The Quest to Eliminate Lead from Units of the National Park System: Understanding and Reaching Out to Audiences

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Introduction

THIS REPORT IS INTENDED TO SYNTHESIZE THE RELEVANT LITERATURE regarding issues involving the use of lead in recreational hunting and fishing activities. We begin the report with a brief overview of lead use in the US and the emerging awareness of the hazards of lead to human health and the natural environment. This overview is followed by a discussion of the National Park Service's (NPS's) efforts to reduce the impacts of lead from hunting and fishing in NPS units. We then turn to an important emphasis of this report, which is on the role of the social sciences and human dimensions information in addressing the issue of lead in the environment. Included in this section is a discussion of the need for public outreach to help raise stakeholder awareness and support for future management actions. Also included is an overview of relevant theories and frameworks from social psychology and risk communication that can be used to inform outreach activities. Later sections of the report provide additional background on the use of lead in hunting and fishing as well as specific measures, including regulatory action and voluntary mechanisms, that have been introduced by agencies and organizations in the US to reduce the lead-related impacts of these activities. We conclude with overall recommendations for future outreach initiatives and research to reduce the impacts of lead from hunting and fishing.

A brief history of lead use and effects on human health and the environment

For over 2000 years the toxic effects of lead in humans and animals have been well documented (Nriagu 1983). As far back as 1848, the famous medical observations of Tanquerel Des Plances described human lead poisoning (Pokras and Kneeland 2009). Despite the long history of lead's adverse health effects, approximately 3,600,000 metric tons of lead are refined annually for commercial uses (Eisler 2000). The use of lead for fishing net sinkers dates back to 3300–1200 BCE (Pulak 1988; Galili et al. 2002), and lead use for ammunition emerged in the 14th century (Tunis 1954). The production of lead ammunition and fishing

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tackle continues today; the US Geological Survey (USGS) estimates that roughly 10% of lead produced in, or imported to, the US is used for sporting purposes (Guberman 2007).

Lead ammunition and fishing tackle, when used as intended, release lead into the environment. The USGS estimates that 6,000–10,000 tons of lead are released by hunters and anglers annually in the US (Guberman 2007), but the use of lead ammunition and tackle is minimally regulated by state and federal agencies. This seems to contradict the efforts of state and federal regulatory agencies in the US that try to minimize the amount of lead released into the environment from mining, manufacturing, and the recycling of lead products by requiring permits for any sort of industrial lead release (Pokras and Kneeland 2009).

The effects of spent lead shot and bullets on wildlife have been recognized in the US since the 1870s (Sanderson and Bellrose 1986), and the hazards of lead fishing sinkers to waterbirds were recognized in the 1970s when swans were poisoned in the UK (Sears 1988). The documentation of lead's toxic effects on wildlife has accumulated; over 500 peer-reviewed articles have examined the impacts of lead ammunition on wildlife (Petterson 2009). Recent studies have illustrated that lead ammunition fragments on impact much more than previously believed, dispersing small lead particles throughout the tissues of game animals (Grund et al. 2010; Pain et al. 2010). Fragmentation varies widely by ammunition type; Grund et al. (2010) found that rapid-expansion bullets fragment to a higher degree than controlled-expansion bullets, for example. Fragments in the tissues of animals harvested with lead bullets or lead shotgun pellets are a serious source of lead exposure to scavenging animals that consume the meat with lead fragments; an estimated 134 species, including reptiles, birds, and mammals, have been poisoned by ingesting lead from spent ammunition and fishing tackle in the environment (Petterson 2009), and similar pathways exist for humans.

The ingestion of lead can lead to a range of molecular and behavioral effects as well as mortality and population-level consequences in some species (Rattner et al. 2008). Some of the noted adverse effects on human health are headaches, fatigue, myalgia, arthralgia, abdominal discomfort, renal system dysfunction, anemia, impaired fetal development, and brain dysfunction (NCM 2003; Kosnett 2009). Recent studies have also tied elevated bone or blood lead levels (BLLs) to increased aggression, delinquent behavior, and attention-deficit hyperactivity disorder (Needleman 2004; Braun et al. 2006). Many of the effects occur at moderate-to-low levels of exposure, and a statement from the Centers for Disease Control and Prevention (CDC) in 2005 stated that there is no threshold BLL value for which there is no effect. Due to the nonspecific nature of many of the symptoms, especially low-level exposure effects, the causes are often attributed to other relatively common acute and chronic diseases (Kosnett 2009). This may be one of the reasons that lead is still being used; even though empirical evidence suggests that lead ingestion does occur, the health risks are not overt enough to prove causation.

