamon Teal	*Anas cyanoptera*	14	12	11	17	15
Blue-winged Teal	*Anas discors*	13	117	95	117	95
Northern Shoveler	*Anas clypeata*	21	74	97	111	146
Gadwall	*Anas strepera*	32	44	88	60	120
American Wigeon	*Anas americana*	26	38	62	67	109
Mallard	*Anas platyrhynchos*	38	2,515	5,973	2,280	5,415
- Feral Domestic Mallard*	*Anas platyrhynchos*	80	209	1,045	136	680
Mottled Duck	*Anas fulvigula*	35	23	50	27	59
American Black Duck	*Anas rubripes*	42	42	110	20	53
Northern Pintail	*Anas acuta*	29	35	63	33	60
Green-winged Teal	*Anas carolinensis*	12	122	92	133	100
Canvasback	*Aythya valisineria*	43	1	2.7	3	8.1
Redhead	*Aythya americana*	37	13	30	11	25
Ring-necked Duck	*Aythya collaris*	24	25	38	17	26
Greater Scaup	*Aythya marila*	37	61	141	38	88
Lesser Scaup	*Aythya affinis*	29	29	53	29	53
Common Eider	*Somateria mollissima*	75	3	14	1	4.7
Harlequin Duck	*Histrionicus histrionicus*	21	2	2.6	-	-
Surf Scoter	*Melanitta perspicillata*	34	3	6.4	-	-
Long-tailed Duck	*Clangula hyemalis*	26	6	9.8	11	18
Bufflehead	*Bucephala albeola*	13	35	28	61	50
Common Goldeneye	*Bucephala clangula*	30	8	15	5	9.4
Barrow's Goldeneye	*Bucephala islandica*	30	14	26	7	13
Hooded Merganser	*Lophodytes cucullatus*	22	37	51	42	58
Common Merganser	*Mergus merganser*	54	47	159	47	159
Red-breasted Merganser	*Mergus serrator*	37	4	9.3	3	6.9
Ruddy Duck	*Oxyura jamaicensis*	19	38	45	72	86
Pied-billed Grebe	*Podilymbus podiceps*	16	23	23	15	15
Red-necked Grebe	*Podiceps grisegena*	35	1	2.2	1	2.2
Horned Grebe	*Podiceps auritus*	16	1	1.0	1	1.0
Eared (*Black-necked*) Grebe	*Podiceps nigricollis*	11	2	1.4	4	2.8
Virginia Rail	*Rallus limicola*	3	-	-	1	0.2
Sora	*Porzana carolina*	2.6	-	-	1	0.2
Common Gallinule	*Gallinula galeata*	11	3	2.1	1	0.7
American Coot	*Fulica americana*	22	2,966	4,078	547	752
Sandhill Crane	*Grus canadensis*	143	21	188	40	358
Black-necked Stilt	*Himantopus mexicanus*	6	36	14	14	5.3
American Avocet	*Recurvirostra americana*	11	4	2.8	3	2.1
American Oystercatcher	*Haematopus palliatus*	22	-	-	1	1.4
Black-bellied Plover	*Pluvialis squatarola*	8	13	6.5	13	6.5
American Golden-Plover	*Pluvialis dominica*	5	22	6.9	1	0.3
Pacific Golden-Plover	*Pluvialis fulva*	4.6	2	0.6	19	5.5
Killdeer	*Charadrius vociferus*	3.3	2,101	433	3,119	643
Semipalmated Plover	*Charadrius semipalmatus*	1.6	26	2.6	33	3.3
Wilson’s Plover	*Charadrius wilsonia*	2.1	-	-	3	0.4
Upland Sandpiper	*Bartramia longicauda*	6	381	143	82	31
Whimbrel	*Numenius phaeopus*	14	16	14	15	13
Long-billed Curlew	*Numenius americanus*	21	22	29	10	13
Hudsonian Godwit	*Limosa haemastica*	11	5	3.4	-	-
Marbled Godwit	*Limosa fedoa*	13	1	0.8	1	0.8
Sanderling	*Calidris alba*	2.1	12	1.6	7	0.9
Dunlin	*Calidris alpina*	2.1	53	7.0	8	1.1
Rock Sandpiper	*Calidris ptilocnemis*	2.5	1	0.2	-	-
Least Sandpiper	*Calidris minutilla*	0.7	77	3.4	40	1.8
White-rumped Sandpiper	*Calidris fuscicollis*	1.5	3	0.3	-	-
Buff-breasted Sandpiper	*Calidris subruficollis*	2.2	-	-	1	0.1
Pectoral Sandpiper	*Calidris melanotos*	2.6	5	0.8	10	1.6
Semipalmated Sandpiper	*Calidris pusilla*	0.88	16	0.9	5	0.3
Western Sandpiper	*Calidris mauri*	0.91	7	0.4	30	1.7
Short-billed Dowitcher	*Limnodromus griseus*	3.9	3	0.7	8	2.0
Long-billed Dowitcher	*Limnodromus*	4	2	0.5	5	1.3
American Woodcock	*Scolopax minor*	7	1	0.4	-	-
Wilson's Snipe	*Gallinago delicata*	3.7	30	6.9	38	8.8
Spotted Sandpiper	*Actitis macularius*	1.4	1	0.1	1	0.1
Solitary Sandpiper	*Tringa solitaria*	1.8	1	0.1	4	0.5
Lesser Yellowlegs	*Tringa flavipes*	2.8	21	3.7	14	2.5
Willet	*Tringa semipalmata*	8	10	5.0	7	3.5

