Assessing the Impacts to Society Associated with the Use of Alternative Ammunition for Hunting on National Wildlife Refuges

Christopher Cahill

University of Massachusetts Amherst

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ASSESSING THE IMPACTS TO SOCIETY ASSOCIATED WITH THE USE OF ALTERNATIVE AMMUNITION FOR HUNTING ON NATIONAL WILDLIFE REFUGES

A Thesis Presented
by
CHRISTOPHER M. CAHILL

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

February 2021

Environmental Conservation
Wildlife, Fish and Conservation Biology
ASSESSING THE IMPACTS TO SOCIETY ASSOCIATED WITH THE USE OF ALTERNATIVE AMMUNITION FOR HUNTING ON NATIONAL WILDLIFE REFUGES

A Thesis Presented

by

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DEDICATION

For Alexis, Jayda, Journey, and Finn.
“Get the spatula!”
ACKNOWLEDGMENTS

First, I would like to thank the National Wildlife Refuge hunters. Without your input in the early stages and voluntary participation, this project would not have been possible. Thank you to the folks at the Institute for Social Science Research at UMass Amherst who provided valuable input at various stages of the project. To the USFWS at Hadley and the individual refuge managers for coordinating resources and making this project run smoothly, thank you. To my advisor Stephan DeStefano and my committee members Gordon Batcheller, John Organ, and Brett Butler, thank you for your guidance over the last three years and for giving me this great opportunity. My gratitude to Gordon for helping me appreciate how hard hunting can be. Finally, Alexis, without you.....
ATTEMPT TO ELIMINATE LEAD AMMUNITION USE FOR HUNTING THROUGH REGULATORY APPROACHES CAN BE CONTROVERSIAL AND CONTENTIOUS, DESPITE EXTENSIVE SCIENTIFIC EVIDENCE OF THE DETERIMENTAL EFFECT OF LEAD ON WILDLIFE SPECIES. IN THE UNITED STATES, VOLUNTARY APPROACHES TO NON-LEAD USE THAT HAVE USED OUTREACH AND EDUCATION IN PLACE OF REGULATORY APPROACHES HAVE ACHIEVED SUSTAINED BEHAVIORAL CHANGE IN HUNTER AMMUNITION CHOICE. HOWEVER, VOLUNTARY APPROACHES TO ALTERNATIVE AMMUNITION USE CAN BE CONFRONTED WITH BOTH PRACTICAL AND SOCIAL BARRIERS. IN COLLABORATION WITH U.S. FISH AND WILDLIFE SERVICE AND U.S. GEOLOGICAL SURVEY COOPERATIVE RESEARCH UNITS PROGRAM, THIS STUDY ASSESSED THE PRACTICAL AND SOCIAL BARRIERS ASSOCIATED WITH A VOLUNTARY APPROACH TO TRANSITIONING TO NON-LEAD AMMUNITION FOR HUNTING WHITE-TAILED DEER (Odocoileus virginianus) ON TARGETED NATIONAL WILDLIFE REFUGES IN THE NORTHEAST UNITED STATES.

This thesis is presented in two sections. Section one examines the continued use of lead ammunition in the context of the North American Model of Wildlife Conservation (the Model). The Model presents a unique approach to wildlife conservation grounded in the sustainable use of wildlife resources maintained in a...
public trust. In accordance with the Model, wildlife resources in the trust are managed by the government at a population level to maintain trust resources in perpetuity for the benefit of current and future generations of the American public. Continued lead ammunition use for hunting that facilitates pathways to exposure for non-target species presents a unique challenge to a core principle of the Model – known as legitimate purpose -- and questions whether lead ammunition use can align with the Model even in the absence of population level impacts. In addition, chapter one explores whether continued lead ammunition use can be considered ethical hunting behavior under the current definition of a “clean kill”.

Chapter two presents the results of a both a quantitative mail-back survey and qualitative focus group discussions conducted at three refuges in the Northeast Region: Rachel Carson in Maine, Edwin B. Forsythe in New Jersey and Rappahannock River Valley in Virginia. The mail-back survey assessed how current lead users view the practical barriers associated with the voluntary use of non-lead ammunition for the purpose of harvesting white-tailed deer and what factors would influence hunters to switch. Focus group discussions assessed hunter understanding of the mechanism of exposure for non-target species and how hunters contextualize the continued use of lead ammunition for the purpose of harvesting white-tailed deer.
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CHAPTER 1

A LEGITIMATELY CLEAN KILL

1.1 Exploitation to Sustainable Use

When North America was first colonized, wildlife resources were used for subsistence means and for the first three and a half centuries there was a general assumption by colonists that such resources were inexhaustible (Eliason 2008). Following the impact of the industrial revolution and as the nation began to grow, a dramatic shift occurred within a few decades from a society chiefly rural and agrarian, to metropolitan (Hirschman and Mogford 2009). Coupled with this demographic shift came an inevitable need for food for the growing nation, fostering the development of market hunting (Organ et al. 2012), an enterprise that grew aided by refrigeration technology in combination with the progression of the railroad west following the Civil War (Ceruli 2012). Ultimately, the cumulative impact of market hunting, habitat destruction, and predator control led to the inevitable decline of wildlife populations in the United States. Overexploitation and the initial inability of certain hunters to recalibrate their values as game species declined (Reisner 1991), resulting in what Hardin (1968) termed “the tragedy of the commons”. Under this scenario, market hunters who sought to maximize their gains in a condition where resources were limited, led to the decimation, and in some cases the complete extirpation of certain species (Ceruli 2012, Organ et al. 2012, Heffelfinger et al. 2013).

As Mahoney (2009) noted, the recognized effect of non-regulated hunting and the decimation of the North American bison (Bison bison) sparked an impetus
towards the non-wasteful use of wildlife, eventually culminating in collaboration between hunters, governments, activists, and the developing field of wildlife management. This engendered a fundamental transformation from the exploitive to sustainable use of wildlife resources in order to aid in the reversal of species declines (Cahoone 2009). This shift to a more sustainable approach to the use of wildlife resources has evolved over time and is now collectively recognized as the North American Model of Wildlife Conservation (Geist 1995, Organ et al. 2012).

The North American Model of Wildlife Conservation, or the Model, is structured on what have been described as seven tenets, components, pillars, or principles (Geist et al. 2001; Mahoney 2009; Organ et al. 2010, 2012). (1) Wildlife resources are a public trust: wildlife is held in a trust to be managed by government agencies at state and federal levels for the benefit of current and future generations (Geist et al. 2001, Organ et al. 2012). (2) Markets for game are eliminated: with the exception of fur bearing animals that can be managed sustainably within normal population fluctuations. Elimination of legal trafficking of game and non-game animal products was essential to eliminate the unsustainable exploitation of North American species (Organ et al. 2010, 2012). (3) Allocation of wildlife is by law: where a surplus of wildlife resources exists, this is allocated for public consumption by law instead of through market, special privileges, or land ownership (Geist et al. 2001). In combination with the Public Trust Doctrine, a network of legislation and democratic processes safeguard American citizens rights to equitable access and sustainable use of wildlife trust resources (Mahoney 2009, Organ et al. 2010, Organ et al. 2012). (4) Wildlife can be killed only for legitimate purpose: that is, the
frivolous killing of wildlife is prohibited by law (Geist et al. 2001) and taking wildlife 
trust resources must be motivated by a legitimate purpose such as acquisition of 
food or fur, self-defense, or property protection (Mahoney 2009, Organ et al. 2012). 
(5) Wildlife is considered an international resource: the recognition that wildlife is 
not always confined within a sovereign state and can transcend international 
boundaries (Geist et al. 2001), necessitating cooperative international management 
of wildlife resources (Mahoney 2009). (6) Science is the proper tool to discharge 
wildlife policy: science is the most appropriate tool to discharge wildlife policy, 
manage wildlife resources within the public trust, and is the basis for informed 
decision making (Geist et al. 2001, Organ et al. 2012). (7) Democracy of hunting is 
standard: all beneficiaries of the public trust can participate in the sustainable use of 
wildlife resources (Geist et al. 2001) and opportunity to hunt and access to trust 
resources is not controlled by wealth, ownership of land, or other privileges (Organ 

Combined, these seven principles reflect wildlife management, policy, and 
legislation surrounding the sustainable use of wildlife resources and present a 
philosophical approach to wildlife conservation strongly rooted in the Public Trust 
Doctrine (Batcheller et al. 2010). The first principle, wildlife resources are a public 
trust, has been described as the keystone component of the model (Geist and Organ 
2004) and originates from a Supreme Court Ruling in 1842 (Martin v. Waddell, 41 
U.S. 234) that established the states as trustees of wildlife (Batcheller et al. 2010). In 
essence, wildlife is owned by no one and wildlife resources are maintained in the 
trust by government (trustee) for the benefit of current and future generations
(beneficiaries) (Geist and Organ 2004). Through this established mechanism of collective public stewardship and application of the Model’s principles, wildlife agencies manage wildlife resources held in the public trust with the mission to protect wildlife populations from overexploitation (Geist 1994).

The application of the Model's principles to wildlife conservation and management have been praised as a resounding success (Geist 1994, Organ et al. 2012, Heffelfinger et al. 2013) and by all accounts is a modern success story, where dramatic species declines due to unregulated harvest and commercial hunting were reversed. As Geist et al. (2001) remarked, possibly the most notable achievement of the Model was the reversal of Hardin's (1968) “Tragedy of the Commons” scenario, illustrating the positive effect of sustainable use and collective public stewardship at protecting wildlife populations.

Since the departure from the exploitive use of wildlife resources, the concept of sustainable use has been ubiquitous in modern wildlife conservation in the United States (Geist 1994; Geist and Organ 2004; Batcheller et al. 2010; Organ et al. 2010, 2012). To be sure, practices that involve the consumptive use of trust resources, such as harvesting managed game animals, necessitate maintaining the renewability of such resources. Consequently, effective management of wildlife resources within the public trust reduces the probability that a population of any given species declines to extinction (Geist and Organ 2004), securing both the goal of biodiversity conservation and sustainability of trust resources for future generations. Thereby, positioning sustainable use as a core function of the wildlife trust administration (Organ et al. 2014).
1.2 Lead Ammunition as a Method of Take

Fundamentally, for the consumptive use of renewable wildlife resources to be sustainable, such uses must not negatively affect the quality, quantity, or distribution of wildlife populations and habitat over time (Decker et al. 2017). However, from a social perspective, sustainable use of wildlife resources in North America is driven by the premise that such use is acceptable given the following conditions: (1) species and populations are not threatened by its use, (2) a legitimate purpose is associated with the use, and (3) methods employed in uses are acceptable to society (Hamilton et al. 1998). As Decker et al. (2017) noted, each condition outlined by Hamilton et al. (1998) reflects societal beliefs or evaluation about sustainable use that in aggregate translate into social acceptability of such use.

When methods of take associated with sustainable use are deemed unacceptable, society can seek to restrict such practices. For example, from the early 1990s onwards increased restrictions in a number of states have been imposed on methods of take such as certain types of traps, baiting, and hound hunting (Minnis 1998, HSUS 2014). Currently, a prominent method of take receiving consistent attention is the continued use of lead ammunition for hunting (Bellinger et al. 2013, Epps 2014, Haig et al. 2014, Arnemo 2016). In recent years large scale attempts have been made in the U.S. to regulate its use by both trustees (Directors Order 219) and beneficiaries of trust resources (EPA 2010, HSUS 2014) due to concerns related to the negative impacts associated with human and non-target wildlife health.
1.3 Population Level Impacts and Legitimate Purpose

The Association of Fish and Wildlife Agencies position statement on lead ammunition use (AFWA 2010), while calling for voluntary approaches to lead ammunition use in place of regulations, states that any increase in regulations should be based on population level impacts or where human health issues have been substantiated. Similarly, when approaching the issue of increased regulation, it is common for hunting and firearms organizations to contend that based on the Model’s current defining principles, increased regulations on lead ammunition use are not warranted where population level impacts are not observed. That is, unless a population of a specific species can be demonstrated to be in decline. Subsequently, in the absence of species decline the continued use of lead ammunition is often viewed by prominent hunting and firearms organizations as aligning with the Model (NSSF 2013, RMEF 2014, CSF 2019, NRA-ILA 2018).

Using population level declines as a metric for increased regulation of lead ammunition is certainly appropriate when considering sustainable use of trust resources within the framework of the Model. However, observations of mortality or morbidity in wildlife and identifying causes is dependent on visual detection and subsequent examination (Cromie et al. 2015). As Cromie et al. (2015) point out, large-scale wildlife mortality events due to epidemics or human influences are highly visible whereas mortality from lead exposure can often go undetected. In addition, mortality events in non-target species due to lead exposure can be spread out temporally or spatially, thereby decreasing potential visibility and detection and creating somewhat of an “invisible disease” (Pain 1991) a condition that may be
further confounded where sublethal lead exposure has the potential to increase
mortality through other routes (Kelly and Kelly 2005, Gongoso et al. 2008, Pikula et
al. 2013, Vallverdu-Coll et al. 2015, Ecke et al. 2017). Consequently, population level
impacts in the context of species declines may be underestimated due to low
detection rates of mortality events, potential for delayed effects of lead exposure,
and reduced ability to detect effects of sublethal lead burdens (Hunt 2012).

Beyond simply focusing on species declines, a species population growth rate
($\lambda$) can be either positive, negative, or neutral, and impacts of lead on non-target
species exposure can depress population growth which in turn can significantly
impact population size (Grade et al. 2017). This has raised a legitimate concern as to
how assessing population level impacts should be approached. For example, even as
populations of species such as bald eagles (*Haliaeetus leucocephalus*) are in fact
increasing, should population level impacts from lead ammunition be focused solely
on negative growth rates and resultant population declines if a populations growth
rate is being impacted? Is that not a population level impact? (G. R. Batcheller,
personal communication, April 6, 2020).

Nevertheless, in the absence of observed population level declines, the use of
lead ammunition in and of itself may not align completely with the Model. Lead
ammunition use for harvesting large game can result in lead being made available to
non-target species through the process of fragmentation and deposition when
harvesting an animal (Grund et al. 2010, Cruz-Martinez et al. 2015, Stokke et al.
2017), thereby connecting lead to a potential food source on the landscape and
facilitating pathways to exposure for non-target scavenging species (Haig 2014). As
Kanstrup (2018) noted, hunting practices that generate such pathways resulting in lethal or sublethal consequences for non-target species are fundamentally non-selective. These non-selective exposure pathways appear counterintuitive given that methods of take such as permissible firearms and ammunition use, seasons, and bag limits associated with the sustainable use of wildlife resources in the public trust are strictly regulated and enforced at the state level. Therefore, while evidence of population level declines can be viewed as a metric for regulatory measures, the indiscriminate nature of lead exposure for non-target species raises concerns about whether such practices align with the Model’s principle of legitimate purpose, even in the absence of observable declines.

Legitimate purpose is a key principle of the Model and one intrinsically linked to the social acceptability of sustainable use of wildlife resources (Decker et al. 2017). The principle of legitimate purpose requires that the harvesting or killing of an animal is legal, purposeful and selective. Motivations behind the extraction of wildlife resources are considered to align with the principle of legitimate purpose when they are for food, fur, self-defense, and property protection (Mahoney 2009; Geist et al. 2001; Organ et al. 2010, 2012). The principle of legitimate purpose has previously received criticism for being overtly vague in its definition (Nelson et al. 2011, Serfass et al. 2018) and the alignment of certain practices with the principle of legitimate purpose such as prairie dog (Cynomys spp.) shooting and crow hunting have been questioned, as ultimately no food or protective benefits are derived (Organ et al. 2012).

While demonstrated population level impacts as a result of lead ammunition
use are limited, individual mortality events (Meretsky et al. 2000, Stauber et al. 2010, Cruz-Martinez et al. 2012, Russell & Franson 2014, Golden et al. 2016, Yaw et al. 2017) and sublethal lead exposure (Gongoso et al. 2008, Ecke et al. 2017, Ganz 2018) for non-target species through lead ammunition use can and do occur. Under the Model's current definition of legitimate purpose, no “benefit” is derived where lead ammunition use results in direct mortality of non-target species or indirect mortality due to sublethal impacts. Proponents of population level impacts as a metric for increased regulations tend to frame lead exposure of non-target species as “isolated instances” and secondary mortality due to such exposure as an acceptable byproduct of hunting (NSSF 2011, RMEF 2014, CSF 2019, NRA-ILA 2018). In the context of sustainable use, the absence of population level impacts does invalidate arguments for increased regulation of lead ammunition use. Nevertheless, this position, while grounded in the Model's population level approach to wildlife conservation and management, disregards the Model’s principle of legitimate purpose which acts at the level of individual hunter and animal.

1.4 The Clean Kill Paradox

At the level of interaction between a hunter and an individual animal the concept of legitimate purpose is intrinsically tied to a universal term in contemporary hunting nomenclature, the “clean kill”. In instances where lead ammunition use results in direct mortality or sublethal impacts to non-target species, this raises the question of whether such behavior can be considered ethical when the underlying value that determines a clean kill is examined.
Outside of an animal's natural death, Rolston (1988) argues that there is a strong ethical rule: when taking an animal, suffering should not exceed that which an animal would encounter under natural conditions. It has been argued that compared to a natural death in the wild, hunting if performed with skill has the potential to reduce the net suffering of a harvested animal (Cahoone 2009). Reducing the potential for suffering is often used by hunters to rationalize the harvesting of an animal, in that “death at the hands of humans is quicker and more humane than death by fangs, claws, or talons” (Dizard 2003). Where suffering of an animal can be maintained at or below this natural threshold it has been argued that hunting in of itself incurs no moral violation (Cahoone 2009) and is an “outcome any true sportsman should strive for” (Dizard 2003).

Minimizing the suffering of a target animal is a prominent value associated with defining a clean kill (Huddleston 1999, Dizard 2003, Ceruli 2012, Gibson 2014, Vucetich and Nelson 2014). Achieving this objective is done through correct shot placement in the vital organs of an animal (Dizard 2003, Spoomer and Stockton 2008, Townsend 2003) with the ultimate goal to maximize the efficiency at which a hunter can dispatch their quarry (Dizard 2003, McLeod 2007, Airhart 2012, Gibson 2014, Gray 2016, Ceruli 2012). Not surprisingly, speed of dispatch is a common metric employed when assessing the efficacy of non-lead alternatives (Knott et al. 2010, Pierce et al. 2015, Kanstrup et al. 2016, McCann et al. 2016, Martin et al. 2017). However, due to lead ammunition use facilitating indiscriminate pathways to exposure for non-target species, the current definition of a clean kill, grounded in minimizing suffering through efficacy of dispatch, appears inadequate. This may be
particularly true when considering the lethal and sublethal impacts to non-target species (outlined in chapter 2), and when individual lead ammunition use is placed within the broader cumulative impact of lead ammunition use.

Hunting practices that incorporate lead ammunition increase bioavailability of lead on the landscape and facilitate pathways to exposure for non-target scavenging species (Church et al. 2006, Hunt et al. 2006, Craighead and Bedrosian 2008, Kelly et al. 2011, Finkelstein et al. 2012, Legagneux et al. 2014, Stokke et al. 2017). The amount of lead made available to scavenging species through harvesting ungulates can be substantial; for instance, Stokke et al. (2017) estimated the potential bioavailability of 690 kg of lead annually for scavenging species in Fennoscandia (Finland, Sweden, and Norway) through moose (Alces alces) hunting alone.

The potential for similar bioavailability of lead for non-target species exists in the United States and the availability of ungulate gut piles can be relatively high in some geographic areas. For example, white-tailed deer harvested by firearm hunters in Wisconsin in 2016 would have produced an average density of approximately 3.5 gut piles per square mile for the area of the state (Witecha 2017). Similarly, in 2015, harvest of white-tailed deer in West Virginia produced 3.59\(^1\) potentially lead laden gut piles per square mile for the state (QDMA 2017). Lead exposure pathways are not restricted to harvesting of white-tailed deer. For example: in 2001 Fry and Maurer (2003) estimated that in addition to the carcasses

\[\text{Calculation based on white-tail deer harvested with firearms in the State of West Virginia during the 2015 hunting season. Using an estimate of 20\% non-lead use.}\]

1
of over 10,000 coyotes (*Canis latrans*) deposited within the California condor range, approximately 30,000 lead laden gut piles of mule deer (*Odocoileus hemionus*) and wild pigs were left in the field. In other states practices such as prairie dog (*Cynomys* spp) shooting, where carcasses are traditionally left in the field can create a significant exposure route for non-target species. Pauli and Buskirk’s (2007) assessment of expanding bullets used in prairie dog shooting suggest there can be enough lead in a single prairie dog to acutely poison non-target avian scavengers. The broader implications of lead ammunition use in this context become more apparent when the amount of prairie dogs shot annually is taken into consideration. For species such as black-tailed prairie dogs (*Cynomys ludovicianus*) in South Dakota this can exceed a million per year (Reeve and Vosburgh 2005). Current estimates on the bioavailability of lead for non-target species in Region $5^2$ through harvesting white-tailed deer are absent. However, the likelihood for non-target species exposure through harvesting white-tailed deer with lead ammunition exits. In addition, the amount of potentially lead laden gut piles introduced to the landscape on an annual basis is indicative of a significant pathway to non-target species exposure.