A lack of overt causation is one of many factors that have contributed to the protracted use of lead for ammunition and fishing tackle. The potential hazardous effects of lead on humans, ecosystems, and fauna have led to greater societal pressure and concerted efforts to reduce the amount of lead introduced into the environment by human activities (Goddard et al. 2008), but strong opposition from sportsmen and industries has limited the success of

such actions. To further mitigate the impacts of lead from spent ammunition and fishing tackle in the environment, the arguments, attitudes, and beliefs of all stakeholders need to be understood.

NPS efforts to reduce the impacts of lead on its lands

The NPS has stepped up efforts to reduce lead in national park environments, starting with the recent policies to eliminate lead from internal NPS activities for the protection of human health, wildlife health, and ecosystem health. Lead reduction efforts began in 2001 when the Environmental Protection Agency (EPA), per Executive Order (EO) 13148 (EO 2000), lowered the threshold for lead releases into the environment from 1,000 to 100 pounds per calendar year. Parks with outdoor firing ranges were required to meet the new requirements for lead, and parks releasing at or over the 100-pound threshold were required to submit a toxic release inventory (TRI) to the EPA. In 2003, to lessen the NPS's reporting burden, comply with the EO, and mitigate further lead contamination of the environment, NPS began phasing out the use of leaded ammunition for firearms qualifications and shooting practice. In 2007, EO 13423 (EO 2007) required federal agencies to reduce the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed. NPS then mandated that a complete transition to non-lead ammunition for law enforcement qualification and training be achieved by October 1, 2008. The NPS transitioned to non-lead ammunition in culling operations and the dispatching of wounded and sick animals in 2009. These actions have advanced the NPS goal of being a leader in the use of least toxic products and services, for the protection of park employees, visitors, and the lands under NPS management.

Future efforts to further reduce lead contamination of the environment include exploring the prospect of reducing the effects from lead in public hunting and fishing activities in NPS units. Recreational hunting is generally prohibited in NPS units except in park areas where it is specifically mandated by federal law, and it may be allowed in park areas where it is specifically authorized as a discretionary activity under federal law; units with discretionary authorization must determine that hunting is consistent with public safety and enjoyment and sound resource management principles and must adopt special regulations to implement that authority (Code of Federal Regulations, Title 36, Pt. 2.2b, 2010). NPS currently manages 62 units that meet these criteria. Hunting is mandated or authorized and implemented on a discretionary basis under federal law in 61 of these units (Figure 1). Except in designated areas, or as outlined in the Code of Federal Regulations (Title 36, Pt. 2.3, 2010), fishing is allowed in park areas in accordance with the laws and regulations of the state in which the park is located. While the NPS is interested in all landscapes, it is first looking at its own footprint from lead use in parks and exploring ways to lessen that footprint as well as the impacts of park visitors who pursue hunting and fishing in units where these activities are allowed.

In March 2009, a NPS news release announced the goals of eliminating lead from NPS activities. It stated the intentions of the NPS to eventually remove all lead from NPS lands. Acting Director Dan Wenk was quoted as saying, "Our goal is to eliminate the use of lead ammunition and lead fishing tackle in parks by the end of 2010" (NPS 2009a). To some, this was an indication that the use of lead ammunition and fishing tackle by visitors in park units