Greater Yellowlegs	*Tringa melanoleuca*	6	22	8.3	22	8.3
Wood Sandpiper	*Tringa stagnatilis*	1.8	-		1	0.1
Red-necked Phalarope	*Phalaropus lobatus*	1.2	-		4	0.3
Red-legged Kittiwake	*Rissa brevirostris*	13	2	1.6	-	-
Bonaparte's Gull	*Chroicocephalus*	7	63	28	89	39
Laughing Gull	*Leucophaeus atricilla*	11	5,264	3,619	4,719	3,244
Franklin's Gull	*Leucophaeus pipixcan*	10	311	194	1,194	746
Heermann's Gull	*Larus heermanni*	18	2	2.3	2	2.3
Short-billed Gull	*Larus brachyrhynchus*	15	182	171	133	125
Ring-billed Gull	*Larus delawarensis*	18	6,053	6,810	6,103	6,866
California Gull	*Larus californicus*	21	1,762	2,313	1,454	1,908
Great Black-backed Gull	*Larus marinus*	58	438	1,588	267	968
Glaucous-winged Gull	*Larus glaucescens*	35	3,762	8,229	1,343	2,938
Western Gull	*Larus occidentalis*	35	258	564	277	606
Glaucous Gull	*Larus hyperboreus*	50	12	38	22	69
Herring Gull	*Larus smithsonianus*	40	5,251	13,128	4,113	10,283
Iceland Gull	*Larus glaucoides*	29	-	-	1	1.8
Gull-billed Tern	*Gelochelidon nilotica*	6	16	6.0	6	2.3
Caspian Tern	*Hydroprogne caspia*	22	10	14	4	5.5
Royal Tern	*Thalasseus maximus*	16	3	3.0	1	1.0
Sandwich Tern	*Thalasseus sandvicensis*	7	3	1.3	-	-
Common Tern	*Sterna hirundo*	4.2	4	1.1	13	3.4
Forster's Tern	*Sterna forsteri*	6	2	0.8	-	-
Black Tern	*Chlidonias niger*	2.2	41	5.6	10	1.4
Parasitic Jaeger	*Stercorarius parasiticus*	16	1	1.0	5	5.0
Long-tailed Jaeger	*Stercorarius longicaudus*	11	2	1.4	4	2.8
Parakeet Auklet	*Aethia psittacula*	11	1	0.7	-	-
Pacific Loon	*Gavia pacifica*	59	1	3.7	2	7.4
Magnificent Frigatebird	*Fregata magnificens*	53	-	-	1	3.3
Anhinga	*Anhinga anhinga*	43	17	46	20	54
Brandt's Cormorant	*Phalacrocorax*	74	2	9.3	1	4.6
Pelagic Cormorant	*Phalacrocorax pelagicus*	62	1	3.9	8	31
Double-crested Cormorant	*Phalacrocorax auritus*	74	19,674	90,992	9,973	46,125
Neotropic Cormorant	*Phalacrocorax brasilianus*	42	-	-	7	18
American Bittern	*Botaurus lentiginosus*	24	1	1.5	1	1.5
Yellow Bittern	*Ixobrychus sinensis*	3.3	18	3.7	100	21
Great Blue Heron	*Ardea herodias*	102	593	3,780	570	3,634
Great Egret	*Ardea alba*	30	327	613	384	720
Snowy Egret	*Egretta thula*	13	150	122	126	102
Little Blue Heron	*Egretta caerulea*	12	16	12	48	36
Tricolored Heron	*Egretta tricolor*	13	3	2.4	3	2.4
Cattle Egret^	*Bubulcus ibis*	12	5,607	4,205	5,992	4,494
Green Heron	*Butorides virescens*	7	24	11	24	11
Black-crowned Night-Heron	*Nycticorax nycticorax*	30	31	58	24	45
Yellow-crowned Night-Heron	*Nyctanassa violacea*	24	33	50	57	86
White Ibis	*Eudocimus albus*	24	140	210	207	311
Glossy Ibis	*Plegadis falcinellus*	19	10	12	11	13
White-faced Ibis	*Plegadis chihi*	21	10	13	10	13
Roseate Spoonbill	*Platalea ajaja*	53	1	3.3	1	3.3
American White Pelican	*Pelecanus*	262	50	819	61	999
Brown Pelican	*Pelecanus occidentalis*	131	3	25	2	16
TOTAL	**131 Sp. + 1 Domestic**	**-**	**84,658**	**415,571**	**70,177**	**355,450**