Understandably, lead laden gut piles and non-recovered carcasses are not evenly distributed on the landscape, and densities of such point sources of lead exposure would be much higher in certain geographic areas primarily due to private

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2 Region 5 or the Northeast Region consists of thirteen states. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and West Virginia.
and public hunting areas concentrating point sources of exposure for scavenging species. For prominent scavenging species such as bald eagles, black vultures (*Coragyps atratus*), turkey vultures (*Cathartes aura*), and golden eagles (*Aquila chrysaetos*) potential exposure can be increased due to the large home range sizes of such species (Garret et al. 1993, DeVault et al. 2004, Braham et al. 2015, Smith et al. 2017). This can increase the likelihood for a non-target animal to interact with multiple lead laden gut piles or carcasses. In addition, large species requiring higher energy requirements, obligate scavengers, and social foraging species may have increased potential for interaction with multiple point sources of lead exposure (Haig et al. 2014). Lead exposure for certain species could be further compounded where gut-piles provide a seasonal attractant, thereby increasing the likelihood for repeated exposure (Bedrosian et al. 2012).

Maintaining lead exposure pathways for non-target species through lead ammunition use can result in lethal and sublethal effects on non-target species through single or multiple exposure events. Where this occurs, suffering is not confined to the interaction between an individual hunter and their quarry. This lack of confinement questions whether the underlying value of minimizing suffering is in fact upheld in the context of lead ammunition use, placing the current definition of a clean kill and ethical hunting behavior in a position of uncertainty. Where lead ammunition use is unable to confine suffering to the interaction between a hunter and their quarry, the ethics of lead ammunition use and what constitutes a clean kill may need to be reassessed to incorporate such impacts.
A recent analysis by Peterson (2014) identified that hunting organizations and wildlife management agencies throughout the United States can prioritize different components that constitute ethical hunting. Nongovernmental organizations place more importance on skill and being motivated by nature, while in comparison, government agencies tend to place a greater emphasis on respecting landowners (Peterson 2014). While both groups share common values on what constitutes ethical hunting, prescriptive language linking hunting decisions to biodiversity impacts did not exist, and where the humane treatment of animals was identified, this was primarily described in the context of a clean kill. While Peterson’s (2014) analysis was limited to online materials from both groups, it suggests there is an opportunity to improve how hunting groups and individuals can be engaged by wildlife management agencies to reassess how lead ammunition use aligns with their code of ethics. In addition, the broader use of lead ammunition by the hunting community and how this translates to increased bioavailability of lead for non-target species, suggests that both wildlife agencies and nongovernmental organizations need to articulate a more comprehensive definition of a clean kill to incorporate non-target species impacts.

1.5 Conclusion
Historically, hunters have unquestionably played a central role in wildlife conservation in North America. Under the current model of wildlife management hunters remain an important wildlife management tool, acting as surrogates for natural predators in order to keep certain game populations under control.
(Cahoone 2009, Heffelfinger et al. 2013). In addition, they provide financial support to state agencies that act as trustees for wildlife resources and their associated habitats (Heffelfinger et al. 2013, Arnett 2015). In addition, nongovernmental hunting organizations contribute significantly to conservation objectives (Poole 2007, Mahoney 2009).

Beyond financial contributions, contemporary hunting as a cultural interaction with nature recognizes the interdependence of humans and the natural world (Adams 2013). This is an important condition, given the exponential increase in society’s dependency on technology since the late 20th century. This dependency coupled with increased urbanization has led to a disconnect between humans and nature (Peterson 2011). As Peterson (2011) describes, our interdependent relationship with the natural world and how we get food becomes clouded, when the processes of life and death associated with the provisioning of food becomes ever increasingly veiled. Contemporary hunting provides individuals with an opportunity for “anachronistic self-sufficiency” (Cahoone 2009) while acting as a mechanism to promote biodiversity knowledge and develop strong connections with nature (Adams 2013, Peterson 2017). Hunting makes the connection between death and the provisioning of food explicit, providing an opportunity to contemplate the ethics surrounding the taking of non-human life while also recognizing how we fit into the ecosystem (Cahoone 2009).

For hunters, when an animal is harvested there is a direct relationship between the hunter and the organism, positioning the hunter as an active member of the ecosystem from which they harvest wildlife resources. Where the reciprocal
connection between a hunter and their quarry provides food resources to non-target species their relationship to the ecosystem as a whole is expanded. The use of lead ammunition where lethal and sublethal impacts occur for non-target species has placed this relationship between the hunter and the extended environment under increasing scrutiny. Prompting many scientists in North America to urge making the switch to non-lead alternatives imperative in order to minimize the risk of human and wildlife exposure (Bellinger et al. 2013).

Such excoriations by the scientific community or non-consumptive beneficiaries concerning lead ammunition use can often be interpreted as anti-hunting (Seng et al. 2006, Ross-Winslow 2013, HFTA 2019). Undoubtedly, hunting in of itself can be a controversial activity (McLeod 2007, Dickson 2009). However, the desire, by trust beneficiaries such as non-lead hunters, the scientific community, and non-consumptive users, for hunters to recognize the impact of lead ammunition use and adjust their behavior accordingly is not inherently anti-hunting. Furthermore, support for hunting by non-consumptive beneficiaries can be relatively high on a national level. For example, in the U.S., even in the face of declining hunting participation in recent decades (USFWS National Survey 2016), Byrd et al. (2017) found that when motivations behind hunting are for a legitimate purpose such as provisioning of food, social acceptability of hunting by non-hunters at a national level can remain high (87% of respondents n = 825) while acceptability other hunting practices such as trophy hunting can be relatively low (37% of respondents n = 825). In addition, practices that are perceived to reduce animal welfare, such as hunting over bait, captive hunts, or hunting with dogs, can be
viewed less favorably by non-hunters (Byrd et al. 2017).

Non-consumptive beneficiaries can often be labeled as anti-hunting when opposition towards aspects of hunting are expressed (Dizard 2003). In the context of sustainable use, non-consumptive beneficiaries often want hunters to honestly signal that the taking of an animal’s life is a serious matter (Dizard 2003). As Nelson and Millenbah (2009) noted, “The desire for this recognition and the objection to its perceived absence, is not the same as being anti-hunter”. More often, social acceptability of hunting and sustainable use of wildlife resources can be dependent on harvesting practices and motivations that are deemed acceptable to the public (Minnis 1998, Knezevic, 2009, Byrd et al. 2017, Decker et al. 2017) and it has been suggested that social support for hunting in general can be increased where hunters demonstrate ethical behavior towards game animals (Dizad 2003, Nelson and Millenbah 2009). By the same note, social support for hunting can be increased where ethical consideration is extended to non-target species through the use of non-lead alternatives that eliminate lead exposure pathways.

Eliminating or reducing such exposure pathways is not a universally straightforward process when practical barriers to non-lead adoption are taken into consideration. Identified practical barriers to the adoption of non-lead alternatives can include aspects of cost, availability, performance, and compatibility with existing firearms (Seng, 2006, Friend 2009, Caudell et al. 2012, Epps 2014, Southwick and Associates Inc 2014, Chase and Rabe 2015). Recent studies have illustrated comparable performance for a variety of non-lead ammunition in terms of terminal ballistics (Knott et al. 2010, Trinogga et al. 2013, Gremse et al. 2014) and
efficacy of dispatch under field conditions (Kanstrup et al. 2016, McCann et al. 2016, Martin et al. 2017). While certain non-lead alternatives can be similar in cost (Thomas 2013), how the economic cost associated with transitioning to non-lead manifests for individual hunters will likely be dependent on their current ammunition and firearm use (EPPS 2014). In addition, where non-lead alternatives have been identified (Thomas 2013) availability can be relatively low (Haig et al. 2014). For example, for three major ammunition manufacturers identified in Thomas’s (2013) price comparison study, none had more than 27% availability for centerfire bullets or shotgun slugs (Haig et al. 2014).

Haig et al. (2014) suggests that either lack of market demand or limited production by ammunition manufacturers may be responsible for reduced availability. Understandably, voluntary approaches to non-lead ammunition use do not create a strong market demand that ammunition manufacturers can rely on. In theory, as demand grows for non-lead alternatives through combined regulatory and voluntary approaches this will incentivize ammunition manufacturers to scale up production lines for non-lead alternatives and in the long run reduce cost and increase availability. As Thomas et al. (2019) noted, the current relationship between hunters and ammunition manufacturers has created a Catch-22 situation, whereby reduced retail availability reduces public demand and disincentivizes manufacturers to scale up production or further invest in the development of non-lead alternatives.

Nevertheless, increasing market demand is not facilitated where population level impacts are used as an impetus for switching to non-lead alternatives. In
addition, using population level impacts as a requisite for action impedes availability through reduced market demand. Furthermore, attempts by hunting organizations to normalize non-target species mortality as “isolated instances” (NSSF 2011, RMEF 2014, CSF 2019) may in fact undermine social support for hunting. Continued use of lead ammunition use in light of secondary poisoning of non-target species does little to reinforce the image of hunters as conservationists in tune with contemporary ecological concerns. In addition, framing secondary poisoning as isolated events signals to other trust beneficiaries that hunters view the indiscriminate poisoning of non-target species as an acceptable consequence of hunting. Furthermore, it acknowledges the negative impact of lead ammunition use on non-target species and implies that non-game species in the trust do not possess any inherent value or warrant the same respect or ethical consideration that hunters grant their quarry.

The current approach to wildlife management in North America as reflected by the Model dictates that population level impacts act as a driver for increased regulation of lead ammunition use. However, the indiscriminate exposure of non-target species and mortality of non-game trust resources through lead ammunition use contravenes the Model’s principle of legitimate purpose. Application of the Model’s principles apply to all species, not just game species (Organ et al. 2012). Consequently, individual mortality and sublethal effects on non-target species, even in the absence of a population level impacts, require hunting and firearm organizations to reassess the alignment of such practices with the Model, especially where the Model’s principles are used to legitimize the continued use of lead
ammunition.

At an individual level, hunters may need to examine their attitudes towards the secondary poisoning of non-target species and reassess lead ammunition use in the context of their extended relationship with the environment and personal code of ethics. As Leopold (1949) wrote, “A peculiar virtue in wildlife ethics is that the hunter ordinarily has no gallery to applaud or disapprove of his conduct. Whatever his acts, they are dictated by his own conscience, rather than a mob of onlookers. It is difficult to exaggerate the importance of this fact”. While originally placed in the context of sportsmanship and placing voluntary restrictions on the use of legal technology that gave hunters the upper hand, Leopold’s approach to wildlife ethics is equally instructive to the ethical issue of lead ammunition use. Adhering to a personal code of ethical behavior can place additional personal restrictions to those put in place by legislation. In this case, using ammunition that does not have a negative impact beyond the interaction between a hunter and their quarry but rather strengthens a hunter’s role in the ecosystem.

Historically, collaboration between consumptive and non-consumptive beneficiaries of the public trust resulted in the reversal of the effects of market hunting and positively impacted North American biodiversity. Nevertheless, modern conservation problems cannot be diluted by the success of predecessors and need to be met head on with the same foresight that challenged the status quo of market hunting. As wildlife and their associated habitats face increasing pressure from external sources there is an opportunity again for all beneficiaries of the public trust to collaborate towards what is a common objective, reducing negative impacts to
wildlife. As Adams (2012) notes, “When we harvest animals and plants for food, it is a direct relationship between ourselves, the organisms and our shared environment, with the only mediation being the tools we use”. Where alternative tools are available or strategies can be employed to eliminate non-target species lead exposure from hunting activities, there is an opportunity and a responsibility for contemporary hunters to achieve a “legitimately clean kill” and expand the conservation legacy of hunters in North America.
CHAPTER 2
BARRIERS TO NON-LEAD AMMUNITION USE FOR HARVESTING WHITE-TAILED DEER ON NATIONAL WILDLIFE REFUGES

2.1 Background

In the United States, anthropogenic lead exposure was recognized as a significant public health issue in the mid 20th century, with lead in paint, fuel, and plumbing products being identified as points of exposure (Newell and Rodgers 2003, Needleman 2004). Subsequently, lead toxicity and its associated effects in humans have been studied at length with both lethal and sublethal effects identified. The effects of lead toxicity in humans include: mortality due to heart attack or stroke (Menke et al. 2006), detrimental effects on the peripheral and central nervous system (Needleman 2004), and disturbances in fine motor function (Needleman et al. 1990). At high levels of exposure lead can cause miscarriages in women and impaired fetal development (Kosnett 2009). Lead exposure can negatively impact male fertility (Wu et al. 2012) and in early childhood, infancy, and at the fetal stage can have long-term negative consequences and has been linked to decreased brain volume in adults (Cecil et al. 2008). Blood lead levels (BLLs) below 10 μg/dL have been associated with reduced cognitive function in children (Canfield et al. 2005) and late effects of early-childhood lead exposure showed more school failure, reading disabilities, and lower class standing in the final year of high school (Needleman et al. 1990). In addition, increased BLLs and resultant intellectual
deficits in children have been observed (Canfield et al. 2003, Lanphear et al. 2005, Schnaas et al. 2006).

Currently, lead in industrial activities and consumer products in the U.S. is strictly regulated and permits are required at the state and federal level for any sort of industrial release (Pokras and Kneeland 2009). Prior to the 1970s, government guidelines for acceptable degrees of anthropogenic lead exposure were based on thresholds indicated by overt toxicity and in 1960 the acceptable BLL in children was 60μ g/dl (Needleman 2004). Removal of exposure pathways in the U.S. resulted in dramatic declines in lead exposure as lead use was phased out from a number of products. Most notably, removing lead from gasoline showed parallel decreases in anthropogenic BLLs, as the average childhood BLL in the U.S. dropped from approximately 16 μg/dL in 1976 to 3.2 μg/dL in 1994 (Gilbert and Weiss 2006). Currently, BLLs in children of 5 μg/dl indicate a high level of exposure (CDC 2017) and presently the consensus is that no level of lead exposure in young children and adults is deemed safe (Abadin et al. 2007, CDC 2017, WHO 2018).

Even though lead as a substance is universally recognized as detrimental to human health with steps taken to eliminate exposure pathways, it is still the main component used to manufacture ammunition intended for hunting applications. In the U.S., common projectiles used for hunting include shotgun slugs, rifle bullets, and clusters of shot (Thomas and Guitart 2013). The physical properties of lead make it ideal for manufacturing ammunition. That is, lead is malleable in nature, has a high density, a low potential for corrosion, a low melting point (Haig 2014), and it is generally cheaper than other available alternatives (Thomas 2013).
Bullets for hunting are designed to expand in diameter upon impact to quickly transfer energy between the projectile and target (Golden et al. 2016) creating a destructive wound channel in order to achieve the purpose of a fast-humane kill (Hemje et al. 2014). The physical properties of lead make it ideal for this application. However, associated with the expansion and transfer of energy comes the potential for fragmentation. Lead can be highly frangible when it is exposed to force; that is, it is easily broken or fragmented (Hemje et al. 2014). Fragmentation occurs significantly more in lead ammunition than in non-lead alternatives with the extent varying between ammunition types (Grund et al. 2010, Cruz-Martinez et al. 2015, Sanchez et al. 2016, Stokke et al. 2017). Rapid expansion bullets and controlled-expansion bullets fired from centerfire rifles both fragment to a greater extent than shotgun slugs and muzzleloader bullets (Grund et al. 2010, Cruz-Martinez et al. 2015), while traditional style round ball and black powder cartridge bullets fragment less than modern lead core muzzleloader hunting bullets (Sanchez et al. 2016).

Where lead ammunition is used, the potential for fragmentation is ever-present, with deposition of lead fragments often occurring far beyond the initial point of impact and wound channel (Grund et al. 2010). This is particularly true where tissue such as bone provides more resistance causing more extensive fragmentation (Stroud and Hunt 2009). Consequently, when lead ammunition is used for hunting applications, lead fragments can be present in the tissues of animals intended for human consumption (Johansen et al. 2001, Cornatzer et al. 2009, Hunt et al. 2009). As a result, through consuming wild game harvested with
lead shot or bullets, humans may inadvertently ingest lead, facilitating pathways to lead exposure (Tsuji et al. 1999, Johansen et al. 2001, Johansen et al. 2006, Hunt et al. 2009, Iqbal et al. 2009). Due to this mechanism of human lead exposure being maintained through lead ammunition use, elevated BLLs have been reported in subsistence hunters who regularly consume game meat harvested with lead ammunition (Bjerregaard et al. 2004, Johansen et al. 2006). Furthermore, lead ingested through the consumption of wild game can often exceed recommended limits (Johansen et al. 2001, Mateo et al. 2007, Abadin et al. 2007, Bjermo et al. 2013).

The use of lead in ammunition can also facilitate pathways to lead exposure for wildlife species. The impacts of lead exposure to wildlife have been recognized in the U.S. since the late 1800s (Friend et al. 2009) and in recent decades there has been a substantial increase in research related to a variety of human and wildlife impacts as a result of lead ammunition use (Arnemo et al. 2016). Where wildlife lead exposure occurs, it predominantly originates from hunting practices that involve lead ammunition use (Fisher et al. 2006, Rattner 2008, Hunt et al. 2009, Tranel and Kimmel 2009). Globally the impact of lead ammunition use on wildlife species is well documented. Upward of 500 peer-reviewed studies exist illustrating the negative effect of lead on 130 species including mammals, reptiles, and birds, killed or exposed by directly ingesting lead ammunition or through prey species contaminated by lead (Trannel and Kimmel 2009). Direct mortality resulting from lead shot and bullet fragment ingestion has been described for upwards of 50 avian non-waterfowl species (Fisher et al. 2006) and reports have shown increased lead
concentrations in both vertebrates and invertebrates in close proximity to shooting ranges, and in areas that are heavily hunted (Rattner et al. 2008).

Initially, lead exposure pathways for wildlife in the U.S. were primarily focused on waterfowl and upland game species (Kendall et al. 1996). Prior to the federal ban on lead shot, lead poisoning in bald eagles (*Haliaeetus leucocephalus*) was originally thought to be associated with the use of lead shot for waterfowl hunting (Pattee and Hennes 1983). However, following the 1991 phase out of lead shot, the lack of reduction in lead poisoning incidents in bald and golden eagles (*Aquila chrysaetos*) pointed to other pathways to lead exposure. The findings of a 16-year retrospective study by Kramer and Redig (1997) suggested that food sources in addition to waterfowl carcasses may provide pathways to lead exposure, including spent ammunition from big game hunting. Subsequent research has confirmed existence of such exposure pathways for non-target species, primarily through the consumption of gut-piles of harvested animals (Church et al. 2006, Hunt et al. 2006, Kelly et al. 2011, Finkelstein et al. 2012, Warner et al. 2014, Stokke et al. 2017) and non-recovered carcasses of animals laden with spent lead ammunition (Knopper et al. 2006, Pauli and Buskirk 2007, Stokke et al. 2017). In addition, temporal correlation of non-target species exposure and hunting seasons has further solidified lead ammunition use for big game hunting as an underlying mechanism of exposure (Craighead and Bedrosian 2008, Stauber et al. 2010, Kelly and Johnson 2011, Bedrosian et al. 2012, Leganeaux et al. 2014, Ecke et al. 2017).

In the U.S. lead exposure in non-target species as a result of scavenging has been shown to have direct mortality impacts on bald eagles (Cruz-Martinez et al.
\((\text{Gymnogyps californianus})\) (Meretsky et al. 2000, Stauber et al. 2010), with lead
poisoning documented as a leading cause of poisoning mortality in both eagle
species and spent lead ammunition as a primary cause of mortality for the California
Condor (Meretsky et al. 2000, Russell and Franson 2014). While other prominent
causes of non-target species mortality exist (Russell & Franson 2014), lead
poisoning has been documented as a leading cause of poisoning mortality in both
bald and golden eagles. A recent assessment of the cause of mortality of 2,980 bald
eagles and 1,427 golden eagles recovered between 1982-2013 indicated 63.5% of
bald and golden eagle poisoning mortalities were attributed to lead poisoning
(Russell & Franson 2014).

Lead exposure in wildlife does not necessarily result in direct mortality and
sublethal lead exposure can result in a wide range of physiological and behavioral
impacts for a multitude of wildlife species (Rattner et al. 2008, Tranel and Kimmel
physiological and behavioral effects due to sublethal lead exposure may increase
susceptibility to predation, starvation, or infection by disease, thereby increasing
the probability of death (see Scheuhammer and Norris 1995 for review, see Fisher
et al. 2006 for review). Sublethal lead exposure in a number of avian species has
been associated with decreases in reproductive success and survival (Hoffman et al.
2015) and increased mortality risk due impaired flight performance and physical
impacts due to sublethal lead exposure in mute swans (Cynus olor) has been associated with increased collisions with power lines (Kelly and Kelly 2005) and, for avian scavengers in particular, sublethal lead exposure can impact bone density (Gongoso et al. 2009) and impair flight performance (Ecke et al. 2017), both of which have been suggested to increase the risk of mortality through collision events. In Europe where raptor populations are in fact increasing, sublethal lead exposure has raised concerns about the overall health of wildlife communities due to ingestion of lead from spent ammunition (Madry et al. 2014, Jenni et al. 2015, Ganz 2018).