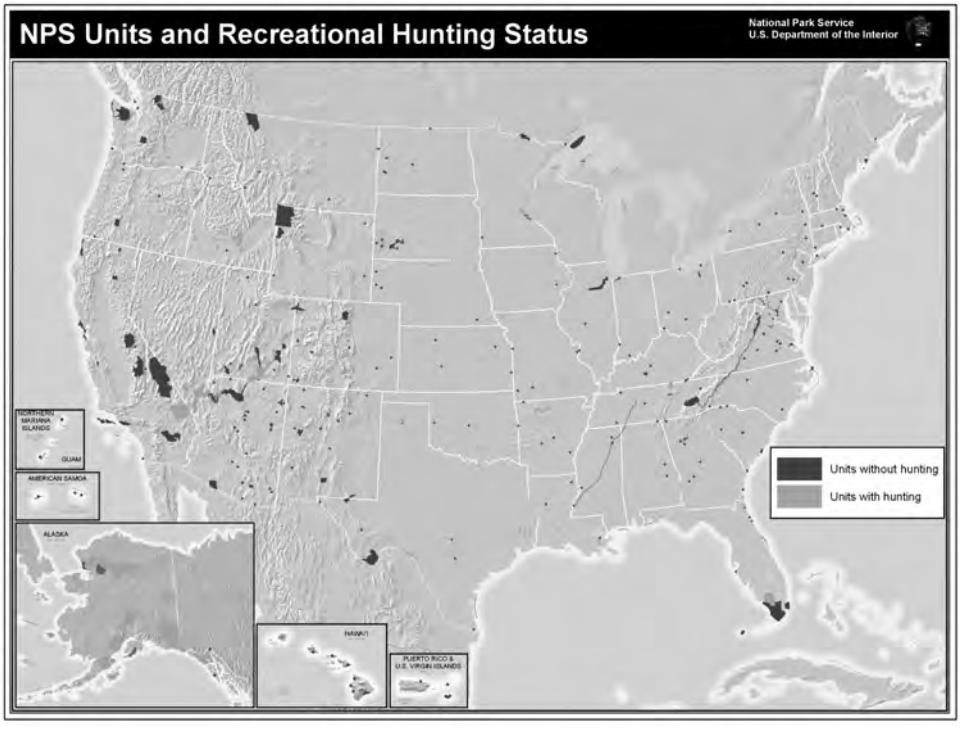

Figure 1. NPS units and recreational hunting status. "Units with hunting" include units where hunting is (1) mandated or (2) authorized and implemented on a discretionary basis, under federal law.

was in jeopardy. Reactions from stakeholders that followed indicated that this issue was highly visible and controversial. Several organizations were quick to offer comments and criticism. For example, the American Sportfishing Association (ASA), which opposes bans on lead fishing tackle, stated that if the NPS pursued such a ban, they would seek an appropriate rule-making process (ASA 2009). The National Rifle Association (NRA) also announced its intent to oppose NPS actions to eliminate lead ammunition, calling these actions unnecessary (NRA-ILA 2009). The response from the National Shooting Sports Foundation (NSSF) was similar (PLD 2009). Thirteen Republican US senators also spoke out against a possible NPS ban on lead ammunition, claiming that the ban would have negative impacts on hunters, the economy, and wildlife populations (PLD 2009).

While there was a strong response by opponents to the potential for future NPS action on this issue, there were also many proponents who demonstrated their support for requiring non-lead-based ammunition and fishing tackle. Public Employees for Environmental Responsibility (PEER) organized a group letter to Interior Secretary Ken Salazar urging him to support an NPS lead ban. In the letter, the groups stated, "We applaud the leadership demonstrated by this effort," and "We strongly support this effort to achieve a lead-free national park system by the end of 2010" (PEER 2009). Signatories included the Coalition of NPS Retirees, the Humane Society of the United States, Wildlife Stewards, the

Arizona Zoological Society, Desert Protective Council, Wilderness Watch, and Delaware Audubon. The groups cite the poisoning of wildlife and the potential for dissolved lead to contaminate groundwater as key reasons for their support.

Responses from all perspectives prompted the NPS to release a clarification statement days after the original news release; it stated that nothing had changed for the public and that the future potential for transitioning to non-lead for recreational use would enlist public involvement, comment, and review (NPS 2009b). The agency stated that its decision-making on this high-profile issue would be guided by a combination of the best available science, accurate fidelity to the law, and commitment to diverse public interests, along with significant public involvement, comment, and review. Further, the agency stated that it would address immediate controversies and long-term challenges, and ultimately improve its ability to preserve the integrity of park ecosystems. The NPS would review and consider all possible mechanisms for reducing the impacts of lead from hunting and fishing in park units. For example, conversion to the use of non-lead ammunition and fishing tackle would eliminate lead pathways to humans, wildlife, and the environment from hunting and fishing. Regulatory action is one way of attempting to achieve such a conversion, but issues of compliance and enforcement may affect the success of this type of action. Non-regulatory mechanisms, including provision of incentives and public outreach to raise awareness and motivate voluntary change, are also options to explore. It is important to note that these action categories (i.e., regulatory vs. non-regulatory) are not necessarily mutually exclusive; the most effective and realistic approach may involve a combination of techniques.