* Introduced Species ^Some populations introduced/invasive [1] Includes escaped trumpeter x whooper swans

Table A7. The annual average number of reptiles, amphibians, and fish killed by WS in WDM between FY11 and FY15 and FY16 and FY20 throughout the United States and its territories (only animals with an annual average take of 0.5 or more included) and the weight of their carcasses.

CROCADILIAN, TURTLE AND LIZARD SPECIES						
Species	**Scientific Name**	**Weight (oz)**	**Annual Avg FY11-**		**Annual Avg FY16-**	
			Killed	**Total Wt**	**Killed**	**Total Wt**
American Alligator^	*Alligator mississippiensis*	800	7	350	12	600
Spectacled Caiman*	*Caiman crocodilus*	640	1	40	11	440

Eastern Box Turtle	*Terrapene carolina*	32	-	-	1	2.0
Pond (*Yellow-bellied*) Slider^	*Trachemys scripta*	64	33	132	41	164
Painted Turtle^	*Chrysemys picta*	14	9	7.9	10	8.8
River Cooter	*Pseudemys concinna*	80	1	5.0	1	5.0
Texas Cooter	*Pseudemys texana*	80	1	5.0	-	-
Common Snapping Turtle^	*Chelydra serpentina*	300	241	4,519	356	6,675
Spiny Softshell^	*Apalone spinifera*	208	3	39	1	13
Unidentified Turtles	Order Testudines (~24	200	2	25	1	13
Common Agama*	*Agama agama*	14	-	-	1,012	886
Black (*Gray's*) Spinytail	*Ctenosaura similis*	88	673	3,702	769	4,230
Green Iguana*	*Iguana iguana*	88	1,057	5,814	1,941	10,676
Brown Basalisk*	*Basiliscus vittatus*	14	11	9.6	55	48
Northern Curly-tailed Lizard*	*Leiocephalus carinatus*	14	-	-	33	29
Argentine Black-and-white	*Salvator merianae*	167	1	10	1	10
Nile Monitor^	*Varanus niloticus*	240	2	30	-	-
Brown Tree Snake*	*Boiga irregularis*	16	21,491	21,491	18,651	18,651
Western Ratsnake	*Pantherophis obsoletus*	44	-	-	1	2.8
Eastern (*Common*)	*Lampropeltis getula*	32	2	4.0	1	2.0
Gophersnake	*Pituophis catenifer*	32	16	32	8	16
Northern Watersnake	*Nerodia sipedon*	12	1	0.8	-	-
Plains Gartersnake	*Thamnophis radix*	12	6	4.5	-	-
Copperhead	*Agkistrodon contortrix*	16	1	1.0	-	-
Cottonmouth	*Agkistrodon piscivorus*	16	3	3.0	2	2.0
Western Diamondback	*Crotalus atrox*	32	8	16	13	26
Western Rattlesnake	*Crotalus oreganus*	5	-	-	13	4.1
Red Diamond Rattlesnake	*Crotalus ruber*	32	-	-	1	2.0
Prairie Rattlesnake	*Crotalus viridis*	16	8	8.0	2	2.0
Burmese Python*	*Python bivittatus*	1600	-		2	200
Marine (*Giant, Cane*) Toad*	*Rhinella marina*	32	60	120	5	10
American Bullfrog*	*Lithobates catesbeianus*	18	3	3.4	-	-
Longnose Gar	*Lepisosteus osseus*	72	-	-	1	4.5
Bowfin	*Amia calva*	200	-	-	1	13
Goldfish*	*Carassius auratus*	60	112	420	-	-
Grass Carp*	*Ctenopharyngodon idella*	80	1	5.0	-	-
Common Carp*	*Cyprinus carpio*	80	26	130	12	60
Northern Pikeminnow	*Ptychocheilus oregonensis*	32	48,501	97,002	59,302	118,604
Unidentified Suckers	*Catostomus* spp. (3	48	40	120	-	-
Channel Catfish^	*Ictalurus punctatus*	160	-	-	1	10
Bluegill^	*Lepomis macrochirus*	16	350	350	-	-
Smallmouth Bass^	*Micropterus dolomieu*	36	-	-	47	106
Largemouth Bass^	*Micropterus salmoides*	48	1	3.0	2	6.0
Walleye^	*Sander vitreus*	128	-	-	9	72
Unidentified Fish	Unknown	60	-	-	1	3.8
TOTAL	**42 Species + 2 Group**		**72,672**	**134,401**	**82,320**	**161,595**