Unquestionably, the amount of lead introduced into the environment by an individual hunter harvesting a deer is lower in comparison to other hunting practices, primarily because the number of shots taken to harvest a deer in a given season is much less in comparison to other types of upland game hunting. However, the lead that is made available through fragmentation and deposition is connected to a potential food source and can increase bioavailability of lead and potential exposure for non-target species, as outlined in chapter one.

In cases where the use of lead ammunition has been reduced, subsequent declines in lead exposure in wildlife species have been observed (Anderson et al. 2000, Samuel and Bowers 2000, Kelly et al. 2011, Bedrosian et al. 2012). Following the five-year phase out due to the federal regulation of lead shot for hunting waterfowl in the U.S, significant decreases in exposure levels in black ducks (Anas rubripes) were observed (Samuel and Bowers. 2000), with an estimated 1.4 million ducks avoiding lead poisoning over two hunting seasons (Anderson et al. 2000).
Additionally, following the initial phase out of lead ammunition use within the California condor range, decreases in lead exposure in scavenging species within the same geographical range was shown (Kelly et al. 2011), with resident golden eagles showing a 100% decrease in lead exposure and the prevalence of lead exposure in turkey vultures (*Cathartes aura*) decreasing by 85%.

Despite the wealth of knowledge on the detrimental effect of lethal and sublethal lead exposure on human and wildlife health, exposure pathways for humans and wildlife are maintained as lead remains a primary component in hunting ammunition in the United States. Since 1991 additional regulatory and voluntary measures to reduce lead ammunition use have been introduced in a number of states (Avery 2009, Bedrosian et al. 2012, see Ross-Winslow 2013 for review, Chase and Rabe 2015, see Henry 2016 for review). Most notably, the recognized impact of lead ammunition use on California condor mortality has led to the complete mandatory statewide use of non-lead alternatives by July 2019 (CDFW 2019). However, for the most part lead ammunition use in U.S. remains typically unregulated (Bellinger et al. 2013). In 2015 over 79,000 metric tons of lead was used to create lead shot and bullets (Guberman 2015) with an estimated 6,000-10,000 tons released annually into the environment through sporting activities (Ross-Winslow and Teel 2011).

In scenarios where regulatory approaches to lead ammunition use have been implemented there have been mixed results. For example, Denmark’s regulatory approach to lead shot use has been shown to be effective without adverse effects on hunter interests or resulting in reduced hunter participation (Kanstrup 2015).
Conversely, in the U.K., regulations aimed to restrict lead shot use for hunting have resulted in relatively poor compliance rates (Cromie et al. 2015). As noted by Epps (2014), hunting can often occur in areas that are not readily accessible or on privately owned land, making enforcement of regulatory approaches problematic, particularly if lead ammunition is readily available for purchase for other activities outside of hunting and where hunters possess a stockpile of ammunition. This combined with the fact that there currently is no way to field test ammunition for containing lead (Chase and Rabe 2015) suggests that compliance through mandatory approaches in the U.S has the potential to be low, with limited scope for enforcement.

Recent state level regulatory approaches in California have been met with opposition from both hunting and firearms groups (NRA-ILA 2013, NSSF 2013). In addition, attempts to regulate the use of lead ammunition on federal lands in 2017 by the exiting Director of the USFWS (Directors Order No. 219, 2017) was promptly overturned by the newly appointed Secretary of the Interior (Order No. 3346, 2017). Similar opposition to increased regulation was evidenced in Norway in 2015, when contrary to the available scientific evidence, a 2005 ban on lead shot for upland game hunting was overturned (Knutsen et al. 2015). This ruling was seen as a success not only by Norway's largest hunting and sport fishing organization but also by the Association of European Manufacturers of Sporting Ammunition (Arnemo 2016), illustrating the potentially transitory and polarizing nature of this approach to the reduction of lead ammunition use.
2.2 Barriers to Non-lead Use

In the U.S., ardent opposition to further restrictions on lead ammunition use is not limited to vocal groups and may be reflective of the views of a large proportion of hunters. For example, the majority of hunters surveyed by Oregon Department of Fish and Wildlife in 2014 were in opposition to introducing statewide regulations on lead ammunition use (ODFW 2014). Furthermore, opposition to further regulations was also identified through a national scale study of 12,000 mourning dove hunters where two thirds of surveyed hunters opposed further restrictions on lead ammunition use (Case and Associates 2014).

As Cromie et al. (2015) suggests, barriers to the adoption of nonlead ammunition are often set within the broader context of hunting being “under threat” and that barriers to change are subsequently reinforced by misconceptions of the problem of exposure for humans and wildlife and inaccurate information on performance and cost of non-lead alternatives. The view of increased regulations as posing a threat to hunting is not unique to the U.K. In the U.S., the majority of mourning dove hunters viewed increased restrictions on lead ammunition use as being inherently anti-hunting and approximately half of surveyed hunters viewed restrictions as a tactic by animal rights groups and gun control advocates to eliminate hunting (Case and Associates 2014). In addition, through a qualitative study of comments to online blogs that addressed the use of lead ammunition and fishing tackle, Ross-Winslow (2013) found that individuals that identified as pro-lead perceived out-groups attempts to regulate lead as being motivated by the desire to eliminate consumptive wildlife activities such as hunting or fishing.
Specifically, in the U.S., where lead ammunition is concerned, prominent firearm and hunting groups view increased regulations as anti-hunting and frame lead ammunition as “traditional ammunition” and an irreplaceable component of hunting (NSSF 2011, RMEF 2014, NRA-ILA 2018).

The use of regulatory approaches to reduce or restrict lead ammunition use that do not incorporate stakeholder input have been noted as potential sources of conflict (Pokras and Kneeland 2008). The enactment of the 1991 lead shot ban for hunting waterfowl in the United States and associated lack of collaboration and communication with hunters has been tied to the controversy surrounding the bans implementation (Pokras and Kneeland 2008). Following the ban, resistance manifested itself in non-compliance and lawsuits filed against state and wildlife agencies (Ross-Winslow and Teel 2013). As Ross-Winslow (2013) describes, while regulatory approaches that result in controversy and low compliance such as the 1991 ban can ultimately be successful, strategies that incorporate stakeholder interests can be preferred as they have a higher potential to reduce initial conflict.

The advocation of non-regulatory approaches has been adopted by the wildlife conservation and management community. The Association of Fish and Wildlife Agencies recommends that public education and voluntary programs can be used in place of regulatory measures, to help reduce lead-based ammunition use (AFWA 2010). In addition, The Wildlife Society (2015) supports education as a means to promote understanding of the negative effects of lead ammunition use and the environmental benefits of switching to non-lead alternatives.
Voluntary approaches that have relied on hunter engagement to achieve behavioral change in regard to ammunition choice have gained positive results in sustained use of non-lead alternatives, particularly for the purpose of harvesting large game. In response to lead exposure in reintroduced California condors in Arizona and Utah in 2003, the Arizona Game and Fish Department initiated a program to mitigate the amount of lead introduced into the environment through hunting activities. Through a combination of outreach, education, and incentive strategies, participation in the voluntary lead-free program rose from 5% to 90% in a four-year period from 2004 to 2008 (Ross-Winslow and Teel 2011). Furthermore, the proportion of hunters using non-lead ammunition or taking some lead reduction action has remained relatively constant in subsequent years (AZGFD 2018).

In Wyoming, the potential for lead exposure for scavenging avian species (Craighead and Bedrosian 2008) resulted in efforts to encourage hunters to use non-lead ammunition voluntarily in designated areas during the 2009 elk-hunting season (Skaggs and Iverson 2009). This voluntary approach has since led to an increase from 24% of successful hunters using non-lead (Bedrosian et al. 2012) to approximately 70% over a 6-year period (CBS, 2018) with initial reports indicating significant reductions in lead exposure for bald eagles when non-lead alternatives are used by hunters (Bedrosian et al. 2012). Both projects in Arizona and Wyoming demonstrated that voluntary approaches can achieve sustained behavioral change in regard to ammunition choice. More importantly, these programs revealed the positive response of hunters to the issue of wildlife lead exposure when they are approached and engaged voluntarily at a local level.
Opposition to increased regulation undoubtedly exists; however, the belief that lead ammunition is an irreplaceable component of hunting is one not universally held by all hunters. Some hunters have made the switch to non-lead ammunition for a number of hunting activities either through their own initiative or in conjunction with voluntary lead reduction efforts (Sieg et al. 2009, ODFW 2014, Chase and Rabe 2015, CBS 2018). However, where voluntary approaches to non-lead use are implemented, practical barriers to its use may manifest in a number of ways. Previous research has identified barriers to the adoption of non-lead ammunition as centering around increased cost, reduced availability, and perceptions of diminished performance (Friend, et al. 2009, Knott et al. 2010, Caudell et al. 2009, Chase and Rabe 2015).

Undoubtedly, non-lead ammunition behaves differently than lead ammunition in terms of terminal ballistic behavior, in that it deforms differently upon impact and fragments significantly less (Grund et al. 2010, Cruz-Martinez et al. 2012, Stokke et al. 2017). Despite this difference Gremse et al. (2014) illustrated that a deforming lead-free bullet can perform comparably to a lead bullet. Using ballistic soap to simulate animal tissue, Gremse et al. (2014) showed that a non-lead deforming bullet was similar in terms of energy conversion, cavity shape produced, and deflection angle. Additionally, Trinogga et al. (2013) used the structural analysis of wound channels to compare the ballistic performance of lead free and lead-core bullets used on 34 wild ungulates under typical hunting conditions. Trinogga et al. (2013) also found no significant difference in wound dimensions between lead and
non-lead ammunition, a property regarded as a good indicator of a projectile’s killing potential.

Under field conditions, flight distance is often used to as an indicator of a projectile’s performance. Flight distance being the distance an animal has to be tracked in order to be retrieved once shot. The shorter the flight distance of an animal the more effective a round is viewed. Using flight distance as a response parameter, a large-scale study by Kanstrup et al. (2016) tested the efficacy of non-lead ammunition to humanely harvest game animals under field conditions. Kanstrup et al. (2016) illustrated the ability of non-lead ammunition to produce rapid incapacitation across a range of scenarios using different calibers, brands, and bullet types. From 2012 to 2014, 15 experienced hunters harvested 357 ungulates consisting of red deer (Cervus elaphus) and roe deer (Capreolus capreolus). Taking the shooting distance and terminal strike energy into account, flight distances of animals shot with lead and copper bullets were shown to be comparable (Kanstrup 2016). In the U.S., over a three-year period at Theodore Roosevelt National Park in North Dakota, 983 elk (Cervus elaphus) were harvested with non-lead rifle ammunition as part of the National Park’s herd management operation. Results from this study illustrated both the ability of non-lead ammunition to achieve the necessary accuracy and incapacitation for effective harvesting of elk (McCann et al. 2016). Furthermore, a study using flight distance of roe deer and wild boar as a primary response parameter concluded that bullet composition is not a decisive factor when effectively harvesting an animal. Other factors such as shot placement,
type of hunting, and age of the animal may play a more significant role in killing efficiency over bullet composition (Martin et al. 2017).

In addition to concerns about diminished performance, increased cost is an ever-present issue where transitioning to non-lead alternatives has been considered (Seng 2006, Friend et al. 2009, Miller et al. 2013, Case and Associates 2013, ODFW 2014, Southwick Associates Inc. 2014, Chase and Rabe 2015). The cost difference between premium lead ammunition and non-lead alternatives can be comparable (Thomas 2013, Henry 2016), however, such comparisons may not be representative of actual hunter economic impacts. As Epps (2014) noted, hunters using premium quality rounds may see no significant increase in cost other than the initial testing cost. However, ammunition that is sold in retail outlets and actually used in the field is often of the non-premium variety and can cost significantly less (Epps 2014). For hunters in the Northeast U.S. common firearms used to harvest big game such as white-tail deer include shotgun (smooth and rifled bore) and muzzleloader. A preliminary comparison indicates that non-lead alternatives for the common 12-gauge shotgun and 0.50 caliber muzzleloader can cost considerably more per round as outlined below.

- **12-gauge smooth bore shotgun: Buckshot**

  In May 2019, 2 ¾ inch cartridge length non-lead 00-buckshot showed a marked increase in price in comparison to lead alternatives. Lead 00-buckshot such as Federal® Power Shock® and Federal Premium® Vital Shock® were priced at $1.16 and $1.70 a round respectively (Bass Pro LLC 2019, Cabela’s Inc. 2019a). In comparison, a non-lead alternative such as Federal Premium® Vital Shock® lead-
free-high-density shot in the same cartridge designation was priced at $2.80 a round (Midway USA 2019a). Furthermore, per round price increased significantly for Dead Cayote® Hevi-shot, made of a tungsten alloy, which cost $7.00 a round for 3-inch cartridge length 00-buckshot (Midway USA 2019b).

- 12-gauge smooth bore shotgun: Single projectile rifled slug

  Single projectile rifled slugs showed similar increases in cost per round. Rounds such as Federal Premium® Vital Shock® 2 ¾” TruBall and Winchester® Super X® could both be sourced at $1.00 a round (Midway USA 2018c, Midway USA 2018d). In comparison, non-lead alternatives such as the Brenneke® TKO® Tin Sabot cost $2.64 a round (Target Sports USA 2019) and Dupleks® expanding steel slugs were priced at $2.00 a round (Midway Arms USA 2019e).

- 12-gauge rifled bore shotgun: Single projectile slugs

  Single projectile slugs for rifled-barrels shotguns also showed similar cost increases per round. For example, a lead based round such as Federal® Power Shock® Sabot slug 2 ¾ inch cartridge was priced at $1.58 a round (Midway Arms USA 2019f). In comparison a lead-free alternative such as the Remington Premier Expander Slug® in the same cartridge size cost $3.48 a round (Cheaper Than Dirt 2019a).

- Muzzleloader: 0.50 Caliber

  Barnes® fully copper rounds for modern inline muzzleloader ranged between $1.20 and $1.33 a round depending on bullet design (Cabela's Inc. 2019b). In comparison, Thompson Center® Maxi-Hunter® 350 grain 0.50 caliber lead rounds were similar in price at $1.34 a round (Cabela's Inc 2019c). However, round balls for
traditional muzzleloaders showed considerable price differences. For example, the ITX® Nontoxic Roundball was $11.99 for 12 rounds (Ballistic Products Inc. 2019) while a lead option by Hornaday® was $11.57 for 100 (Cheaper Than Dirt 2019b).

As outlined above, the potential cost difference per round for switching to non-lead can increase significantly when common firearms outside of center fire and rim fire rifles are considered. As illustrated, for the 12-gauge shotgun and 0.50 caliber muzzleloader, the per-round retail cost of ammunition has the potential to increase considerably when comparing non-premium lead ammunition and non-lead alternatives.

A recent estimate put the average amount spent on ammunition for big game hunting in the U.S. at $62 annually per hunter (USFWS 2016). Typically, 1-5 rounds per year is needed to sight in a firearm and harvest a deer. Therefore, the per round increase has the potential to be relatively insignificant in relation to the average annual expenditure on big game hunting (e.g., $1,616, in table 18 of USFWS 2016). However, per round increases in ammunition cost in the context of average annual hunter expenditure does not fully capture the economic impact to individual hunters associated with transitioning to non-lead. As Epps (2014) noted, how the per round increase will impact individual hunters will vary depending on whether a hunter uses non-lead for applications outside of hunting and whether a hunter uses off the shelf ammunition or reloads their own.

The recalibration process for individual hunters, that is finding a non-lead round that functions comparably to their existing ammunition, can present increased economic impacts, primarily because the accuracy of a round can be
dependent on factors idiosyncratic to a particular firearm and bullet combination (Epps 2014). That is, a round that shoots well with one brand of firearm may not perform the same with another of the same caliber or gauge. Therefore, finding a non-lead round and learning to shoot with it will require some hunters to find a round that works well with their specific firearm. While some hunters may find an acceptable round easily, for others this may require purchasing multiple boxes of different brands to test for accuracy. Furthermore, testing a round at a range for accuracy does not necessarily translate to acceptable ballistic behavior in a field setting and may require additional rounds of testing. Therefore, while the process involved for some hunters to recalibrate to non-lead may be straightforward for others there is potential to incur significant time and monetary costs.

The idiosyncratic relationship between individual firearms and ammunition brands may compound the economic barrier for some hunters even further. For example, hunters that have gone through the process of testing a round and finding one that has worked in terms of accuracy and effectiveness in the field may possess enough of their favored type of ammunition or reloading components to last a number of hunting seasons or beyond. As Chase and Rabe (2015) identified, in these instances hunters with stockpiles of ammunition may not want to waste the ammunition they have already purchased. For other hunters switching to nonlead may not be an option with their existing firearm. Public outreach in relation to the lead ammunition phase out in California identified firearm incompatibility as a practical concern for hunters associated with transitioning to nonlead (Duncan 2014). Namely, the inability of vintage or antique firearms to cope with the
increased pressure associated with non-lead rounds. Hunters using antique or vintage firearms incompatible with non-lead rounds will have to purchase new firearms if they do not have them already. Duncan’s (2014) analysis of the average financial impact associated with switching to non-lead in California suggests that the cost ($1,300) of purchasing a new firearm can be amortized over the life of the firearm (20 years). This of course assumes that a hunter in such a position has the funds to purchase a new firearm if a suitable one is not available and that they fall into an age demographic that will see a return on that investment. Chase’s (2017) analysis focusing on the decline in hunting numbers and the potential knock on effect to conservation funding suggest this may not be the case, identifying a large 20-year cohort of hunters and anglers poised to age out as soon as 2024. Therefore, economic impacts that amortize the cost of purchasing a new firearm may not fully capture the realized economic impact to hunters within age demographics close to retirement from hunting.

For hunters currently using premium ammunition, switching to non-lead alternatives may incur limited if any additional cost and the economic burden may be insignificant in the broader context of annual hunting expenditure. However, the economic burden associated with transitioning will likely be context dependent. For example, hunters using smooth bore shotguns may use a single rifled slug or 00-buckshot depending on the terrain they are hunting in. To retain this ability, these hunters will no doubt face additional economic impacts associated with recalibration, as will low income hunters and households with multiple hunters.
Consequently, where multiple cost associated barriers converge there is potential for significant economic impacts for individual hunters to recalibrate.

In addition to economic impacts, availability of non-lead alternatives can present a fundamental practical barrier to its use. When considering availability, it is worth differentiating between product and retail availability. Product availability refers to the production and distribution of a product while retail availability denotes the ability to purchase a product (Thomas 2016). California’s regulatory approach to lead ammunition use has raised concerns about the ability of ammunition manufacturers to increase retail availability. As of 2014, an estimated 10% of ammunition produced for the California market was non-lead (Southwick and Associates Inc 2014) with demand for certain calibers of alternative ammunition predicted to exceed the then current national production levels (Southwick and Associates Inc 2014). Thomas’s (2013) review of online product availability for 37 corporations that produce non-lead ammunition, identified that non-lead alternatives were made in 35 rifle calibers and 51 rifle-cartridge designations for centerfire rifles. In addition, non-lead alternatives were produced for common muzzleloader calibers and 12-gauge shotgun cartridges. Online product availability has been cited as a positive factor that can facilitate the process of transitioning to non-lead (Bellinger 2013, Kanstrup 2018). For hunters that purchase ammunition online this may hold true, however, product availability does not automatically translate to retail availability. When Haig et al. (2014) assessed the retail availability of Thomas’ identified non-lead centerfire bullets and shotgun slugs at Bass Pro Shops, Cabela’s, and Cheaper Than Dirt, only 10%, 18%, and 27%
of non-lead options were available for purchase from each source respectively. For shotgun and muzzleloader rounds outlined previously, only one type, Federal Premium® Vital Shock® lead-free-high-density shot, was unavailable for purchase. While online retail availability of common rounds potentially used by refuge hunters exists, a snapshot of availability is not a sufficient indicator of mass availability nor is it necessarily reflective of how hunters purchase ammunition. Therefore, while all of the major U.S. ammunition manufacturers produce non-lead alternatives for a variety of firearms (Thomas 2013), online product availability does not always reflect online retail availability (Haig 2014). In addition, where hunters have traditionally purchased ammunition from local vendors, reliance on online purchasing methods as a mechanism to facilitate voluntary non-lead use may overestimate the ability and willingness of hunters to navigate this process and may in fact present an additional barrier to voluntary use.