Most prior efforts to mitigate lead contamination from hunting and fishing focused on the switch to non-lead alternatives, but for hunting at least, there may be other strategies to consider. For example, in some areas, removal of visceral remains (or offal piles) of animals harvested with lead has been suggested. To illustrate, a proposed regulation by the US Fish and Wildlife Service (USFWS) for Turnbull National Wildlife Refuge reads, "Hunters must use nontoxic ammunition or remove or bury the visceral remains of harvested animals" (National Wildlife Refuge System 2010). While offal piles can provide wildlife with an excellent source of nourishment, they can also have adverse impacts when lead ammunition is used. High concentrations of lead can be found in these remains given that hunters typically aim for vital organs to ensure a humane and rapid takedown. Removal of the remains would eliminate this source of lead for wildlife, but there is some question as to whether simply burying the remains is effective (Sullivan 2009). Suggesting that remains be buried also may not be an option in some NPS units where digging is prohibited due to the presence of sensitive resources, such as soils and historical or archeological resources. This strategy also does not address game that is wounded but not recovered by hunters, which would still be a likely source of lead ingestion for wildlife.

In selecting among these and other alternatives for reducing lead in NPS units, an important consideration is the extent to which measures will be supported by different stakeholder groups and the effectiveness of these measures in producing desired changes. In recognition of this, we now turn to a discussion of the role of human dimensions in informing future NPS decisions and public outreach on the lead contamination issue.

The role of human dimensions in addressing lead in the environment

Management decisions regarding lead ammunition and fishing tackle have the potential to be highly controversial, with stakeholders with different perspectives becoming highly involved. As discussed in greater detail later on in this report, a nationwide ban on the use of lead shot for waterfowl hunting in 1991 was implemented without much regard for hunters' attitudes toward the regulation (AFWA 2007); it was subsequently met with much resistance and animosity, thereby diminishing its effectiveness (Pokras and Kneeland 2008). From past experiences like this, natural resource agencies have come to understand that stakeholders want to be included in the decision-making process; that they need to understand human behavior and its impacts upon natural resources; and that successful solutions to conservation and management problems will depend upon effective communication with and acceptance from the public. None of the NPS's current efforts to reduce impacts from lead ammunition and fishing tackle include human dimensions research, but the need for such research to inform NPS response to this issue has been recognized. Future decisions regarding these issues should begin with an understanding of factors at the root of human behavior and stakeholders' preferences for management. These social considerations are crucial to successfully address impacts of lead in NPS environments.

The need for public outreach

Human behavior is the root cause of lead in the environment from spent ammunition and fishing tackle; it is only by affecting human behavior that these pathways can be modified or eliminated. Public outreach includes a broad spectrum of activities, ranging from education and information provision to persuasive communication strategies, and can play an important role by serving as a mechanism to promote behavior change and build support for management actions. Outreach efforts often are among the preferred mitigation strategies to address undesirable behaviors and promote alternative forms of human action (Jacobson 2009). At times, outreach may be preferred over regulatory measures for altering behavior because it can provide an enduring solution that transcends many contexts; it retains one's freedom of choice and is typically less intrusive; and it is thought to be less expensive than other alternatives. For example, we may hypothesize that some hunters and anglers use non-lead products only in areas where there are regulations, but through effective communication these individuals might resolve to use non-lead products outside of regulated areas as well. Public outreach can also be viewed as a necessary complement to regulatory solutions. In situations where regulations may be the preferred management option, they contribute to mitigation only when individuals comply with them or when they can be stringently enforced. In these situations, outreach may be used to help raise awareness of the need for regulatory action and thereby contribute to greater levels of support and compliance.