* Introduced Species ^Some introduced populations/invasive

Table A8. Weight of white-tailed deer harvested in 2015-2017 and road kills from insurance claims in State Fiscal Year 2018 (July 2017-June 2018) (QDMA 2019), and of the annual average waterfowl harvested by sportsmen for FY11-FY20 in the United States (USFWS 2012, 2014, 2016, 2018, 2020).

WHITE-TAILED DEER HARVEST/ACCIDENTS				
Species	**Scientific Name**	**Est. Harvest**	**Weight (oz)**	**Total Wt (tons)**
White-tailed Deer	Harvest (2015-2017 Annual Average)	5,900,000	2,800	516,250
White-tailed Deer	Car Collisions (July 2017-June 2018)	1,300,000	2,800	113,750
TOTAL		**7,200,000**	**2,800**	**630,000**
AVERAGE ANNUAL WATERFOWL HARVEST (FY11-FY20)				
Greater White-fronted Goose	*Anser albifrons*	264,463	77	636
Snow Goose	*Chen caerulescens*	357,046	102	1138
Ross's Goose	*Chen rossii*	56,316	43	76
Brant	*Branta bernicla*	20,533	50	32
Cackling/Canada Goose	*Branta hutchinsii/canadensis*	2,350,084	106	7785
Wood Duck	*Aix sponsa*	1,151,441	21	756

Gadwall	*Anas strepera*	1,488,431	32	1488
American Wigeon	*Anas americana*	651,513	26	529
American Black Duck	*Anas rubripes*	89,571	42	118
Mallard	*Anas platyrhynchos*	3,667,402	38	4355
- Feral Domestic Mallard*	*Anas platyrhynchos*	7,362	80	18
Mottled Duck	*Anas fulvigula*	42,175	35	46
Blue-winged/Cinnamon Teal	*Anas discors/cyanoptera*	1,076,970	13.5	454
Northern Shoveler	*Anas clypeata*	683,647	21	449
Northern Pintail	*Anas acuta*	527,500	29	478
Green-winged Teal	*Anas carolinensis*	1,652,152	12	620
Canvasback	*Aythya valisineria*	112,147	43	151
Redhead	*Aythya americana*	240,085	37	278
Ring-necked Duck	*Aythya collaris*	485,960	24	364
Greater Scaup	*Aythya marila*	67,369	37	78
Lesser Scaup	*Aythya affinis*	281,692	29	255
Common/King Eider	*Somateria millissima/spectabilis*	11,146	75	26
Surf/Black/White-winged Scoter	*Melanitta perspicillata/americana/deglandi*	53,928	34	57
Long-tailed Duck	*Clangula hyemalis*	29,227	26	24
Bufflehead	*Bucephala albeola*	222,417	13	90
Common/Barrow's Goldeneye	*Bucephala clangula/islandica*	81,650	30	77
Hooded Merganser	*Lophodytes cucullatus*	94,569	22	65
Common/Red-breasted Merganser	*Mergus merganser/serrator*	33,288	46	48
Ruddy Duck	*Oxyura jamaicensis*	41,733	19	25
TOTAL 35 sp.	**USFWS 2012/14/16/19/21**	**15,841,817**		**20,516**