2.3 Purpose Statement

There are a number of identified practical and perceived barriers to the adoption of non-lead ammunition. However, as Ross-Winslow and Teel (2011) noted, the solution to reducing lead deposition in the environment is social in nature with human behavior being the root cause for such deposition. Voluntary approaches using outreach and education have been successful in influencing hunter ammunition choice and maintaining sustained non-lead use. For voluntary non-lead use in the context of harvesting white-tailed deer on NWRs to be successful, it is necessary to understand how hunters view the practical and perceived economic
and technical dimensions associated with transitioning to non-lead ammunition. Understanding these barriers in the context of harvesting white-tailed deer is imperative in order to direct effective outreach and education to achieve behavioral change in ammunition choice and mitigate the recalibration process.

The purpose this study was to identify how NWR hunters that are currently using lead ammunition to harvest white-tailed deer view previously identified practical barriers in comparison to hunters using non-lead alternatives. In addition, motivations behind current non-lead ammunition use, and factors that would influence hunters to switch to non-lead were assessed through mail back-surveys. Current firearm and ammunition use were also assessed in addition to sources lead users view as credible when seeking information on ammunition. This will provide the National Wildlife Refuge System with data that can inform strategies to mitigate the initial barriers to non-lead use and guide more targeted outreach and education in regard to potential recalibration barriers that hunters may encounter.

To what extent hunters on NWRs in the Northeast Region understand the underlying mechanism of lead exposure for non-target species through lead ammunition use is currently unknown, as is how refuge hunters view the consequences of their individual use of lead ammunition in the broader context of non-target species exposure. To explore these topics a qualitative approach in the form of focus group discussions with hunters from each NWR was conducted.
2.4 Methods

2.4.1 Mail-back Survey Instrument Design

The mail-back survey instrument used modified elements of the Oregon Department of Fish and Wildlife Lead Ammunition Survey conducted in 2014 (ODFW 2014). Questions related to hunting practices (Q 1-9), purchasing methods (Q 10), current ammunition use (Q 11), influences to switch to non-lead (Q 12), sources of information on ammunition (Q 19), reliability of sources (Q 20), and statements concerning lead ammunition usage impact on human and wildlife health as they related to big game hunters (Q 23-25) were used. Questions were modified to fit the context of white-tailed deer hunters on NWRs in Region 5 in order to identify barriers to a voluntary transition to non-lead ammunition use. The survey instrument consisted of a booklet 8 ½ x 11 inches folded in the middle. Survey questions consisted of single response, check all that apply, and Likert rating scale of agreement. The 5-point Likert scale ranged from Strongly Agree to Strongly Disagree with the option of Don’t Know. The survey instrument was designed to assess hunters’ 1) refuge hunting frequency, 2) firearm and ammunition use, 3) barriers to non-lead ammunition use for current lead users, 4) motivations behind current non-lead use for Non-lead Users, and 5) factors that would influence Lead Users to switch to non-lead. Factors that would influence hunters to switch to non-lead use were collected using Yes, No, and Don’t Know responses. An open-ended question was used to identify the primary reason that Lead Users would not be willing to voluntarily switch to non-lead ammunition. Mail-back survey instruments
were catered for each of the three refuges. An example of the survey instrument for Edwin B. Forsythe NWR is contained in Appendix A.

Prior to mail-back survey implementation, a pilot study was conducted at Great Swamp NWR in New Jersey following the 2016 deer hunting season. Great Swamp NWR was chosen based on white-tailed deer management practices in the form of an annual permitted deer hunt using firearms. In addition, absence of any outreach or education program related to lead or non-lead ammunition use was a requisite. Survey responses were reviewed by the primary investigator to improve instrument layout, skip patterns, and overall instrument design. The survey instrument was further refined through consultation with the Institute for Social Science Research and through an independent study on survey design, implementation, and analysis at the University of Massachusetts Amherst. Additional input was provided by the primary researcher's advisors and committee members, a number of non-hunters, and from points of contacts identified at each refuge for constructive feedback. Cognitive interviews with two hunters in Massachusetts were also conducted to improve survey question comprehension. The survey instrument was adjusted accordingly at each stage of input, to improve clarity of questions, question ordering, skip patterns, and to reduce question bias.

2.4.2 Population of Interest and Refuge Selection

The population of interest for this study was white-tailed deer hunters on NWRs in USFWS Region 5. Through consultation with the USFWS in Hadley, Massachusetts, three NWRs were identified to partake in the study: Rachel Carson NWR in Maine,
Edwin B. Forsythe NWR in New Jersey, and Rappahannock River Valley NWR in Virginia. Refuges were identified for the 2017/2018 hunting season based on the same criteria used for the pilot study, in that each refuge actively manages its white-tailed deer population through an annual hunt using firearms and did not have an outreach or education program related to lead or non-lead ammunition use in place.

2.4.3 Mail-back Survey Implementation

Each refuge supplied the names, mailing addresses, and phone numbers for potential respondents. Mailing addresses of respondents were provided by hunters to the refuge through the application process for a firearm hunting permit. The mail-back survey implementation followed Dilman’s five contact approach (Dilman et al. 2014). This consisted of an advance notice letter mailed to all adult hunters that applied for a permit to hunt white-tailed deer using muzzleloader and/or shotgun at each refuge. The advance notice letter was provided to hunters by each respective refuge. This letter informed applicants of the purpose of the study and encouraged voluntary participation. Implementation of the mail-back survey procedure began in January 2018. Each hunter was sent a survey package consisting of a personalized introductory letter (Appendix B), a survey instrument catered for their specific refuge and a business reply envelope. One week following this, hunters were sent a non-personalized reminder letter (Appendix C). A second non-personalized reminder letter was sent one week later (Appendix C). Mailings that were unable to reach hunters and were returned were checked for correct addressing. Where possible hunters were contacted via phone or email to verify the correct address
and the survey package was resent. Business reply envelopes provided as part of the survey package were coded alphanumerically to identify respondents and avoid sending early respondents further mailings. This also provided a means to identify non-respondents. The final mail-out consisting of a refuge specific personalized cover letter (Appendix D), refuge specific hunter survey, and business reply envelope was sent to all identified non-respondents six weeks from when the first survey package was sent.

2.4.4 Non-response Bias Assessment

A non-response bias assessment was conducted in May of 2018. A random sample of 20% of identified non-respondents at each refuge were contacted via telephone and administered a non-response survey consisting of three questions and demographic information consisting of age and level of education (Appendix E). Non-respondents were chosen randomly using their assigned mail-back alphanumeric identifier and the statistical program R-Studio 3.2.0. Non-respondents that completed a non-response bias survey and respondents that were called three times were removed from subsequent rounds of calling. Fisher Exact Tests were used to test for significant differences between question responses and demographics between mail-back survey responses and non-response telephone surveys.

2.4.5 Focus Group Discussion - Participant Recruitment

Permitted hunters at each refuge were informed of and invited to the focus group discussions and given equal opportunity to participate. Hunters were initially
informed about the focus group discussions by the refuge where they held a firearm hunting permit for that season through the advance notice letter. Participants for focus group discussions were recruited via telephone from the permitted deer hunter list provided by each refuge point of contact two weeks before the scheduled end date for their refuge hunting season. The first round of calls resulted in either direct contact with a participant or non-contact. Willingness to participate was elicited from hunters that answered the initial call. If a hunter was available and willing to talk, they were informed of the time and location of the focus group discussion. If a hunter did not answer, a voicemail was left where possible informing the hunter about the group discussion using a scripted message (Appendix F). The voicemail explained the reason for the call and supplied contact information for the primary researcher, giving hunters the opportunity to call back if they were interested in attending. Hunters that were not spoken to directly or were left an initial voicemail were contacted two more times. No voicemails were left on the following calls. Hunters that returned calls following the voicemail or answered subsequent follow up calls were spoken to and were recruited if interested in participating. Hunters that expressed interest in attending were placed on a “potentially attending” list and were contacted via telephone four days prior to the group interview date to verify attendance.

2.4.6 Timing and Location

Focus group discussions were conducted at each refuge where the mail-back survey instrument was implemented. Focus group discussions were arranged on the
weekend following the end of the refuge hunting season in order to not interfere with participants’ hunting opportunities on the refuge. Due to logistic reasons, the focus group discussion at Edwin B. Forsythe was conducted two weeks before the end of the refuge hunting season. Focus group discussions were scheduled for Saturday mornings at 10am. Focus group discussions were conducted on site in a private room at each of the NWRs and consisted of only the permitted hunters and the primary researcher acting as moderator. No incentives were offered for participation.

2.4.7 Data Collection

A semi-structured interview guide was developed based on research questions within the mail-back survey (see Appendix G). Questions were designed to 1) initiate discussion about hunter understanding of lead as a substance and its biological effect on humans and wildlife, 2) identify primary barriers to a voluntary transition to non-lead use, and 3) assess hunter understanding of lead ammunition use in the context of creating potential exposure pathways for non-target species. Additional probing questions were used during the group interviews as needed. Focus group interviews were recorded using two Tascam DR-05 Stereo Portable Digital Audio Recorders. Digital recordings were then manually transcribed verbatim by the primary researcher. Review of the transcripts was then conducted by the primary researcher while listening to the digital recordings to check transcription accuracy.
2.5 Data Analysis

To assess barriers to non-lead use from survey data, respondents were categorized as “Lead Users” or “Non-lead Users” based on information provided on current ammunition use. Responses to Likert scale statements were grouped into three categories: Practical Barriers, Lead Ammunition Use and Wildlife, and Lead Ammunition Use and Humans. A Wilcoxon rank-sum test was used to assess differences between Lead Users and Non-lead User responses between statements in each category. Lead Users were then grouped into individuals that indicated they were willing to voluntarily switch to non-lead “Volunteers” and those individuals that indicated they would be unwilling to voluntarily switch to non-lead “Opposers”. Differences in Yes/No responses to statements of what would influence Volunteers and Opposers to use non-lead alternatives were assessed using Chi Square tests. All Survey data were analyzed using R-Studio 3.2.0.

Focus group data were analyzed using an inductive approach. Participant’s statements were openly coded through a thematic step-by-step analyzing method using Braun & Clark’s (2006) six steps. Focus group transcripts were read and reread for topics that could be used to organize the data into broad themes. Through an iterative process, as new themes emerged existing themes were combined or modified. Broad themes were then subsumed into two major themes: “Individual Behavior” and “Mechanism of Exposure”. Patterns in the focus group data that related to practical barriers to the voluntary use of non-lead were also summarized. Findings from the focus group interviews are used to provide a more in-depth understanding of how hunters make sense of lead and non-lead ammunition use and
provide insight into the mail-back survey findings. Two focus groups conducted at Great Swamp NWR in 2016 were also included to provide a more comprehensive understanding of the issue.

As Neufeld (2006) noted, both study participants and readers can have a level of expectation for the flow of written words that can often differ from spoken words. When adapting spoken word transcripts to written text, editing words has the potential to unintentionally modify meaning. However, standardizing rules for editing spoken word text for readability is unlikely (Neufeld 2006). Therefore, where quotes and dialogue sections drawn from focus group transcripts have been edited to improve flow and readability, such edits were made using the primary researcher’s judgment and were only conducted if the focus group participant’s intent was preserved. Words that appear in square brackets are inputted by the primary researcher to place the quote in its original context. The presence of four periods within a quote indicates the continuation of a thought that was interrupted by the flow of conversation.

2.6 Ethical Statement

Participants were notified at all stages that their participation was voluntary and that they could withdraw from involvement at any time. This was explicitly stated, both verbally, during all stages of the recruitment process for focus group discussions, and in writing on all mailings and focus group consent forms. Consent for participation in the mail-back survey was assumed by a participant returning a completed survey. Consent for participation in focus group discussions was
obtained through a written consent form (APPENDIX H). The primary researcher was responsible for distributing and collecting consent forms to participants prior to focus group discussions. To maintain the anonymity of focus group discussion participants, personally identifying information of was not recorded and only digital audio recordings were used. Participants were assigned an alphanumeric indicator based on their seating position to aid in the transcription of the digital recordings. RC refers to Rachel Carson, EF to Edwin Forsythe, RK to Rappahannock River Valley, GS to Great Swamp (Saturday), and SG to Great Swamp (Sunday). For example, RCH2 refers to participant 2 at the Rachel Carson NWR focus group discussion. Digital recordings and focus group transcripts were stored in accordance with IRB requirements. Mail-back survey participants were assigned a similar alphanumeric value which was applied to the exterior of the business reply envelope. The purpose of the alphanumeric value was to remove participants from unnecessary mailings and facilitate in the identification of non-respondents. Participants were informed of this in the survey package introductory letter and alphanumeric values were removed before data analysis. Prior to the implementation of any research component, protocol approval was secured through the Institutional Review Board at the University of Massachusetts, Amherst, Protocol ID #: 2016-3357.

2.7 Study Limitations

Results from this study are not applicable to youth hunters as they were not included in this study. Due to the extremely low number of female respondents (n=4), female respondents were grouped with male respondents. Likewise, four
respondents in total indicated that they were under 25 years old. These respondents were combined with the 25-44 age group to create a single age group of under 45 years. While low female and under 25 response rates may be representative of actual demographics it may also indicate underrepresentation of these demographics. Additionally, due to the controversial nature surrounding issues pertaining to firearm and ammunition use, respondents in focus group interviews may have given socially desirable responses. Furthermore, the use of convenience sampling limits generalizations to deer hunters at all NWRs in Region 5.

2.8 Mail-back Survey Results

2.8.1 Non-response Bias Assessment

Hunters from Rachel Carson (n = 25), Edwin B. Forsythe (n = 9), and Rappahannock River Valley (n = 8) completed the non-response bias survey. Response rates for the non-response bias survey were 19%, 20%, and 32% for each refuge, respectively. No differences were detected between the mail-back survey and non-response bias survey responses at Rachel Carson or at Edwin B. Forsythe (Table 1). A difference between mail-back survey and non-response bias survey responses was detected for one response at Rappahannock River Valley NWR, “Willingness to voluntarily switch to non-lead use” \( (P < 0.05, \text{Fisher’s Exact Test}) \) (Table 1). Some demographic differences were detected between mail-back survey respondents and non-response bias survey respondents at the level of the individual refuges. For example, at Rachel Carson NWR, education level differed \( (P < 0.01, \text{Fisher’s Exact Test}) \) and at Edwin B. Forsythe NWR there was a difference between the age \( (P < 0.05, \text{Fisher’s Exact Test}) \)
of mail-back respondents and non-respondents. Mail-back survey responses from all three refuges were grouped and tested for differences based on age and education for the same three questions. No differences were found. Additionally, no difference was found between the same three mail-back survey responses based on refuge. Due to only one question response being different at the 0.05 level at Rappahannock River Valley NWR, no influence of demographics on mail-back survey responses, and no difference in responses based on refuge; mail-back survey response data from all three refuges was considered representative and combined. Descriptive statistics for demographics and some variables are provided at the refuge level.

Table 1: Results of Fisher's Exact Test analyses of refuge specific non-response bias assessments. Results significant at P < 0.05 are bolded.

<table>
<thead>
<tr>
<th>Refuge</th>
<th>Responses</th>
<th>Demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-lead use</td>
<td>Voluntary Switch</td>
</tr>
<tr>
<td>Rachel Carson</td>
<td>0.075</td>
<td>1</td>
</tr>
<tr>
<td>E. B. Forsythe</td>
<td>0.587</td>
<td>0.285</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>1</td>
<td><strong>0.046</strong></td>
</tr>
</tbody>
</table>

2.8.2 Survey Response Rate

We received 257 of our 468 mail-back surveys, yielding an overall response rate of 55%. Ten surveys were undeliverable despite attempts to find the correct mailing addresses. Of these, 228 of returned surveys were deemed usable. The highest response rate was observed at Rappahannock River Valley NWR (68%), followed by Edwin B. Forsythe NWR (63%) and Rachel Carson (51%).
2.8.3 Current Non-lead Use

Overall, 18% of surveyed hunters indicated that they currently use non-lead ammunition to harvest white-tailed deer. Current non-lead use was 21% at Rachel Carson NWR, 13% at Edwin B. Forsythe NWR, and 17% at Rappahannock River Valley NWR.

2.8.4 Demographics, Firearm, and Refuge Use

Education level of respondents varied across refuges with Rappahannock River Valley NWR having the highest proportion of respondents (42%) achieving a graduate degree. Hunters predominantly fell into the 45-64 age group with Edwin B. Forsythe having the highest proportion of hunters (31%) over 65 years of age (Table 2). At each refuge the majority of respondents hunt deer on an annual basis with Edwin B. Forsythe NWR having the highest annual use at 86%. Edwin B. Forsythe NWR had a higher percentage of hunters (60%) using shotgun only in comparison to Rappahannock River Valley NWR (Table 3).

Ninety five percent of muzzleloader hunters indicated using 0.50 caliber rifles with 0.58 making up the remaining. Muzzleloader ammunition used consisted of sabot slugs (75%) and conical bullets (22%). Three percent indicated that they used patched round balls. Where hunters pursue deer with shotguns, 78% use 12-gauge exclusively, while the majority of remaining hunters use 20-gauge (16%) or a combination of both (6%). Shotgun ammunition type used consisted of rifled slugs (38%), sabot slugs (34%), and buckshot (28%). Firearm use is currently restricted to shotgun only at Rachel Carson NWR.
2.8.5 Sources of Information for Ammunition

The majority of hunters use personal experience (84%) and other hunters (61%) as sources of information regarding the type of ammunition they use. Approximately a third of hunters have used either the state agency relative to their refuge or sporting/hunting magazines as a source for information on ammunition. Personal experience was chosen as the most reliable source when choosing ammunition to hunt (Table 4).
Table 4: Summary of information sources for ammunition used by hunters and the source that is viewed as the most reliable.

<table>
<thead>
<tr>
<th>Ammunition Information Source</th>
<th>Indicated YES (n=228)</th>
<th>Most Reliable (n=195)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Experience</td>
<td>0.84</td>
<td>0.47</td>
</tr>
<tr>
<td>Other Hunters</td>
<td>0.61</td>
<td>0.17</td>
</tr>
<tr>
<td>Sporting/hunting magazine</td>
<td>0.36</td>
<td>0.07</td>
</tr>
<tr>
<td>State Agency</td>
<td>0.32</td>
<td>0.14</td>
</tr>
<tr>
<td>National Rifle Association</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td>Gun Store Clerk</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>U.S. Fish and Wildlife Service</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Refuge Employee</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td>Media</td>
<td>0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Hunting Organization</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Federal Science Agency</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

2.8.6 Purchasing Methods for Ammunition

The majority of mail back respondents at each refuge indicated off the shelf instore purchasing of ammunition for the 2017/18 hunting season (Fig 1). The majority of hunters at Rachel Carson NWR (90%), 77% of hunters at Edwin B. Forsythe NWR, and 65% of hunters at Rappahannock River Valley NWR indicated that they purchased ammunition off the shelf in a store. Online purchasing was most
prevalent at Rappahannock River Valley NWR but absent at Rachel Carson. The proportion of hunters reloading was less than 5% across all refuges.

2.8.7 Non-lead Users - Motivations for Switching

Hunters currently using non-lead ammunition indicated that performance was the main motivating factor for switching to non-lead ammunition use. Motivations for switching to non-lead out of concern for wildlife or human health were chosen less by respondents with concern for wildlife health being indicated as more of a motivating factor than human health (Figure 2). Respondents were also given the opportunity to supply additional reasons for switching to non-lead voluntarily that would not otherwise have been captured through the survey instrument. Responses to the open-ended option “Other” mainly focused on aspects of performance. For example, responses included: “Better accuracy and ballistic coefficient” “Weight
retention”, “It’s more accurate in my guns and expands better for me”. Two hunters indicated availability as a motivating factor.

2.8.8 Practical Barriers to Non-lead Use
Overall, 98% of surveyed hunters (n = 228) agree that hunters are valuable wildlife conservationists and the majority of surveyed hunters (70%) agree that hunters can contribute to wildlife conservation through the type of ammunition they use. After grouping responses to statements concerning practical barriers to non-lead ammunition use into two groups, Lead users and Non-lead Users, there were 218 observations consisting of 179 lead users and 39 non-lead users. The proportion of “Don’t Know” responses indicated in text are calculated from the initial 218 observations.

When asked to respond to the statement that lead and non-lead ammunition perform the same responses differed between Lead Users and Non-lead Users (W = 3903, P = < 0.001, Fig. 3a). Overall Lead Users tended to disagree that performance is equal with the most frequent response being “Strongly Disagree” (34%). Non-lead users tended to agree or indicate a neutral response with “Agree” being the most frequent response (34%). A higher proportion of Non-lead Users indicated a neutral response (32%) compared to lead users (19%). Twenty one percent Lead Users and 3% of Non-lead Users responded, “Don’t Know.”

When asked if lead and non-lead ammunition is equally effective at guaranteeing an efficient kill, responses between Lead and Non-lead Users differed (W = 3813.5, P < 0.001, Fig. 3b). Overall Lead Users viewed the efficacy of non-lead
as being unequal with the most frequent response being “Strongly Disagree” (27%). Non-lead Users tended to view the efficacy non-lead as being equal with the most frequent response being “Agree” (43%). A higher proportion of Non-lead Users indicated a neutral response (30%) compared to Lead Users (20%). Twenty three percent of Lead Users and 5% of Non-lead Users indicated “Don’t know.”