In addition to the reasons stated above, public outreach can often attenuate contentious debates over scientific evidence that are commonplace with issues involving environmental impacts and their mitigation. Health and environmental policies are always based on scientific evidence, up to a point (Wilson and Anderson 1997). While this is necessary and valuable for many reasons, Wilson and Anderson (1997) argue that defining that point can

become particularly problematic and controversial for certain issues. They go on to articulate specific concerns in this matter. Scientific uncertainty and disagreement among scientists create the greatest challenges for applying science to policy. Policymakers, who often hear from different scientists who have drawn disparate conclusions, most often agree with evidence that is in line with their previously held views. Also, scientific uncertainty is frequently cited as a reason to hold off on decision-making, but waiting for science to be definitive, if that is achievable, may not be possible for matters of public health. Uncertainty can be introduced easily and there is no guiding principle for the amount of scientific evidence necessary to inform a particular course of action. The precautionary principle has emerged as a counter-argument to the belief that a lack of proof should suspend action. Sometimes described as "better safe than sorry," the precautionary principle has been defined as "a general rule of public policy action to be used in situations of potentially serious or irreversible threats to health or the environment, where there is a need to act to reduce potential hazards *before* there is strong proof of harm" (Harremoës et al. 2002, 4). Despite being frequently cited and discussed, there is no set criterion with which to apply the precautionary principle to decision-making and policy. With regard to the use of lead products in hunting and fishing, the perceived lack of scientific certainty has called into question the justification for policy decisions (e.g., regulatory bans) in many cases. Justification has become very subjective, as it often does when threats and causation are not visible, direct, immediately detectable, ignored, or the issue is political. Due to such concerns and the overall nature of environmental policy decisions in the US, public outreach (and more specifically, communication aimed at promoting voluntary behavior change) may prove to be the most promising alternative for effectively reducing the impacts of lead from hunting and fishing activities on a large scale.

Practitioners often embark upon communication initiatives rather naively, assuming that simply by making information available, desired behavior changes will follow. In reality, effective communication is notoriously difficult to develop. Various factors confound our ability to persuade someone with informational messages (Wood 2000). The extent of attitude and behavior change may depend upon source factors, recipient factors, and message factors (Eagly and Chaiken 1993; Petty and Cacioppo 1996; Wood 2000). Some important source factors to consider are how credible a source is to recipients and the perceived intent of the source. Pertinent characteristics of recipients include their prior knowledge and the strength and function of existing attitudes. Message factors that are important to consider may seem apparent, but many entities embark upon persuasive communication campaigns without asking these key questions: (1) Are messages relevant to the issue and to the audience? (2) How strong are the arguments being presented? (3) Are messages comprehensible to recipients? (4) What is an appropriate number of arguments to be persuasive, but not overwhelm and dilute key points? (5) Should messages be personal or non-personal in nature? (6) Are messages one-sided or do they provide both sides to an argument? (7) What is the channel of communication (e.g. radio, television, brochures, events) that will be most effective for conveying the message to the target audience? These factors are likely to be highly salient for communicating about lead issues; lessons learned by practitioners, discussed later in this

report, give credence to their importance to the development of effective communication with hunters, anglers, and other stakeholders.

While research has been unable to identify simple and broadly generalizable conclusions about persuasion, important conceptual advancements in relation to these and other factors have been made recently that can help guide communication programs (Crano and Prislin 2006). Adding to this body of literature, Schweizer et al. (2009) recently identified "10 key principles" for effective communication that provides practical guidance to natural resource agencies (Table 1). Although the focus was on informing strategies for communicating about climate change, the authors acknowledged that many of these principles apply to communication in any situation. This would be particularly important for this issue because, like climate change, communication about lead issues often spark highly adversarial and divisive debates.

Additional lessons learned from social psychology

Theories from social psychology can be useful in understanding the factors that form the basis for human behavior and in facilitating more targeted communication initiatives that are able to account for those factors (Teel 2008). Two theories which have been widely-applied in a natural resources context are the Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB; Fishbein and Ajzen 1975; Ajzen and Fishbein 1980; Ajzen 1991; for example applications, see Manfredo et al. 1990; Bright et al. 1993). According to TRA, individual behavior stems from one's behavioral intentions, which are in turn a function of specific attitudes and norms. In many cases, hunters and anglers may have well-established social and personal norms for the use of lead-based ammunition and tackle; they may have grown up using lead products and close others (i.e., friends and family) may also use lead-based products. TPB, introduced later, also accounts for the role of perceived behavioral control, recognizing that some behaviors require certain resources and skills to enable individual action. Two possibly applicable considerations for communication with hunters

Table 1. Ten key principles for effective communication (adapted from Schweizer et al. 2009).

1.	Know your audience and select a credible messenger for that audience.
2.	Know what type of claim or argument you are asserting and why it is appropriate for your audience. Lead with your strongest argument or your most confident point.
3.	Connect your message to cultural values and beliefs; people react to traditions, experiences, and shared values – not abstract concepts and scientific data.
4.	Make the message meaningful; appeal to values that are meaningful for your audience.
5.	Make the message empowering; tell your audience what specific actions they can take to make a difference.
6.	Encourage your audience to engage in systems thinking and help them to understand dynamic interrelationships and interconnections.
7.	Partner with other organizations, key players, leaders, employees, entertainers, and neighbors.
8.	Start from the inside – get your organization's top leaders involved, inspire action internally first, then communicate about it.
9.	Communicate about actions and remember that actions and events are an effective mode of communication.
10.	Situate the issue in a specific location or place.

are that: (1) they may not know if or where they can acquire non-lead ammunition, and (2) they may believe that the performance of non-lead bullets is inferior. Strategies that focus on minimizing perceived barriers to individual action might yield better results than the mere provision of scientific information.

Another important theoretical framework that builds upon these attitude–behavior models is the cognitive hierarchy, which specifies relationships among attitudes and more general and more enduring cognitions such as values and value orientations (Manfredo et al. 2009). Attitudes are a key concept in each of these models and have been a major focus of human dimensions investigations because they are useful in predicting behaviors and can offer a parsimonious way of describing a group's thoughts on an issue (Manfredo et al. 2004; Manfredo 2008). Attitudes are defined as the evaluation of an object (e.g., an issue, entity, or behavior) with some degree of favor or disfavor (Eagly and Chaiken 1993). Individuals have thousands of attitudes in memory that are held with varying levels of strength and certainty. The extent to which attitudes guide behavior and are resistant to change is based in part on how strongly they are held by an individual (Petty and Krosnick 1995). A number of strength-related attributes of attitudes have been identified in the literature. These include, for example, degree of involvement with the issue or attitude object, level of emotion experienced in relation to the issue/object, and prior knowledge about the issue/object (Table 2).

The functions and characteristics of attitudes, especially their strength, make mere provision of information about a natural resource issue an oftentimes ineffective strategy if the goal is attitude (and ultimately, behavior) change. One approach to improving communication effectiveness is the belief-targeted approach, which builds upon attitude-behavior models such as TRA (Fishbein and Manfredo 1992; Bright et al. 1993). According to this approach, the content of messages should be designed to target beliefs that form the basis for attitudes. Here it is important to know which beliefs are accessible and salient to the audience; that is, which beliefs come to mind readily when thinking about the issue (Stutman and Newell 1984). For example, an angler may have a negative attitude toward using non-

Table 2. A sample of attitude strength-related attributes.

Attribute	Definition	Example
Involvement	- Outcome-relevant involvement (the decision affects me personally)	- A ban on lead ammunition will affect my success as a hunter.
	- Value-relevant involvement (the issue is important to me because of my basic values)	- A ban on lead fishing tackle will protect wildlife from lead poisoning.
Emotion	- Affective response (the issue make me angry, sad, happy, etc.)	- The thought of a lead ban makes me very angry. - The thought of lead poisoning in condors makes me very sad.
Knowledge	- Objective knowledge (factual information)	- I know a lot about the issue.
	- Subjective knowledge (what I believe to be true about the issue)	- My beliefs may not all be factual, but they are many.

lead sinkers. His/her attitude may be based on the belief that the monetary costs of using non-lead alternatives is too high, and/or that non-lead sinkers do not perform as well as lead ones. In this example, simply providing information about the scientific justification for transitioning to non-lead products is likely not enough to affect change. Instead (or in addition), it would be important to consider the angler's pre-existing beliefs in terms of what gets emphasized in the persuasive messaging. In the belief-targeted approach, the structure of the persuasive message consists of an argument followed by evidence. Ideally, the message recipient accepts the supportive evidence, which in turn leads to acceptance of the arguments, and ultimately a change in beliefs and corresponding attitudes. This approach often yields better results than providing information alone; however it is not a guaranteed success, as many other factors can intervene and influence communication effectiveness.