Responses to the statement that the cost of lead and non-lead ammunition is the same were different between Lead and Non-lead Users ($W = 2968.5, P < 0.01$, Fig. 3c). The majority of Lead Users (76%) and Non-lead Users (54%) viewed the cost as not being equal. Twenty three percent of Non-lead Users and 15% of Lead Users indicated a neutral response. Twenty seven percent of Lead Users and 10% of Non-lead Users indicated they did not know if the cost of lead and non-lead ammunition is equal.

Responses to the statement that the availability of lead and non-lead ammunition is the same differed between Lead and Non-Lead Users ($W = 3507.5, P < 0.001$, Fig. 3d). Overall agreement was higher among Non-lead Users with the most frequent response being “Agree” (32%). The majority of Lead Users viewed availability as not being equal with the most frequent response being “Strongly Disagree” (31%). Neutral responses were similar for both groups. Twenty four percent of Lead Users and 5% of Non-lead Users indicated they did not know if availability is equal.

Responses to the statement that non-lead ammunition has the potential to damage firearms were different between the two groups ($W = 1345, P < 0.01$, Fig. 3e). Overall Non-lead Users indicated that they did not think non-lead can damage
firearms with the most frequent response being “Strongly Disagree” (35%). Lead User responses were more evenly dispersed with neutral being the highest chosen response (33%). Thirty percent of Lead Users and 21% of non-lead users indicated they did not know if non-lead ammunition can damage firearms.

Figure 3: Proportional responses of Lead and Non-lead users to statements related to practical barriers to non-lead ammunition use. Error bars indicate 95% confidence intervals.
2.8.9 Lead Ammunition Use and Wildlife

Responses to statements related to lead ammunition use and wildlife were grouped by Lead Users and Non-lead Users. After removing item non-responses there were 219 observations consisting of 180 lead users and 39 non-lead users. Wilcoxon rank-sum tests were conducted on responses to statements between Lead and Non-lead Users. The proportion of “Don’t Know” responses are calculated from the initial 219 observations.

When asked to respond to the statement that lead ammunition can fragment and become lodged in the carcass and gut piles of deer there was no difference in responses between Lead Users and Non-lead Users. The majority of Lead (61%) and Non-lead (76%) Users viewed the fragmentation and deposition of lead as a potential occurrence when harvesting a deer. Eleven percent of Lead users and 15% of Non-lead Users indicated that they “Didn’t Know” (Fig. 4a).

Responses to the statement that scavenging birds can ingest lead through consuming the gut piles of deer differed between groups (\( W = 3743, P < 0.01 \), Fig. 4b). The majority of Lead Users and Non-lead Users were in agreement that scavenging birds can be harmed through ingesting lead from spent ammunition. The most frequent response from Lead Users was “Agree” (33%) while Non-lead Users picked “Agree” and “Strongly Agree” at the same frequency (38%). Overall disagreement was higher for Lead Users. Neutral responses were 21% and 19% for Lead and Non-lead Users respectively, while 11% of Lead Users and 8% of Non-lead Users indicated that they “Didn’t Know” (Fig. 4b).
There was no difference in responses to the statement that lead is not a problem for wildlife between Lead and Non-lead users. Responses were relatively evenly dispersed with disagree being the most frequent response chosen for both Lead (26%) and Non-lead users (33%). Seven percent of Lead Users and 8% of Non-lead Users indicated that they “Didn’t Know” (Fig. 4c).

When asked if wildlife managers should be concerned about the effects of lead ammunition on wildlife responses differed between Lead and Non-lead users ($W = 4100.5, P < 0.001$, Fig. 4d). The majority of Non-lead Users indicated that wildlife managers should be concerned about the effects of lead from spent ammunition on wildlife with the most frequent response being “Strongly Agree” (31%). Lead User responses were split with the neutral response being most frequent (27%). Neutral responses were 27% for both groups. Eight percent of Lead Users and 5% of Non-lead users indicated that they “Didn’t Know” (Fig. 4d).
Figure 4: Proportional responses of Lead and Non-lead users to statements related to lead ammunition use and wildlife. Error bars indicate 95% confidence intervals.
2.8.10 Lead Ammunition Use and Human Health

Responses to statements related to lead ammunition use and human health were grouped by Lead Users and Non-lead Users. After removing item non-responses there were 226 observations consisting of 186 Lead Users and 40 Non-lead Users. Wilcoxon rank-sum tests were used to assess differences in responses to statements between Lead and Non-lead users. These statements addressed a number of factors associated with beliefs about lead ammunition use and human health (Fig. 5).

When asked to respond to the statement that it is possible to ingest lead fragments through consuming deer harvested with lead ammunition, responses differed between Lead and Non-lead Users ($W = 3703.5, P < 0.05$, Fig. 5a). The majority of Lead and Non-lead users viewed the fragmentation and deposition of lead as a potential occurrence when harvesting a deer with the most frequent response being “Agree” (40%) for Non-lead Users and Lead Users (35%). Seven percent of Lead Users and 13% of Non-lead Users indicated that they “Didn’t Know” (Fig. 5a).

When asked to respond to the statement that consuming deer harvested with lead ammunition can have a negative impact on human health responses differed between Lead and Non-lead Users ($W = 3875, P < 0.001$, Fig. 5b). Half of Non-lead Users viewed consuming deer harvested with lead ammunition as having a negative impact on human health with the most frequent response being agree (32%). The majority of Lead Users did do not view consuming deer harvested with lead ammunition as having a negative impact on human health, with “Strongly Disagree” being the most frequent response (27%). Neutral responses were relatively
frequent for Lead (25%) and Non-lead (21%) Users. Ten percent of Lead Users and 15% of Non-lead Users indicated that they “Didn’t Know” (Fig. 5b).

When asked to respond to the statement that consuming deer harvested with lead ammunition has no impact if properly field dressed, no difference was observed between Lead and Non-lead Users. The majority of Lead and Non-lead Users viewed human lead exposure as not being an issue if the deer is properly field dressed. Nine percent of Lead Users and 13% of Non-lead Users indicated that they “Didn’t Know” (Fig. 5c)

Figure 5: Proportional responses of Lead and Non-Lead users to statements related to lead ammunition use and human health. Error bars indicate 95% confidence intervals.
2.8.11 Voluntary Non-lead Use

When Lead Users were asked if they would be willing to voluntarily switch to non-lead ammunition for harvesting white-tailed deer on NWRs, 54% (n = 179) indicated yes. Lead users were placed into two groups, individuals that indicated they were willing to voluntarily switch to non-lead (Volunteers), and individuals that indicated they would be unwilling to voluntarily switch to non-lead (Opposers). Eighty six percent of Volunteers indicated they would make use of a reimbursement program that offset additional cost associated with purchasing non-lead ammunition. Forty five percent of Opposers indicated they would make use of a potential reimbursement program (Fig. 6).

Figure 6: Proportional responses of Lead hunters willing to voluntarily use non-lead ammunition Volunteers" and those unwilling “Opposers” to participation in a reimbursement program. Error bars indicate 95% confidence intervals.
2.8.12 Influences to Switch to Non-lead Use

Ninety percent of Volunteers indicated similar performance as a factor that would influence non-lead use compared to 64% of Opposers ($X^2 = 15.8$, df = 1, $P < 0.001$, Fig. 7). Eighty three percent of Volunteers indicated that knowledge of impacts to human health would influence them to switch in comparison to 57% of Opposers ($X^2 = 11.996$, df = 1, $P < 0.001$, Fig. 7). Eighty four percent of Volunteers indicated that knowledge of negative impacts to wildlife health would influence them to switch in comparison to 55% of Opposers ($X^2 = 17.176$, df = 1, $P < 0.001$, Fig. 7). Eighty one percent of Volunteers indicated that knowing that non-lead would not cause firearm damage would influence them to switch in comparison to 49% of Opposers ($X^2 = 18.156$, df = 1, $P < 0.001$, Fig. 7). Seventy six percent of Volunteers indicated that local availability would influence them to switch in comparison to 36% of Opposers ($X^2 = 25.544$, df = 1, $P < 0.001$, Fig. 7). Fifty nine percent of Volunteers indicated a cost increase less than 25% would influence them to switch compared to 29% of Opposers ($X^2 = 15.229$, df = 1, $P < 0.001$, Fig. 7). There was no difference between group responses based on online availability. Similarly, there was no difference in responses between groups based on cost of non-lead being more than 25% higher than lead ammunition. Both online availability and increased cost above 25% were identified as the least influential factors for both Volunteers and Opposers (Fig. 7).
Hunters that indicated they would not be willing to voluntarily switch to non-lead ammunition for hunting white-tailed deer on NWRs (Opposers) were provided with an open-ended follow up question. The open-ended question gave Opposers the opportunity to provide further information as to why they are unwilling to use non-lead alternatives in order to identify factors that the survey instrument did not assess. Responses to the question “What is the primary reason you would not be willing to voluntarily switch to non-lead ammunition to hunt white-tailed deer on National Wildlife Refuges” were provided by 102 respondents. The open-ended
responses were compiled and analyzed using NVivo Software to identify categories of responses. The “Performance” category which incorporated components of accuracy and effectiveness of ammunition was the most frequently provided response (34%) followed by cost (21%). A relatively small percentage of hunters (5%) offered responses incorporating components related to non-lead use being anti-hunting (Fig. 7).

Figure 8: Relative frequency of open-ended responses as to the primary reason Opposers would not be willing to switch to non-lead ammunition for hunting white-tailed deer on National Wildlife Refuges.
2.9 Focus Group Discussion Findings

Recruitment for focus group interviews resulted in five sessions over the 2016/2017 (n = 2) and the 2017/2018 (n = 3) hunting seasons, with a total of 18 participants. Focus group discussions consisted of exclusively male participants over 40 years of age. Focus group discussions during the 2017/2018 hunting season consisted of one at Rachel Carson NWR in Maine (n = 4), one at Edwin B. Forsythe NWR in New Jersey (n = 5), and one at Rappahannock River Valley NWR in Virginia (n = 3). Two focus group discussions were conducted on separate days at Great Swamp NWR in New Jersey during the 2016/2017 hunting season (n = 2 and n = 4).

Focus group findings are separated into two sections. Section one explores the practical barriers in the focus group data that differentiate how current lead and non-lead users view the effectiveness, cost, and suitability of non-lead alternatives for harvesting white-tailed deer. Section two consists of two major themes in the data: “Individual Behavior” and “Mechanism of Exposure”. These themes explore how hunters using lead ammunition frame their individual behavior as a source of exposure for non-target species, and hunter understanding of the pathway to lead exposure for non-target species through lead ammunition use.

2.9.1 Practical Barriers

Effectiveness of ammunition in the context of harvesting a deer refers to the capability of a projectile to limit the potential for wounding and non-recovery of an animal. For hunters currently using lead ammunition there was a general tendency to view the effectiveness of non-lead alternatives for both single projectiles and
buckshot to be inferior and negative attitudes towards the effectiveness of non-lead alternatives were often tied to their material composition. For example: the terminal ballistic behavior, that is, how a projectile behaves on impact, was seen as a prominent factor that influences the efficacy of monolithic copper projectiles, as outlined below:

Lead has that ability to mushroom and flatten unlike copper. Here is the thing, bullets don’t kill deer by tissue damage, a bullet kills a deer by shock. And when that bullet hits, the cooper solid is not mushrooming [and] you’re not getting that transfer of energy from that round to the deer. It’s basically just punching right through it ... you're not getting a lot of fragmentation. You’re getting just basically a flattened slug. The copper solids are just awful. (GSH1)

One of the things that I saw is for a copper bullet to be effective [it has] to get expansion. [For that to occur] on light bodies game like white-tailed deer, it has to be travelling a 2000 ft per second. That’s way over the velocity you get out of a muzzleloader. It’s the same thing with a slug. So, you get plenty of penetration [but] you wouldn't get the hydrostatic shock, which is actually what kills the animal quickly. (RKH1)
At these ranges [distances] we're never going to get full energy transfer. If it's blowing through, that bullet still has energy that's not deposited in the deer. You don't get that wound channel deformation [hydrostatic shock]. (GSH2)

For monolithic projectiles, projectile design, insufficient velocity, and close hunting distances where pass-through can occur were viewed by some hunters as negatively affecting the potential for expansion (mushrooming) and energy transfer between the projectile and target. Likewise, when considering steel shot as an alternative to lead buckshot, hunters did not view it as being suitable:

If you're using steel shot you've probably got to decrease your effective range by at least 10 to 15 yards and let's face it most people don't do that. (RKH2)

You purchase the most effective round of ammunition to not maim the animal. I don't like to use the word "kill" because as a hunter I don't go out and kill, I go out and I harvest, that's what I do....If you go out and buy steel, your velocity and the distance at which you can kill something dramatically, it really decreases. And your chances of now maiming the animal is more probable than actually harvesting it. (RKH3)

Literally, you're hunting in a jungle out there. So, the density and weight of lead, and its ability to penetrate through saplings and twigs is key to being able to hunt here. If you start making people use lighter ammunition, lighter
projectiles ok, your rate of wounded animals is going to go up. You're going
to lose more from wounding than the number of vultures and eagles that
you're going to protect. (RKH1)

As noted in the previous quotes, in situations where hunters use buckshot to
harvest deer, they can perceive steel buckshot to be an unsuitable alternative for a
number of reasons. First, because steel is a lighter material, steel buckshot is seen as
decreasing the distance at which a hunter can harvest a deer successfully (effective
range). Due to a possible decrease in effective range through the use of steel
buckshot, hunters anticipate an increase in potential for wounding of deer.
Additionally, the lighter physical property of steel is seen as unsuitable for some
field conditions as it would be ineffective at coping with vegetative undergrowth.
Both factors are seen as increasing the likelihood of wounding and non-recovery of
an animal, which can be viewed as a disproportionate tradeoff for reducing lead
exposure for non-target species.

Tied to negative attitudes towards the efficacy of non-lead ammunition were
beliefs that both voluntary and regulatory moves to reduce lead ammunition use
were driven by motives to reduce hunting opportunity:

I think it’s a complete over reaction and quite frankly I think even more than
that it’s a scare tactic used by the anti-hunting community to try to impede
hunters. (RKH2)
In my mind the only reason they are trying to ban lead is not because the effect that it has through consumption for humans or the other animals but more as a deterrent. Ok, when you say we’re not going to use lead anymore we’re going to use steel shot. Steel shot can’t break down as much and it’s not really a good material to use for hunting. At some point they’re going to come back and say steel creates this type of “condition”, so it’s really a deterrent that is slowly but surely pushing away the ability for hunters to obtain their game. (RKH3)

In addition, voluntary use of non-lead alternatives can be seen as opening the door to potential regulations.

I’ll tell you the one thing I would be concerned about. They go with a voluntary program I’ll literally bet all my fingers and toes that it’s eventually going to become mandatory…. I see that word transition. That’s the key word there for me. That’s the beginning of a transition to eventually a mandatory…. I love it here and I would always want to do things to make sure that I get to enjoy the refuge as well as the other people. But on this one issue I would say I’m not going to give an inch because if I give an inch, they are going to take a mile. (GSH1)

Once you open the door. (GSH4)
For other hunters currently using lead ammunition, voluntary non-lead use was not viewed as a mechanism to limit hunting opportunity. Openness to voluntary non-lead use was based on personal research on the effectiveness of non-lead:

I haven’t shot copper yet, but I want to start shooting copper. I actually do because I’ve researched some of the bullets and they look actually a lot better than the lead bullets. The Barnes Spitfire they look like they would just be really badass. (EFH3)

Where environmental impacts could be demonstrated:

If you showed a study that what we were shooting is causing an adverse effect to the environment and the animals then sure, I would definitely agree with that. (EFH4)

I agree with that. (EFH1)

While also limiting increase in cost:

I can go one step further and go with something that’s a little more environmentally sound. I wouldn’t have a problem with it as long as you know we’re paying a buck a round. (RCH1)

And without decreasing effectiveness
Can I get the accuracy? Can I get the deformation, the mushrooming effect, and then what’s that cost going to be? Can I put the animal down, so I can recover it and not have problems down the road? (GSH2)

Lead is an element, copper is an element, and ammunition is a tool. I've got no emotional love for lead whatsoever. Show me something that does the job as well or better at a similar cost, I'll use it. I don't think you're going to find anything. (RKH1)

As noted in above, a number of factors such as proof of environmental impact, similar cost, and comparable effectiveness of non-lead ammunition can manifest as practical barriers its use. However, while the effectiveness of non-lead alternatives was identified as a prominent concern for hunters using lead ammunition similar concerns were absent for hunters that had favorable experiences using them to harvest deer.

I’ve used the copper ones 20 years ago when they came out …. I was shooting the full Copper slugs, 2 and ¾. I used it for bear hunting, and for deer, absolutely deadly and it was accurate. (EFH2)

One hunter at Great Swamp using Hevi-shot 00 buckshot, a heavier than lead alternative indicated no difference in the effectiveness. However, the same hunter
indicated that the cost associated with using this type of ammunition was significantly higher.

Now in my case I didn't notice the difference .... It dropped that deer just like lead. He went down like a sack of potatoes ... So for me the performance was the same, the big difference was the price because it's about double. It's like $35 a box. (GSH3)

Similarly, a hunter that currently uses monolithic projectiles viewed them as comparable in terms of effectiveness:

Oh, they're terrific. The deer doesn't move. I mean if you hit them, it seems to have tremendous knock down power .... They have better accuracy per second. It's pretty fast. It's like 2000 feet per second .... About 3 years ago I shot a buck over in lot 17 and it was a long shot. Talk about accuracy. That buck was on a dead run. He couldn't have been going any faster and I hit him with one of these copper slugs and he went head over heels like a buffalo. I couldn't believe it. And I hit him from a long distance out. (SGH2)

The same hunter placed the increase in cost per round in perspective relative to other hunting expenditures and viewed paying more as acceptable as it aligned with his personal code of ethics:
The difference in cost is nothing compared to the amount of money I've invested in equipment. It's much more expensive... but it doesn't matter, really it doesn't matter when you know you've got a nice deer in your sights. You can say you know, I'm doing my very best to get him or her. (SGH2)

Differences in cost between lead and non-lead ammunition is a recognized practical barrier to non-lead use (EPPS 2014), and such concerns about increased cost were raised consistently during focus group discussions by hunters using lead ammunition and non-lead ammunition. Cost, effectiveness, and suitability of non-lead alternatives were prominent concerns for hunters associated with non-lead use, however, for other hunters that participated in the focus group discussions, lack of awareness of alternatives was identified as an initial but important potential barrier to non-lead use.

For example:

I wasn't even aware of other alternatives to heavy game loads. I was fully aware of waterfowl and steel-shot but I never looked at bismuth or copper for you know big game. (SGH1)

I was not aware. (RCH2)

I didn't even realize there was alternative buckshot. I didn't even know it existed cuz there was no need for me know that. (EFH4)
In summary: decreased effectiveness of non-lead alternatives was the most salient topic for hunters currently using lead ammunition. The perceived inability of copper monolithic rounds to achieve expansion and ineffectiveness of steel-buckshot under certain hunting conditions are viewed as increasing the potential for wounding and non-recovery of deer. For some hunters a lack of awareness of viable alternatives was identified as an initial practical barrier to non-lead use. Focus group findings presented in section 2 identify themes in the data that provide insight into a) how hunters contextualize their individual behavior in regard to lead ammunition use and the associated impacts for non-target species and b) how hunters make sense of the underlying mechanism of exposure for non-target species.

2.9.2 Theme I - Individual Behavior

When addressing the effects of lead ammunition use on wildlife, the primary focus of hunters was associated with lead ammunition use for waterfowl hunting. Hunters described the lead exposure pathway for waterfowl as a consequence of how waterfowl feed. For instance:

[Waterfowl] are more likely to ingest [lead pellets] than probably most game animals would because of the peculiarities of the way they feed. (RKH1)

You know there’s a long-standing debate about the effects of lead on waterfowl and I think you know that it is pretty well conceded now because wildfowl have a gizzard and ingest gravel and lead shot in heavily hunted
areas. Because it looks like gravel, they can ingest lead that can theoretically have a deleterious effect on them. (RKH2)

Most hunters associated how waterfowl feed and the composition and size of lead shot as creating a legitimate pathway for waterfowl lead exposure through lead ammunition use. In general, hunters acknowledged that this pathway to exposure formed the basis for regulations surrounding lead shot use and the subsequent transition from lead to steel shot for waterfowl hunting:

I have heard that the reason they went from lead to steel with the duck hunting was the fact that the ducks ate the little pellets unknowingly. (RCH4)

From what I read they went to steel from the thousands of [lead] pellets because ducks actually eat them when they land. Especially in the shallower marsh because ducks actually consume [lead pellets] because they think it's food. (EFH1)

I only know that ducks ingest it. Somehow there must be some toxic effect on especially the bird populations. I mean I think that's why there was a shift from lead to steel shot in duck hunting. (SGH2)

Overall, hunters illustrated a basic understanding of the lead exposure pathway for waterfowl and how this pathway of exposure influenced regulations surrounding
the use of lead shot. However, there were instances where some hunters expressed doubt about the level of impact of lead shot use on waterfowl and the subsequent effect of regulation on waterfowl populations. For example:

I don't see any shortage of waterfowl and I believe the return in their numbers has little to do with the amount of lead that they were consuming and the subsequent restrictions on it. (RKH1)

I hunted for a long time with lead before they made the switch and I never encountered, like, we never harvested a duck that had bad flesh or looked sick. I understand that some of the dabblers get in the mud and they might have eaten some of the pellets, but I never saw any of the effects on any of the animals. (SGH1)

Fish and Wildlife has now mandated the use of non-toxic shot for waterfowl and I think it's an overreaction. I think in very heavily hunted areas it is a significant problem, but I think you know in a typical place around here where you have a duck or goose blind that might be hunted by two or three hunters a dozen times a year, the amount of lead shot that's in the water wouldn't be a problem. (RKH2)

In the context of lead ammunition use and waterfowl hunting, some hunters indicated a lack of direct contact with a chronically exposed animal or visible
indications of lead impacts at as sources of doubt about the impacts of lead ammunition use. For a number of hunters, small volumes of lead ammunition use for waterfowl hunting is still seen as having minimal impacts. Likewise, secondary poisoning of non-target species through deer hunting was categorized as insignificant unless a population level impact is shown:

There have been some anecdotal reports of bald eagles with lead poisoning, onesies and twosies here and there. Personally, I see that as a success story because over the last 40 to 50 years we’ve brought the bald eagle back from extinction if we hadn’t done that you wouldn’t be hearing about this stuff. The fact of the matter is the bald eagle is pretty common in this day and age. I go out on the river by my house there I see bald eagles all the time. I see them eating roadkill out in the middle of the road. (RKH1)

When considering the impacts of lead ammunition use on non-target species through deer hunting, hunters’ understanding of the issue remains grounded in other hunting practices. When examining their individual use of lead ammunition, hunters contextualized their behavior relative to lead use for waterfowl hunting and current lead use for upland game hunting. Hunters drew comparisons between deer hunting and these two practices with comparisons centering around two prominent differences. Namely, the volume of lead introduced into the environment by their individual actions, and the composition of the rounds used.
When you talk about waterfowl, even though the ounce of a lead slug [for
deer hunting] versus shot for waterfowl is sometimes the same in terms of
the amount. It’s the fact that it’s so many little bb’s that are going out in the
water and you know they are directly impacting .... We’re talking about big
game where it’s not like I’m sitting here in a duck pond putting out volume
and shooting like 50 shots. (GSH1)

I never really thought lead was a problem except for like duck shooters that
sit in a blind and might shoot 500 rounds a day. So, you can imagine all the
lead pellets that are out there. (EFH5)

If you're only focusing on wildlife refuges, there is a lot more lead being
dispensed everywhere in the world of small game hunting. I'm mean, if I'm
out pheasant hunting, I think I may have several hundred pellets in one
cartridge. So, if you go out to some of our public hunting lands, the number of
shots that are taken at pheasant and rabbit and grouse and whatever else,
that's millions of pellets. Here [deer hunting on refuges] its negligible. (GSS2)

For deer hunters, waterfowl and upland game hunting can be viewed as hunting
practices that result in significant lead deposition in the environment. Lead
deposition in the environment through deer hunting was predominantly viewed as
insignificant by hunters. Consequently, hunters tended to frame their individual use
of lead ammunition for deer hunting in the context of the volume they deposit in the environment, as illustrated in the following quotes:

A muzzleloader is one shot. (GSH4)

Hunting waterfowl [you] shoot thousands of rounds into the water compared to hunters who hunt deer. One slug into the ground here or there. It’s kind of, insignificant. (EFH3)

I’m literally shooting one round ... I honestly would be absolutely stunned if there was anything above a .01% impact to wildlife out here. Honestly, because you’re talking one shot ... I think there is other things to worry about other than one shot. (GSH1)

If you listen you don’t hear very much shooting, you know. So, I can’t see where it’s an issue if [deer hunters] were in here and they were firing machine guns and [the projectiles] were all lead. I could see, hey you know, that’s too much. But to shoot at a deer, if you’re right on the target you’re only going to use one bullet. You’re not going to use 40 or 50 of them. (RCH3)

Hunters tended to categorize lead ammunition use for harvesting deer as not constituting a level of deposition in the environment to warrant concern. Through comparisons between other hunting practices that use higher volumes of
ammunition, hunters viewed lead deposition in the environment through deer hunting as being insignificant in relation to other hunting practices and do not view their individual behavior as contributing to lead exposure for non-target species.

2.9.3 Theme II - Mechanism of Exposure

Intrinsically linked to the previous theme of individual behavior is hunter understanding of the underlying mechanism of exposure for non-target species. A key factor that may limit hunter understanding of the potential for non-target species exposure is the terminal ballistic behavior of a round when harvesting a deer. Hunters view “pass-through”, whereby the round enters and exits a deer as a process that results in little to no lead deposition in the deer. For example:

Most of the time when you shoot an animal, at least with a rifle, the bullet passes all the way through. So, the bullet doesn’t remain in the animal ..... If you’re shooting with muzzleloader slugs, odds are it’s going to exit, and if it exits obviously there is not much left. Almost nothing left in the deer. (RKH2)

In my mind right, just doing the simple math in my head. How much really could be somewhere in the animal? Again, if you're at an elevated position and it's a pass-through shot. (GSH2)
That deer was about 20, 25 yards. It wasn't that far. I hit it with #4 buck so it's like 35 pellets. So, that blew right through it and he went right down. So any [lead] went right through. Went right into the ground. (GSH3)

Blew right through it. Even after hitting a sapling, it's still blowing right through it. So, it's just going right in the ground. (GSH1)

Hunters viewed “pass-through” as a process that limits bioavailability of lead for non-target species. Namely, because the discharged projectile is perceived to leave an insignificant amount of lead in the deer or the lead associated with the projectile ends up embedded in the ground. The belief that pass-through results in the deposition of lead outside the harvested deer is associated with removing the potential for non-target species exposure. Namely, because the feeding habits of scavenging species would not result in exposure. The following quotes demonstrate how hunters make sense of the exposure pathway for non-target species through lead ammunition use for deer hunting:

Honestly, because you're talking one shot. Most of them end up in the ground and to your point, you said you went looking for that [projectile] to try and find it and if you can't find it, I can't imagine an eagle or red tailed hawk is going to go in there and dig up that slug from six inches in the ground. (GSH1)
You’re not going to have anything going around digging through the ground trying to pick up a piece of lead. I really don’t think it matters. (RCH3)

If it’s a pass-through shot, the slugs in the ground where I hit it .... I only shoot with 100 grains so I have always had to go 35, 40, 50 yards to recover my deer. So, there’s the point of shot and here is the gut pile. There’s no way anything is going back to dig around and suck it up [the projectile]. In my opinion, I don’t see that happening. (GSH2)

When a projectile achieves “pass through”, there is a general belief among hunters that lead associated with a projectile does not remain in the deer and as a result, the feeding habits of non-target species do not facilitate a pathway to lead exposure.

2.10 Discussion

2.10.1 Purpose

The purpose of this study was to identify barriers to the voluntary use of non-lead alternatives for harvesting white-tailed deer as perceived by hunters on NWRs in Region 5. Where lead ammunition use for hunting activities occurs, it presents a biological issue for humans and wildlife. It has been demonstrated that through alternative ammunition use non-target wildlife lead exposure can be reduced. In addition, the existence of nonlead alternatives has presented a viable solution to reduce exposure pathways for humans without introducing any additional health risks (Schlichting et al. 2017). Non-lead alternatives for harvesting game animals
have been available for many years for a variety of hunting applications and the voluntary adoption of non-lead alternatives for harvesting white-tailed deer on NWRs in Region 5 has already occurred for a proportion of hunters. For current NWR Lead Users however, non-lead alternatives may still be viewed as a relatively novel innovation. Lead Users’ beliefs concerning performance, efficacy, cost, and availability of non-lead alternatives, in addition to limited understanding of the mechanism of exposure for scavenging species, have been identified as potential barriers to voluntary use.

Rogers (2003) defines an innovation as an object, idea, or behavior that is perceived as new by an individual or group, and the willingness of individuals to accept a new innovation determines whether it is adopted and subsequently how its use increases in a population. For the adoption of an innovation there are five factors that influence adoption: (1) relative advantage, is there an advantage of using an innovation compared to the product it is replacing? (2) compatibility, how compatible is the new innovation with the needs of potential adopters? (3) complexity, is the new innovation difficult to use? (4) trialability, can the new innovation be tested prior to adoption? and (5) observability, does the innovation provide tangible results? The following discussion outlines the mail-back survey and focus group findings in the context of these five factors.

2.10.2 Relative Advantage

The mail-back survey identified that there was almost universal agreement that hunters on NWRs in Region 5 consider themselves valuable wildlife
conservationists. In addition, the majority of Lead and Non-lead Users agreed that through the process of fragmentation and deposition, lead can become lodged in the gut pile or carcass of a deer. Responses to whether lead ingestion can harm birds that scavenge gut piles of deer while differing between Lead and Non-lead Users, both groups tended to agree that lead ingestion can harm non-target avian scavengers that feed from these food sources. However, the majority of Lead Users and a large proportion of Non-lead Users were neutral, uncertain, or did not view lead from spent ammunition as being a problem for wildlife or an issue that wildlife managers should be concerned about.

Lack of awareness of the consequences of individual behavior regarding lead ammunition use was identified as a barrier to non-lead use and subsequent California condor recovery in Arizona (Chase and Rabe 2015). As part of this study, a portion of hunters surveyed through open ended responses expressed that they believed condors did not inhabit the area they hunted as they had not seen them, even though those areas were within the condor distribution zone. A lack of visibility of condors within hunting areas was interpreted by a number of hunters as justifying continued lead ammunition use, as hunters did not attribute their individual actions as contributing to the problem of non-target species exposure (Chase and Rabe 2015).

Knowledge is a key component that determines how people process information and ultimately make decisions (Raju et al. 1995). In the context of hunting, Vaske et al. (2006) noted that how hunters think about chronic wasting disease (CWD) is influenced by hunters’ knowledge about the relationship between
CWD and human health. In addition, individuals with higher levels of knowledge on a conservation issue are more likely to be aware of the consequences of their actions (Vaske and Donnelly 2007). Furthermore, if a person believes that their actions would not result in meaningful change their behavior may not reflect the attitude they hold on a topic (Ajzen 1991).

Focus group discussions were able to provide insight as to why a large proportion of refuge hunters may not ascribe their individual lead ammunition use as having a significant impact on non-target species. Rather than a lack of visibility of non-target species as identified in Arizona, perceived impacts and justification of continued lead ammunition use appear to be rationalized through the volume of ammunition used in comparison to other hunting practices. Taking “one shot” to harvest a deer was not perceived by refuge hunters as an action that deposits enough lead to have a significant impact on non-target species. Further, where hunters harvest deer at close proximity resulting in passthrough, this can be seen as reducing the potential for fragmentation. Perceived lack of fragmentation is seen as removing the likelihood of lead exposure for non-target species, primarily because it is viewed that sufficient energy is not deposited by a round when passthrough occurs, thereby reducing the likelihood of fragmentation. Therefore, where passthrough occurs it is seen by some hunters as disassociating lead from a non-target species food source, essentially removing the potential for exposure due to the feeding habits of non-target scavenging species. However, due to the physical properties of lead and its use in ammunition, the potential for the fragmentation and deposition of lead particles in animal tissue is ever present (Hunt et al. 2006, Hunt

Underestimating fragmentation rates and viewing passthrough as removing bioavailability of lead belies a deficit in understanding by some NWR hunters of the mechanism of lead exposure for non-target species through harvesting deer. This may explain why a large proportion of NWR hunters do not view the continued use of lead ammunition for harvesting deer as a problem for non-target species or an issue that wildlife managers should be concerned about. In instances where lead ammunition use has been reduced in specific geographic areas lead exposure in non-target species has followed suit (Anderson et al. 2000, Samuel and Bowers 2000, Kelly et al. 2011, Bedrosian et al. 2012), highlighting the effect of individual non-lead use in improving overall wildlife health by removing a potential source of individual mortality and sublethal lead exposure. A deficit in understanding of the underlying mechanism of lead exposure places the relative advantage of non-lead use for this hunting application in doubt. Outreach and education strategies that outline the mechanism of exposure and frame individual non-lead use as a means to contribute to wildlife health may be key in demonstrating the relative advantage of non-lead use to NWR hunters.

2.10.3 Compatibility

Compatibility refers to the extent that an innovation is perceived as meeting the needs of potential adopters while being consistent with both existing values and past experiences (Rogers 2003). For NWR Lead Users, perceptions about non-lead
performance and efficacy differed between Lead and Non-lead Users, identifying these factors as potential barriers to future voluntary use. Negative responses to statements concerning the equal performance and efficacy of lead and non-lead ammunition were higher among Lead Users. In addition, a quarter of Lead User responses to the same statements indicated uncertainty and a third of responses were neutral in both cases. It is possible that some Lead Users have considered the ballistic properties of non-lead alternatives and how this relates to performance and efficacy in detail and are truly neutral on the issue. However, some Lead Users may not have considered the topic in sufficient detail to form a truly neutral position. This fact is highlighted by the high proportion of Volunteers and Opposers (subsets of Lead Users) indicating that knowing non-lead alternatives would perform the same as the primary factor that would influence voluntary use. Suggesting that a relatively small proportion of NWR Lead Users currently view non-lead alternatives as being compatible for the purpose of harvesting white-tailed deer.

Knowing similar performance can be achieved using non-lead alternatives has been identified as a primary influence for big game, and unprotected mammals and furbearer hunters to switch to non-lead in Oregon (ODFW 2014). Performance was also indicated as an influencing factor by 62% of youth deer hunters as part of the Hunter’s Choice program in Minnesota (Henry 2016). Knowing that the performance of non-lead ammunition would be similar in terms of accuracy and killing efficiency, while differing between Volunteers and Opposers was the highest chosen influence to switch for both groups. This highlights the importance of outreach and education strategies that illustrate the compatibility of non-lead
ammunition for harvesting white-tailed deer. However, strategies designed to
demonstrate the compatibility of non-lead alternatives may benefit from focusing on
firearm and ammunition types specific to what NWR hunters use. An even more
focused refuge level approach may be more appropriate when current firearm and
ammunition usage and restrictions are considered.

Refuge-specific hunting regulations are often more restrictive than state
regulations and of the 39 NWR locations in the Northeast Region that permit
harvesting white-tailed deer with firearms, 30 have restrictions on the type of
firearms that hunters can use. Nineteen of these refuges are restricted to shotgun
and muzzleloader use, 9 are shotgun only, and 2 are muzzleloader only (USFWS
2018). For this study, Both Edwin B. Forsythe and Rappahannock River Valley
NWRs are restricted to shotgun and muzzleloader use while Rachel Carson is
restricted to shotgun only.

The assessment of firearm usage on these refuges suggests that variation in
shotgun gauge and muzzleloader caliber used to harvest white-tailed deer may be
limited. Results showed that 95% of hunters pursuing white-tailed deer with
muzzleloaders are using 0.50 caliber with the majority using sabot slugs (75%) and
conical bullets (22%). A relatively small proportion of muzzleloader hunters (3%)
indicated that they used patched round balls. Similarly, where hunters pursue deer
with shotguns, 78% use 12-gauge exclusively, while the majority of remaining
hunters use 20-gauge (16%) or a combination of both (4%). Shotgun ammunition
type used consisted of rifled slugs (38%), sabot slugs (34%), and buckshot (28%).
Both rifled slugs and buckshot are generally used with smooth bore shotguns where
there is no rifling in the barrel to stabilize the projectile, unlike sabot slugs which are encased in a plastic jacket (sabot) designed to engage the rifling. While technically a rifled slug or buckshot could be used with a rifled barrel, it is an unlikely practice due to the potential for barrel fouling, where lead is deposited in the rifling. Therefore, ammunition use by NWR shotgun users indicated predominantly smooth bore shotgun use.

Focus group discussions allowed further exploration of how NWR hunters viewed the performance and effectiveness of non-lead alternatives relevant to what they currently use and how these factors were tied to concerns related to harvest success. For focus group participants currently using lead-based ammunition there was a general tendency to view the efficacy of non-lead alternatives for both single projectiles and buckshot to be inferior, with negative beliefs concerning the effectiveness of non-lead alternatives often tied to their material composition. For example: material composition and subsequent terminal ballistic behavior was seen as a prominent factor that influences the efficacy of monolithic copper projectiles, in that monolithic copper rounds, due to close hunting distances, were viewed as not being capable of depositing sufficient energy in an animal to achieve a clean kill (i.e., resulting in passthrough), therefore resulting in them being viewed as unsuitable for the purpose of harvesting deer. Interestingly, passthrough was also noted by some hunters as a possibility when using lead-based ammunition at the same hunting distances. Further, passthrough was viewed positively by the same hunters as it was seen as disassociating lead from a potential food source and thereby reducing bioavailability for non-target species. Similar to non-lead monolithic
rounds, the material composition (lower density) of steel buckshot rounds were seen as reducing a hunter’s effective range. In addition, they were viewed as being unable to cope with vegetative undergrowth in comparison to higher density lead buckshot. Different component materials for both monolithic rounds and buckshot alternatives were ultimately seen as inferior and thereby increasing the potential for wounding and non-recovery (crippling) of an animal.

A survey conducted by the Minnesota Cooperative Fish and Wildlife Research Unit and Minnesota Department of Natural Resources on small game hunters’ knowledge and opinions of non-lead shot found similar concerns, with 50% of surveyed hunters indicating increased wounding and crippling rates as a potential outcome of alternative ammunition use (Schroeder et al. 2008). For NWR deer hunters, harvest success and avoiding the crippling of an animal ultimately comes down to the performance of a single round which can impact its effectiveness, potentially increasing the likelihood of wounding and non-recovery of an animal.

Currently, in-field assessments of the efficacy of non-lead alternatives to shot have been limited to hunting applications involving waterfowl and upland game birds (Pierce et al. 2015, Mondai-Monval et al. 2015). Furthermore, where in-field comparative assessments on the performance and efficacy of monolithic rounds have been conducted, these have tended to focus exclusively on rifle ammunition (Knott et al. 2010, Trinogga et al. 2013, Kanstrup et al. 2016, McCann et al. 2016, Martin et al. 2017). While current research indicates comparable in-field performance and efficacy for non-lead alternatives, it is not representative of firearm and ammunition combinations used by the majority of NWR hunters. This
places the compatibility of non-lead alternatives for this hunting application in question and underscores the importance of outreach and educations strategies that highlight the compatibility of non-lead alternatives relevant to what NWR hunters currently use.

2.10.4 Complexity
Rogers (2003) defines the complexity of an innovation as the extent to which it is perceived as difficult to understand and use, with ideas or innovations that are easier to understand more readily adopted than innovations that require the development of new skills and understandings. Performance of both lead-based and non-lead ammunition is dependent on factors distinctive to particular firearm and ammunition combinations (Epps 2014) with factors other than material composition of rounds identified as predictors of harvest success (Pierce et al. 2015, Mondai-Monval et al. 2015, Martin et al. 2017). From a performance standpoint recalibrating to non-lead ammunition involves the same process as switching between two brands of lead ammunition (HWNL 2019), that is, finding a round that achieves consistent grouping over a specified distance. To achieve similar effectiveness in the field, a slight change in shot placement is recommended when harvesting a deer with monolithic rounds (HWNL 2019) while alternatives to lead buckshot may require a reassessment of a hunter’s effective range. As Such, complexity of use of non-lead alternatives for NWR hunters may ultimately lie in slight adjustments of existing harvesting techniques depending on the combination of firearm and ammunition used. Nonetheless, the complexity of use associated with
non-lead alternatives is compounded by the ability of NWR hunters to navigate the recalibration process.

The technical aspects associated with the transition to non-lead shot for waterfowl hunting in the 1990s was simplified because first shot is limited to use in shotguns with smooth bore barrels, and secondly, smooth bore shotguns for waterfowl hunting are limited to six gauges with gauges 12 and 20 making up the overwhelming majority used (Epps 2014). From a technical standpoint, Epps (2014) noted the transition to non-lead ammunition for waterfowl hunting is not analogous to hunting with rifles and handguns, as in contrast there are dozens of common non-interchangeable types of cartridges and many more that are less commonly used. For hunting applications that involve rifle or handgun use this certainly holds true. In the context of harvesting white-tailed deer on NWRs, refuge-specific firearm regulations and limited variability in firearm and ammunition use may in fact help limit the broader complexity associated with voluntary non-lead use. Nevertheless, at the level of individual hunters, this does not account for the process of recalibration where more practical barriers may increase complexity of use.

As previously outlined, to find an effective round that achieves comparable performance and efficacy with their firearm may require a hunter to purchase multiple boxes of varying non-lead ammunition brands. The ability for NWR hunters to recalibrate successfully requires availability of non-lead alternatives, something Lead Users view as not being equal when compared to Non-lead Users. This may be due to two factors. First, how refuge hunters purchase ammunition, and secondly, current ammunition usage.
Across all three refuges hunters predominantly indicated purchasing ammunition in-store. For example, 90% of hunters at Rachel Carson NWR, 77% of hunters at E. B. Forsythe NWR, and 65% of hunters at Rappahannock River Valley NWR indicated purchasing ammunition in-store exclusively. Overall, online purchasing of ammunition, whether exclusively or in combination with in-store purchasing constituted a relatively small proportion of how hunters purchase ammunition. Therefore, voluntary use strategies that rely on hunters to purchase non-lead ammunition online can make the process of acquiring ammunition more complex for the majority of refuge hunters. Further, local availability of non-lead alternatives was identified as a greater influence to switch over online availability for both Volunteers and Opposers. This suggests that strategies that work to increase local availability of non-lead alternatives may be key, as it would reduce the complexity of recalibration by maintaining existing purchasing methods that the majority of NWR hunters use.

In addition to purchasing methods, current ammunition use may also impact negative views of availability of non-lead alternatives. Online product availability does not necessarily reflect local retail availability. This may be increasingly important for smooth bore shotgun users where rifled slugs and buckshot are a preferred method of take. Of surveyed hunters, 38% of shotgun users reported using rifled slugs and 28% reported buckshot as a method of take, indicating a high proportion of hunters using smooth bore shotguns. Currently, only five manufacturers make non-lead rifled slugs for smooth bore shotguns, Winchester, Brenneke, Ddupleks, Sauvestre, and Rio.
Only Rio, Ddupleks and Brenneke TKO could be sourced online at time of writing. In addition, both Ddupleks and Sauvestre use novel designs unlike the traditional foster type slug produced by the other manufacturers and only Sauvestre manufactures single projectile non-lead 20-gauge rounds. Limited production of non-lead alternatives to rifled slugs combined with limited online retail availability of a range of viable alternatives, may decrease the likelihood of a hunter using a smoothbore shotgun at being able to obtain a round that works effectively with their firearm. In addition, novel designs outside of the traditional foster type slug like those produced by Ddupleks and Sauvestre may add further apprehension towards use as material composition in of itself is seen as reducing the effectiveness of non-lead alternatives. Furthermore, Ddupleks and Sauvestre are located outside the U.S in Latvia and France respectively which may limit retail availability of these products, particularly at a local level.

The complexity associated with the voluntary use of non-lead alternatives for NWR hunters hinges on their ability to successfully recalibrate, a process affected by current purchasing methods in addition to actual product and retail availability of viable alternatives. For NWR hunters using 12-gauge rifled barrel shotguns or 0.50 caliber muzzleloaders that require a sabot slug, product and retail availability may not be an issue. However, availability of viable alternatives to rifled slugs for hunters using 12 and 16-gauge smooth bore shotguns appear to be limited. In addition, online retail availability of the same rounds appears to be deficient. How reflective this is of local retail availability, the preferred method of ammunition purchasing for NWR hunters, is currently unknown. Highlighting the importance of
outreach strategies that reduce the complexity of use at the recalibration stage and beyond.

2.10.5 Trialability

Intrinsically tied to reducing complexity of use of non-lead ammunition for NWR hunters are strategies that simplify trialability at the recalibration stage. Trialability is the extent to which a new innovation can be experimented with prior to use. As Rogers (2003) noted, trialability of a new innovation reduces uncertainty for an adopter and can be positively related to its rate of adoption. Voluntary approaches to non-lead use that have facilitated trialability from an economic perspective have been met with success (Chase and Rabe 2015, CBS 2018, AZGFD 2018). Where strategies have reduced economic impacts to hunters, significant increases in initial non-lead use have been observed (Chase and Rabe 2015) and also maintained annually (AZGFD 2018, CBS 2018). Albeit on a much smaller scale and in conjunction with the pilot study at Great Swamp NWR in 2016, twenty hunters were offered a voucher to recoup the cost of purchasing non-lead ammunition. Ninety one percent of respondents (n = 11) that used the voucher indicated they would hunt again with non-lead ammunition and 73% indicated they would recommend non-lead to other hunters based on their experience.

Following the 2017-2018 hunting season, fifty four percent of Lead Users indicated they would be willing to voluntarily use non-lead ammunition to harvest deer on NWRs. While this is promising, a large proportion of Lead Users (27%) indicated uncertainty about a difference in cost. This may be partly due to a lack of
awareness of viable non-lead alternatives for harvesting deer, a potential issue that was identified through focus group discussions. However, the additional per-round cost may be viewed as a significant barrier to non-lead use, which could directly impact the perceived trialability of non-lead alternatives. Focus group findings suggest that while some Lead Users may place an associated cost increase for non-lead use in the context of annual hunting expenditure, many may view it in terms of the per-round increase, a fact highlighted by the mail-back survey responses.

The mail-back survey indicated that Lead Users and Non-lead Users differed in responses to statements about the cost of non-lead as being equal to lead with Lead Users overwhelmingly viewing cost as being unequal. Furthermore, for Lead Users, a low increase in cost ($x \leq 25\%$) was identified as a factor that would influence future use by 59% of Volunteers while only 29% of Opposers view the same increase as influencing future use. However, both Volunteers and Opposers both indicated a moderate increase in cost ($25\% \geq x \leq 50\%$) as the lowest influential factor for future voluntary use.

Economic impacts that are contextualized at the per-round level may be influenced by the type of ammunition a hunter currently uses. Epps (2014) noted that ammunition that is sold in retail outlets and actually used in the field is often lead-based and of the non-premium variety and findings from the mail-back survey on hunter ammunition use support this observation. When asked "What type of ammunition do you normally use to hunt deer?" and given the options “Lead”, “Lead Alloy”, “Lead Core”, and “Non-lead”, 57% of hunters indicated that they used “Lead” ammunition. While it is possible that some Lead Users may not distinguish between
the different types, it is likely uncommon as in most cases hunters are generally knowledgeable of the type of ammunition they use.

Per-round increase in cost to switch to non-lead can vary considerably depending on whether a hunter is currently using premium or non-premium ammunition. Further, increases in cost are substantiated for the primary ammunition used on refuges when comparing premium and non-premium ammunition. For the prominent firearms used by surveyed refuge hunters, namely 12-gauge shotgun and 0.50 caliber muzzleloader, the per round increase in cost to switch to non-lead alternatives can exceed 50% if a hunter is currently using non-premium lead ammunition.

Per-round cost increases may be especially relevant for hunters using smoothbore shotguns and buckshot rounds. In situations where hunters view steel buckshot as ineffective for harvesting deer, as identified through focus group discussions, switching to heavier than lead tungsten alloys can result in approximately a five-fold increase in cost per round. While on the surface this appears cost prohibitive, when per-round cost is placed the context of the average number of rounds a deer hunter uses to sight in and harvest a deer (~ 5), the cost increase is relatively insignificant in relation to a hunter’s annual expenditure. That notwithstanding, this does not account for the process of recalibration. Furthermore, limited product and retail availability of comparable alternatives to rifled slugs may have further economic impacts for hunters using such ammunition. Where such alternatives are unavailable there can be added economic impacts if a
new firearm, barrel, or rifled choke would need to be purchased in order to participate in voluntary non-lead use programs.

Following the 2017/2018 hunting season NWR Lead Users were asked about participation in a future program to offset any additional cost associated with purchasing non-lead ammunition. Volunteers overwhelming indicated (86%) that they would participate in such a program. In addition, 45% of Opposers indicated that they would participate. The large proportion of Lead Users using non-premium lead ammunition highlights the importance of utilizing strategies that reduce the initial cost in order to facilitate trialability and ultimately the recalibration process. The large proportion of Volunteers and Opposers indicating that they would avail of monetary incentive strategies suggests this may be a critical first step in overcoming perceived economic barriers, facilitating trialability, and promoting sustained voluntary non-lead use.

2.10.6 Observability

A population can be divided into five categories based on characteristics that determine the adoption of a new innovation (Rogers 2003). Innovators make up 2.5% of the population and are the first to try a new innovation. Innovators have the ability to understand and apply complex technical knowledge and cope with a high degree of uncertainty about an innovation. Early Adopters which make up 13.5% of the population adopt new ideas before the average person, are opinion leaders, and play a key role decreasing uncertainty about new innovations. The Early Majority which make up 34% of the population generally adopt new innovations before the
average person but typically need evidence that the innovation works before adopting it. The Late Majority, which constitutes 34% can be skeptical of change and will only adopt an innovation after it has been tried by the majority. With Laggards make up the remaining 16% of the population and are generally very conservative and skeptical of change.

Mail-back survey responses indicated that 18% of surveyed NWR hunters currently use non-lead ammunition for the purpose of harvesting white-tailed deer, highlighting the fact that the voluntary adoption of non-lead is underway on surveyed NWRs in Region 5. According to the Diffusion of Innovation Theory, currently non-lead ammunition use has been adopted by innovators and Early Adopters at all three refuges with a small proportion of the Early Majority at Rachel Carson and Rappahannock River Valley, underlining the potential importance of outreach and education strategies designed to target the Early Majority of potential adopters, the same category of potential adopters that typically need evidence that an innovation works prior to adopting it.

Rogers (2003) describes “observability” as the extent to which an innovation is visible to others and where tangible results of a novel innovation can be seen, the more likely an individual is to adopt its use. In this case, for non-lead to be observed to work by NWR hunters, it has to be observed to have comparable performance and efficacy. As previously discussed, performance and efficacy of non-lead ammunition are not viewed as equal by refuge Lead Users, with focus group discussions identifying that negative views regarding the compatibility of non-lead ammunition may be grounded in material composition. Nonetheless, approximately
one fifth of surveyed hunters currently use non-lead ammunition as a method of take with the primary motivation identified for switching being performance. While Non-lead Users generally viewed the performance of non-lead favorably or neutrally in comparison to lead ammunition, the efficacy of non-lead ammunition at guaranteeing an efficient kill was seen as slightly more positive. Furthermore, uncertainty about performance and efficacy of non-lead was relatively low among Non-Lead Users. The fact that a small proportion of Non-lead Users view performance as not being equal is not surprising. Different component materials of non-lead alternatives can affect the ballistics of a round. For example, non-lead monolithic rounds are designed to behave differently in terms of terminal ballistic behavior and a slight adjustment of shot placement may be needed when harvesting a deer (HWNL 2019). It is possible that Non-lead Users that view performance as being unequal may in fact view non-lead as superior given that performance was a primary motivation indicated for switching.

For refuge Lead Users, knowing that the performance of non-lead ammunition would be similar in terms of accuracy and killing efficiency (observability) was indicated as the primary factor that would influence both Volunteers and Opposers to switch to non-lead alternatives. Unfortunately, existing comparative studies are not reflective of the most common firearm and ammunition combinations used by NWR hunters to harvest white-tailed deer (Knott et al. 2010, Trinogga et al. 2013, Kanstrup et al. 2016, McCann et al. 2016, Martin et al. 2017). In the absence of representative in-field studies, the use of existing studies to demonstrate observability is questionable as it may signal to NWR hunters a lack of
understanding of the technical aspects associated with transitioning to non-lead. Placing uncertainty on whether using results from such studies to demonstrate observability of non-lead alternatives to refuge hunters is appropriate. Especially, considering that the voluntary use of non-lead ammunition has already occurred for Innovators and the Early Majority. As Rogers (2003) noted, outside of Innovators the majority of individuals within a population depend on the subjective evaluation of an innovation by those who have already adopted it. Drawing attention to trusted sources on ammunition and effective communication strategies as a means to demonstrate observability.

As part of their assessment of the impact of monetary incentive programs on initial use rates of non-lead ammunition, Chase and Rabe (2015) suggested that agencies can share success stories and anecdotal endorsements from hunters currently using non-lead as a mechanism to demonstrate observability and promote voluntary use. Communication and the transfer of ideas occurs more frequently between individuals that are homophilic, or alike, and as Rogers (2003) describes, when individuals are alike, the transfer of ideas is likely to be more effective because they share common beliefs, similar definitions, and have mutual understandings. Considering the absence of comparative in-field studies for prominent firearm and ammunition combinations used by NWR hunters, communication strategies that utilize change agents and homophilic communication channels in this way may be necessary to demonstrate observability and counter negative perceptions of the efficacy of non-lead alternatives. Change agents in the context of non-lead use being identified individuals or groups that can promote the
flow of innovation from the change agency (in this case the refuge system) to hunters (Schulz et al. 2019).

At the individual level, sharing harvest success stories has the potential to counter negative perceptions of non-lead alternatives in two ways. First, they can illustrate the viable use of non-lead ammunition for harvesting white-tailed deer by placing non-lead use in a context that is understandable and relatable to NWR hunters. Secondly, sharing harvest success stories enables non-lead use to be linked not just to specific refuges and hunting conditions but also to particular firearm and ammunition combinations used by NWR hunters. However, sharing harvest success stories while potentially important in overcoming initial perceptions of non-lead performance and efficacy for some refuge hunters, may be limited in achieving broader scale behavioral change in ammunition choice in of itself. The reason being that while 61% of surveyed hunters indicated other hunters as a source for information on ammunition, only 17% indicated other hunters as a reliable source. Questioning the broad scale effectiveness of individual change agents at influencing voluntary non-lead use among refuge hunters. Two other main sources on ammunition choice outside of other hunters were hunting magazines and state agencies with about a third of hunters indicating each as a source. Interestingly, only 14% of hunters indicated state agencies as being a reliable source with reliability of other sources being either low or virtually absent. However, 84% of hunters indicated personal experience as a source of information regarding ammunition with 47% of hunters indicating personal experience as a reliable source.
As part of the “Oregon Zoo Non-lead Hunter Education Program” outreach strategies to demonstrate observability of non-lead alternatives have incorporated shooting demonstrations. Using ballistic gel or water barrel bullet collection methods has helped mimic real life scenarios and provided attendees with evidence of fragmentation rates of different lead-based ammunition in addition to performance of non-lead alternatives. Under certain conditions, such outreach strategies can provide hunters with the ability to test non-lead alternatives with their existing firearm, providing first-hand experience with non-lead use. However, as Brown (2017) noted such events are complex to hold and are considered a high value outreach strategy. Brown (2017) concluded that for demonstration clinics a more strategic approach engaging local hunting organization chapters as in lieu of individual hunters may be more effective at influencing larger scale behavioral change towards non-lead ammunition use. NWRs in Region 5 could use a similar approach in conjunction with other outreach and education strategies which would allow such demonstrations to be catered to firearm and ammunition combinations specific to each refuge, ultimately demonstrating observability of non-lead alternatives relevant to combinations NWR hunters actually use.

2.10.7 Conclusion

The purpose of this study was to identify barriers to the voluntary use of non-lead alternatives for harvesting white-tailed deer as perceived by hunters on NWRs in Region 5. Information collected through the mail-back survey and focus group discussions have important implications for future outreach and education
strategies designed to reduce lead ammunition use for this hunting application. Overall the findings from this study suggest that while the majority of NWR Lead Users are willing to switch to non-lead for harvesting deer, a number of perceived and practical barriers may impede voluntary non-lead use.

An overwhelming number of NWR hunters indicated that they view themselves as valuable wildlife conservationists. However, only a small proportion of hunters viewed continued lead ammunition use as an issue that wildlife managers should be concerned about. An attitude that may be partly due to how hunters interpret the mechanism of exposure for non-target species as a result of harvesting white-tailed deer. A deficit in understanding or misinterpretation of the underlying mechanism of lead exposure among refuge hunters places the relative advantage of non-lead use for this hunting application in doubt. This combined with hunters not attributing their individual actions as contributing to the problem of non-target species exposure is further compounded by the current dialogue on population level impacts in the U.S.

Discussions surrounding population level impacts as a result of continued lead ammunition use have been predominantly focused on whether impacts reduce population levels and disregard effects on population growth rates. A position that may reinforce a perceived lack of negative impacts on non-target species among hunters. Furthermore, it may propagate the belief among some members of the hunting community that individual mortality of non-target species through lead exposure is an acceptable byproduct of hunting. Therefore, outreach and education strategies that clearly outline the mechanism of lead exposure and frame individual
non-lead use as a means of removing a potential source of both individual mortality and sublethal lead exposure for non-target species may be key in demonstrating the relative advantage of non-lead use. As part of this approach, reframing the current dialogue around population impacts from decreasing populations to incorporate impacts to depressing population growth may be beneficial. In addition, to demonstrate the relative advantage of non-lead use, it may be constructive for education strategies to emphasize the rich conservation legacy of hunters and their role as active members of the ecosystem from which they extract wildlife resources. Thereby, promoting the positive impacts of individual non-lead use and how this can strengthen and expand their relationship to the ecosystem as a whole.

Information collected through focus group discussions and mail-back surveys identified the compatibility of non-lead alternatives as a major concern for NWR hunters when harvesting white-tailed deer. With negative perceptions of reduced performance and subsequent efficacy in the field and harvest success often grounded in material composition of non-lead alternatives. How hunters view the future voluntary use of non-lead ammunition will undoubtedly be dependent on current firearm and ammunition use, as this directly impacts perceptions of efficacy and the ability of hunters to recalibrate successfully. Current research related to the efficacy and performance of non-lead alternatives in the field is positive, with factors other than material composition of non-lead alternatives identified as greater predictors of harvest success. However, it is not reflective of firearm and ammunition combinations used by the majority NWR hunters in Region 5. Questioning the use of such studies in outreach and education to illustrate the
compatibility of non-lead alternatives for harvesting deer. Thereby, underscoring the importance of outreach and educations strategies that highlight the compatibility of non-lead alternatives relevant to what hunters actually use on specific NWRs.

For NWR hunters to switch to non-lead alternatives involves the same process as switching between two brands of lead ammunition with complexity of use from a technical standpoint ultimately lying in slight adjustments of existing harvesting techniques depending on the combination of firearm and ammunition used. To get to this point a hunter has to recalibrate. As a result, the technical complexity of use associated with non-lead alternatives is compounded by the availability of viable alternatives. A condition that may disproportionately affect hunters using smooth bore shotguns and rifled slugs. This issue of product availability of course needs to be addressed at the stage of alternative ammunition development and manufacturing and is beyond the scope of outreach and education. However, it is ultimately a critical step in facilitating the recalibration process for a large proportion of NWR hunters. For hunters using firearm and ammunition combinations where a wider variety of product availability exists, perceptions of retail availability may be influenced by how hunters purchase ammunition. NWR hunters predominantly acquire ammunition through local vendors, indicating that from a voluntary use standpoint, strategies that work to maintain existing purchasing routes by increasing local availability instead of relying on the use of online purchasing routes may be more effective at reducing the complexity associated with recalibration and may be critical in facilitating voluntary use.
Beyond strategies aimed to increase local availability of non-lead alternatives, complexity of use hinges on the ability of NWR hunters to successfully recalibrate. The current focus on per-round increases in cost by refuge hunters suggests that approaches that incorporate economic incentives at the refuge level may be an important factor in overcoming perceived economic barriers and influencing alternative ammunition use. Both by challenging how hunters contextualize the associated cost of non-lead use, in addition to the reducing the potential cost associated with recalibration. A large proportion of Volunteers and Opposers indicated that they would avail of such economic incentive strategies. Indicating that such approaches can encourage trialability of non-lead alternatives and may be vital outreach component in overcoming negative perceptions of cost and facilitating the recalibration process.

The voluntary use of non-lead ammunition for harvesting white-tailed deer is already underway on NWR’s in Region 5. Based on the proportion of refuge hunters that have already adopted non-lead use of their own volition (Innovators and Early Adopters). Outreach and education strategies may benefit by initially focusing on demonstrating observability of non-lead alternatives to the Early Majority. A necessary step involved in influencing broader use of a novel innovation, as the Late Majority are typically skeptical of change and will only adopt a novel innovation after is being used by the majority of a population. Sources that refuge hunters use for information on ammunition and viewed reliability of those sources suggest that recruiting individual hunters and hunting groups as change agents to demonstrate
observability and influence ammunition choice may have limited effectiveness in the absence of outreach strategies designed to facilitate trialability.
**APPENDIX A**

**MAIL - BACK SURVEY**

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**EDWIN B. FORSYTHE NATIONAL WILDLIFE REFUGE**

**HUNTER SURVEY 2017/2018**

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UMassAmherst
The Commonwealth's Flagship Campus

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**INSTRUCTIONS**

- Where applicable, please place an “X” in the box of your answer.
- Where applicable please provide written answers.

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**HUNTING**

1. How many years have you hunted white-tailed deer?
   - ☐ Less than 5 years
   - ☐ Between 5 and 10 years
   - ☐ Between 11 and 20 years
   - ☐ More than 20 years

2. How many days did you hunt white-tailed deer at Edwin B. Forsythe NWR during the 2017/2018 hunting season?
   - ☐ Yes
   - ☐ No

3. How many days did you spend hunting at Edwin B. Forsythe NWR during the 2017/2018 hunting season?
   - ☐ Days

4. How many days did you spend hunting at Edwin B. Forsythe NWR for the 2017/2018 hunting season?
   - ☐ Days

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**AMMUNITION USAGE**

6. What type of ammunition do you normally use to target practice?
   - Please check all that apply:
     - ☐ Lead
     - ☐ Lead alloy
     - ☐ Lead core
     - ☐ Non-lead
     - ☐ I don’t target practice

7. a. What type of ammunition do you normally use to hunt white-tailed deer?
     - Please check all that apply:
       - ☐ Lead
       - ☐ Lead alloy
       - ☐ Lead core
       - ☐ Non-lead

7. b. If you answered Non-lead to question 7a, why did you switch to using non-lead ammunition?
     - Please check all that apply:
       - ☐ I tried non-lead ammunition and liked how it performed
       - ☐ I switched to non-lead ammunition out of concern for wildlife health
       - ☐ I switched to non-lead ammunition out of concern for personal or family health
       - ☐ Other: __________________

8. What type of ammunition did you use to hunt white-tailed deer at Edwin B. Forsythe NWR during the 2017/2018 hunting season?
   - Please check all that apply:
     - ☐ Lead
     - ☐ Lead alloy
     - ☐ Lead core
     - ☐ Non-lead
     - ☐ I didn’t hunt

9. How did you obtain your ammunition for the 2017/2018 hunting season?
   - Please check all that apply:
     - ☐ Purchased in-store (Off the shelf)
     - ☐ Ordered online (Off the shelf)
     - ☐ Reloading
     - ☐ Other: __________________
11. Did you use a muzzleloader to harvest white-tailed deer at Edwin B. Forsythe NWR during the 2017-2018 hunting season?  
☐ Yes  ☐ No  ☐ If you checked No, skip to question 13

b. What calibre did you use?  
☐ 45  ☐ .50  ☐ .54  ☐ .58  ☐ Other: __________

e. Which projectile type did you use?  
☐ Punctured round ball  ☐ Conical bullet  ☐ Sabot slug

12. Which of the following have been sources of information for you regarding the type of ammunition you use? Please check Yes or No for each source
☐ Edwin B. Forsythe National Wildlife Refuge employee  ☐ Yes  ☐ No
☐ U.S. Fish and Wildlife Service  ☐ Yes  ☐ No
☐ New Jersey Division of Fish and Wildlife  ☐ Yes  ☐ No
☐ Federal science agency: Please list: __________  ☐ Yes  ☐ No
☐ Conservation organization: Please list: __________  ☐ Yes  ☐ No
☐ National Rifle Association (NRA)  ☐ Yes  ☐ No
☐ Hunting organization: Please list: __________  ☐ Yes  ☐ No
☐ Sportsmen’s hunting magazine  ☐ Yes  ☐ No
☐ Mass media  ☐ Yes  ☐ No
☐ Gun Store clerk  ☐ Yes  ☐ No
☐ Other Hunters  ☐ Yes  ☐ No
☐ Personal experience  ☐ Yes  ☐ No
☐ Other: __________

13. Based on the sources of information on ammunition in question 12, which one do you feel is the most reliable source?  

14. Information about ammunition choices can be delivered to hunters in a variety of ways. Which do you prefer? Please check all that apply.
☐ Printed materials  ☐ Personal contact  ☐ TV or radio
☐ Social media  ☐ Email
☐ New Jersey Division of Fish and Wildlife “Hunting Regulations”
☐ Other: Please list: __________

15. How much do you agree or disagree with the following statements about ammunition and hunting?  

a. Hunters are valuable wildlife conservationists.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

b. Hunters contribute to the conservation of wildlife resources through the type of ammunition they use.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

c. Non-lead ammunition and lead based ammunition perform the same.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

d. Non-lead and lead based ammunition are equally effective at preventing an effective kill.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

e. Non-lead ammunition can damage deer tissues.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

f. Availability of lead and non-lead ammunition is about the same.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

g. Non-lead and lead based ammunition cost about the same.  
☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

16. How does lead ammunition impact your consumption of deer meat, if at all?  

Please pick the answer that most closely applies to you:
☐ Using lead ammunition does not impact my consumption of deer meat.
☐ I serve out deer meat but try to minimize exposure to lead fragments by removing meat around the wound channel.
☐ I only hunt with non-lead ammunition, so lead ammunition has no impact on my consumption of deer meat.

17. How much do you agree or disagree with the following statements concerning the use of lead ammunition for hunting deer?  

☐ Strongly Agree  ☐ Somewhat Agree  ☐ Neither Agree nor Disagree  ☐ Somewhat Disagree  ☐ Strongly Disagree  ☐ Don’t Know

- Lead projectiles can fragment into tiny pieces and become lodged in the entrance and exit wounds of deer as a result of impact.
- It is possible to ingest lead fragments through consuming deer shot with lead ammunition.
- Consuming deer killed by a lead projectile poses no risk to humans if it is properly field-dressed.
- Lead is a naturally occurring element that can be harmful when consumed by living animals.
- Consuming deer harvested with lead ammunition can have a negative impact on human health.
- I do not think lead from spent ammunition is a problem for wildlife.
- Lead ingestion can harm birds that scavenge gut piles of deer.
- Lead ingestion can harm animals other than birds that scavenge gut piles of deer.
- Wildlife managers should be concerned about the effects of lead from spent ammunition on wildlife.
- Hunters are generally well informed about non-lead ammunition available for hunting deer.
18. How much do you agree or disagree with the following statement?  
   a. Lead shot for hunting waterfowl was banned because it was negatively affecting waterfowl populations in the U.S.  
      | Strongly Agree | Somewhat Agree | Neither Agree nor Disagree | Somewhat Disagree | Strongly Disagree | Don't Know |
      |                |                |                           |                  |                  |           |

   b. Scientific research is the most reliable way to determine if spent lead ammunition is having a negative effect on wildlife.  
      | Strongly Agree | Somewhat Agree | Neither Agree nor Disagree | Somewhat Disagree | Strongly Disagree | Don't Know |
      |                |                |                           |                  |                  |           |

19. What are the reasons, if any, that would influence you to switch to non-lead ammunition when hunting white-tailed deer?  
<table>
<thead>
<tr>
<th>Reason</th>
<th>Yes</th>
<th>No</th>
<th>Don't Know</th>
</tr>
</thead>
</table>
   a. If I knew there were negative health effects on people as a result of using lead-based ammunition. |     |    |           |
   b. If I knew there were negative health effects on wildlife as a result of using lead-based ammunition. |     |    |           |
   c. If I knew performance would be similar to lead-based ammunition in terms of accuracy and killing efficiency. |     |    |           |
   d. If I knew non-lead ammunition for my firearm was available locally. |     |    |           |
   e. If I knew non-lead ammunition for my firearm was available online. |     |    |           |
   f. If I knew non-lead ammunition would not damage my firearms. |     |    |           |
   g. If the cost was no more than 25% greater than lead-based ammunition. |     |    |           |
   h. If the cost was between 25% and 50% higher than lead-based ammunition. |     |    |           |
   i. I would never switch to non-lead ammunition. |     |    |           |
   j. Other reason. Please describe: |     |    |           |

20. Some states have created voluntary programs in which hunters are given coupons or rebates for any additional cost of purchasing non-lead ammunition. How much do you agree or disagree with the following statement?  
   If provided, I would use a coupon or reimbursement program to offset any additional cost of purchasing non-lead ammunition.  
      | Strongly Agree | Somewhat Agree | Neither Agree nor Disagree | Somewhat Disagree | Strongly Disagree | Don't Know |
      |                |                |                           |                  |                  |           |

21. If a pilot study to reduce or eliminate the use of lead-based ammunition were introduced at National Wildlife Refuges, how would your participation in hunting change, if at all?  
   a. I would quit hunting at refuges (like Edwin B. Forsythe NWR). |     |    |           |
   b. I would change my hunting activities at refuges (like Edwin B. Forsythe NWR). |     |    |           |
   c. I would increase my hunting activities at refuges (like Edwin B. Forsythe NWR). |     |    |           |
   d. I don't know. |     |    |           |

22. Would you be willing to voluntarily switch to using non-lead ammunition to hunt white-tailed deer on National Wildlife Refuges?  
   If so: What is the primary reason you would not be willing to voluntarily switch to non-lead ammunition to hunt white-tailed deer on National Wildlife Refuges?  
      | Yes | No | Reason |
      |     |    |       |

Demographic Information:  
Your demographic information will help with data analysis. This information will ONLY be used for research purposes. When you return your survey in the enclosed envelope, it goes directly to the researcher. Your individual results will not be provided to Edwin B. Forsythe National Wildlife Refuge or any other party.  

Gender:  
- [ ] Male  
- [ ] Female  

Age:  
- [ ] 24 or under  
- [ ] 25-44  
- [ ] 45-64  
- [ ] 65 or over  

Education:  
- [ ] High School  
- [ ] Some college  
- [ ] College degree  
- [ ] Graduate degree  

Zip Code:  

Thank you for participating in this survey!  
Please return the survey in the postage-paid envelope provided.
Date:

Dear

I am writing to ask for your help to improve our understanding of hunters’ views on lead and alternative non-lead ammunition usage when hunting white-tailed deer on National Wildlife Refuges. You are part of a small group of hunters that have been selected because you applied for a permit to hunt white-tailed deer at Edwin B. Forsythe National Wildlife Refuge. You will be asked for your opinions about the use of lead ammunition for hunting and the factors that influence your ammunition purchases.

This study is important and I encourage you to participate to help ensure that the thoughts and opinions of hunters are reflected in any future discussions regarding lead ammunition use for hunting on National Wildlife Refuges. By taking the time to complete this survey you will be contributing to our understanding of hunters’ attitudes and beliefs towards lead and alternative non-lead ammunition.

Please return the completed survey in the postage paid return envelope provided. The return addressed envelope is numbered to remove your name from any further contact. Your responses are completely voluntary and will never be linked to your name or your mailing address. If you have any questions about this survey please contact me (Christopher Cahill) by telephone at (617) 435-3449 or by email atchrmcahill@umass.edu. I look forward to receiving your responses.

Many Thanks,

Christopher Cahill

Massachusetts Cooperative Fish and Wildlife Research Unit
University of Massachusetts-Amherst
Department of Environmental Conservation
160 Holdsworth Way
Amherst, MA 01003
Appendix C

Non-personalized reminder letter

Date:

Dear

Recently I sent you a survey asking for your views on lead and alternative non-lead ammunition usage when hunting white-tailed deer on National Wildlife Refuges. To the best of my knowledge, I have not yet received your responses. If you have returned the survey please ignore this letter.

I am writing again because of the importance of your responses and the insights your views will contribute to our understanding of hunters’ attitudes and beliefs towards lead and alternative non-lead ammunition. Thus, I hope you will fill out the survey soon. This study is important and I encourage you to participate to help ensure that the thoughts and opinions of hunters are reflected in any future discussions regarding lead ammunition use for hunting on National Wildlife Refuges.

Please complete the survey and return it in the postage paid return envelope provided. The return addressed envelope is numbered to remove your name from any follow up contact. Your responses are completely voluntary and will never be linked to your name or your mailing address. If you have any questions about this survey please contact me (Christopher Cahill) by telephone at (617) 435-3449 or by email at chrncahill@umass.edu. I look forward to receiving your responses.

Many Thanks,

Christopher Cahill

Massachusetts Cooperative Fish and Wildlife Research Unit
University of Massachusetts-Amherst
Department of Environmental Conservation
160 Holdsworth Way
Amherst, MA 01003
Date:

Dear

Recently I sent you a request asking for your views on lead and alternative non-lead ammunition usage when hunting white-tailed deer on National Wildlife Refuges. To the best of my knowledge, I have not yet received your responses. If you have already returned the survey please ignore this package.

I am writing again to ask for your help to improve our understanding of hunters’ views on lead and alternative non-lead ammunition usage when hunting on National Wildlife Refuges. You are part of a small group of hunters that have been selected because you applied for a permit to hunt white-tailed deer at Edwin B. Forsythe National Wildlife Refuge. You will be asked for your opinions about the use of lead ammunition for hunting and the factors that influence your ammunition choice.

Please return the completed survey in the postage paid return envelope provided. The return addressed envelope is numbered to remove your name from any follow up contact. Your responses are completely voluntary and will never be linked to your name or your mailing address. If you have any questions about this survey please contact me (Christopher Cahill) by telephone at (617) 435-3449 or by email at chrmcahill@umass.edu.

This will be the final mail you will receive in regards to this study. This study is important and I encourage you to participate to help ensure that the thoughts and opinions of hunters are reflected in any future discussions regarding lead ammunition use for hunting on National Wildlife Refuges. I look forward to receiving your responses.

Many Thanks,

Christopher Cahill

Massachusetts Cooperative Fish and Wildlife Research Unit
University of Massachusetts-Amherst
Department of Environmental Conservation
160 Holdsworth Way
Amherst, MA 01003
APPENDIX E
NON-RESPONSE TELEPHONE SURVEY

1. What type of ammunition do you normally use to hunt white-tailed deer?
   ☐ Lead ☐ Lead alloy ☐ Lead core ☐ Non-lead

2. Would you be willing to voluntarily switch to using non-lead ammunition to hunt white-tailed deer on National Wildlife Refuges?
   ☐ Yes  ☐ Skip to question 3  ☐ No
   If no: What is the primary reason you would not be willing to switch to non-lead ammunition to hunt white-tailed deer on National Wildlife Refuges?

3. If a program to reduce or eliminate the use of lead-based ammunition were introduced at National Wildlife Refuges, how would your participation in hunting change?
   ☐ I would quit hunting at refuges (like Great Swamp NWR).
   ☐ I would not change my hunting activities at refuges (like Great Swamp NWR).
   ☐ I would increase my hunting activities at refuges (like Great Swamp NWR).
   ☐ Don’t know.

Demographics:
What age group do you belong to?
Age: ☐ 24 or under ☐ Between 25-44 ☐ Between 45-64 ☐ 65 or over

Education:
What level of education do you currently hold?
☐ High School ☐ Some college ☐ College degree ☐ Graduate degree
Hello,

My name is Christopher Cahill. I am calling on behalf of (Refuge Name) NWR. This is in relation to a study on ammunition use that I am conducting at the refuge. I am calling because I am looking for hunters to participate in a focus group at the refuge next Saturday (Time and Date). If this is something you might be interested in doing, please give me a call at (Phone Number).

Thank you.
APPENDIX G

FOCUS GROUP INTERVIEW GUIDE

1. Have you heard or read anything on the effects of lead on humans?
2. Have you heard or read anything on the effects of lead ammunition use on humans?
3. Have you heard or read anything on the effects of lead ammunition use on wildlife?
4. Who or what influences your decision to purchase a particular type of ammunition?
5. Which sources on non-lead ammunition would you view as credible?
6. Have you ever switched brands or types of ammunition? What brought about the change?
7. What are the reasons, if any, that would influence you to switch to nonlead ammunition for hunting white-tailed deer?
8. What is the primary reason you would not be willing to voluntarily switch to non-lead ammunition to hunt white-tailed deer?
9. What ways do you prefer to receive information on ammunition choices?
10. If a program to reduce use of or eliminate ammunition that contains lead were on National Wildlife Refuges, how would your participation in hunting change, if at all?
11. Of all the things we discussed, what to you is the most important?
12. Have we missed anything?
APPENDIX H

FOCUS GROUP CONSENT FORM

Consent Form for Participation in a Research Study
University of Massachusetts Amherst

RESEARCHER: STUDENT: Christopher Cahill, Massachusetts Cooperative Fish and Wildlife Research Unit, Department of Environmental Conservation, University of Massachusetts, Amherst, MA 01003
Phone: (617) 435-3449
Email: chrmcahill@umass.edu

ADVISOR: Stephen DeStefano, U. S. Geological Survey, Massachusetts Cooperative Fish and Wildlife Research Unit, Department of Environmental Conservation, University of Massachusetts, Amherst, MA 01003
Phone: (413)-250-4083
Email: sdestef@eco.umass.edu

Study Title: Assessing Attitudes And Impacts To Society Associated With The Use Of Alternative Ammunition For Hunting On National Wildlife Refuges

Funding Agency: U.S. Fish and Wildlife Service; U.S. Geological Survey

I. WHAT IS THIS FORM?

This form is called a Consent Form. It will give you information about the study so you can make an informed decision about participation in this research. This consent form will give you the information you will need to understand why this study is being done and why you are being invited to participate. It will also describe what you will need to do to participate and any known risks, inconveniences or discomforts that you may have while participating. We encourage you to take some time to think this over and ask questions now and at any other time. If you decide to participate, you will be asked to sign this form and you will be given a copy for your records.
2. WHO IS ELIGIBLE TO PARTICIPATE?
All adult hunters possessing a permit to hunt white-tailed deer, at Edwin B. Forsythe National Wildlife Refuge for the 2017/18-hunting season.

3. WHAT IS THE PURPOSE OF THIS STUDY?
We are conducting this research study to understand the attitudes and beliefs of hunters towards a voluntary transition to using non-lead ammunition when hunting white-tailed deer at Edwin B. Forsythe National Wildlife Refuge. Specific topics for discussion are outlined in question 5.

4. WHERE WILL THE STUDY TAKE PLACE AND HOW LONG WILL IT LAST?
The focus group will take place at Edwin B. Forsythe National Wildlife Refuge and will last approximately 60 to 90 minutes.

5. WHAT WILL I BE ASKED TO DO?
If you agree to take part in this focus group, you will be asked to provide feedback on a variety of human dimensions topic areas associated with a voluntary switch to non-lead ammunition. Each focus group session will be recorded using digital audio. Questions will address understanding of the goals of non-lead ammunition use, current ammunition usage and perceptions of non-lead based ammunition performance. Additional question topics will include: attitudes regarding the effects of lead-based ammunition on wildlife and human health, availability and cost of non-lead based ammunition, factors that influence choice of ammunition, sources that hunters use for information on non-lead ammunition and viewed credibility of sources, viewed credibility of alternative sources for information on non-lead based ammunition, prior hunting experience with non-lead ammunition.

6. WHAT ARE MY BENEFITS OF BEING IN THIS STUDY?
You may not directly benefit from this research; however, we hope that your participation in the study may help inform potential management decisions regarding a voluntary switch to non-lead ammunition on National Wildlife Refuges.
7. WHAT ARE MY RISKS OF BEING IN THIS STUDY?
We believe there are no known risks associated with participating in this focus group; however, a possible inconvenience may be the time it takes to complete the focus group.

8. HOW WILL MY PERSONAL INFORMATION BE PROTECTED?
The following procedures will be used to protect the confidentiality of your responses at this focus group. The researchers will keep all audio recordings on a password-protected computer. Focus group members will be randomly assigned numerical identifiers when the audio from the focus group is transcribed. No key to identify individual participants from numerical identifiers will be kept. Digital transcripts of focus group audio recordings will be kept on a password-protected computer. Signed consent forms will be contained in a locked filing cabinet in the office of Dr. Stephen DeStefano at the University of Massachusetts, Amherst. Hard copy and digital data sources will only be accessible to the researcher and research advisors. The digital audio recordings will be destroyed within 6 years or upon completion of the study. At the conclusion of this study, the researchers may publish their findings. Summary information will be provided to Edwin B. Forsythe National Wildlife Refuge and National Wildlife Refuge administrators of the U.S. Fish and Wildlife Service to help inform them on stakeholder attitudes and beliefs relative to possible management implications. Summary information will be provided in aggregate form. Your individual responses will not be provided and you will not be identified in any publications or presentations. Please be advised that although the researchers will take every precaution to maintain confidentiality of the data, the nature of focus groups prevents the researchers from guaranteeing confidentiality. The researchers would like to remind participants to respect the privacy of your fellow participants and not repeat what is said in the focus group to others.

9. WILL I RECEIVE ANY PAYMENT FOR TAKING PART IN THE STUDY?
Participation in this focus group is voluntary.
10. WHAT IF I HAVE QUESTIONS?
Take as long as you like before you make a decision. We will be happy to answer any question you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the researcher (Christopher Cahill (617) 435-3449). If you have any questions concerning your rights as a research subject, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) at (413) 545-3428 or humansubjects@ora.umass.edu.

11. CAN I STOP BEING IN THE STUDY?
You do not have to participate in this study if you do not want to. If you agree to be in the focus group, but later change your mind, you may drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate.

12. WHAT IF I AM INJURED?
The University of Massachusetts does not have a program for compensating subjects for injury or complications related to human subjects research, but the study personnel will assist you in getting treatment.

13. SUBJECT STATEMENT OF VOLUNTARY CONSENT
When signing this form I am agreeing to voluntarily participate in this focus group. I have had a chance to read this consent form, and it was explained to me in a language, which I use and understand. I have had the opportunity to ask questions and have received satisfactory answers. I understand that I can withdraw at any time. A copy of this signed Informed Consent Form has been given to me.

Participant Signature: ________________________ Print Name: ________________________ Date: ________________________

By signing below I indicate that the participant has read and, to the best of my knowledge, understands the details contained in this document and has been given a copy.

Signature of Person obtaining consent ________________________ Print Name: ________________________ Date: ________________________


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