Another lesson learned from social psychology is that the level of attitude change can depend on the extent to which individuals elaborate on, or think about, the information in a message (Petty and Cacioppo 1986). Dual-process models, including the Elaboration Likelihood Model (ELM) and Heuristic–Systematic Model (HSM), detail the factors that make recipients more or less prone to do this (Petty and Cacioppo 1986; Giner-Sorolla and Chaiken 1997; Na 1999). According to these models, effortful processing can result in more lasting attitude change, but it demands understanding and elaboration of message content by the recipient. This type of processing can be facilitated by ensuring that recipients have both the motivation and ability to engage in thoughtful evaluation of information contained in the message. Tactics along these lines might include limiting distractions and making messages more personally relevant and understandable to members of the target audience. Alternatively, a less-demanding route to persuasion that does not depend on careful scrutiny of message content relies instead on heuristics, or simple decision rules. In this case, recipients may evaluate messages rapidly based on prior experience or intuitive judgments; source credibility can also serve as a heuristic. The use of celebrities in advertising and the use of simple slogans or visual images that appeal to recipients' basic values are examples of approaches that rely on heuristic cues for persuasion. Eagly and Kulesa (1997) discussed the relevance of these approaches for communicating about environmental issues, which indicate they would also be relevant to communicating about lead. Specifically, they used the northern spotted owl controversy in the western US as an illustration and described how stakeholders on both sides of this issue were effective in garnering support for their positions through persuasive techniques. The timber industry promoted an "owls versus people" slogan that portrayed the controversy as "a simple case of jobs for people versus habitat for one seemingly less important species" (Eagly and Kulesa 1997, 133). Environmentalist groups responded by releasing photographs to the media of devastation in the form of large expanses of clear-cut forests to convey the importance of environmental protection. Both groups were successful in framing the issue around human values and appealing to those values through simple heuristic-based approaches.

As Eagly and Kulesa (1997) argued, persuasive communication methods often involve cognitive-based appeals that, in order to be effective, presume recipients process information with care. However, the reality is that recipients may lack the motivation and/or ability to do so. As stated previously, various factors related to the source, message, recipient, and context

can influence communication effectiveness and, more specifically, the extent to which people elaborate on message content. A phenomenon known as "biased processing" sheds additional light on this topic of factors contributing to the complexity of attitude change. Biased processing occurs when an individual critically evaluates incoming information subjectively and in such a way as to confirm and protect existing attitudes and beliefs (Wood et al. 1995). In other words, information that is consistent with an individual's prior attitudes and beliefs is accepted, while information that is contradictory is discounted as erroneous. The end result is minimal, if any, attitude change following exposure to the new information. In a study of biased processing of information related to drilling for oil in the Arctic National Wildlife Refuge, Teel et al. (2006) found that recipients were not persuaded by arguments that contradicted their initial attitudes toward the issue, even though they were told the arguments were from credible sources. Further, they rated arguments in line with their preexisting attitudes more favorably. Evidence of biased processing serves as another example of why communicators can't assume that provision of factual information about an issue, especially a controversial one, is enough to produce desired attitude or behavior change. This is not to say that informational messages should be abandoned, but rather they should account for the characteristics of the target audience, including audience members' attitudes, beliefs, and values as well as their ability/motivation to process information.

Another consideration worth mentioning in the context of attitude/behavior change is the influence of norms on attitudes and behaviors. Norms have been conceptualized in the literature in a variety of ways, but here we refer to them as a person's beliefs about what is proper or improper behavior for individuals in a given context (Donnelly et al. 2000; Manfredo 2008). Norms are associated with social groups and social roles and can be a powerful influence on behavior. Therefore, an understanding of norms can enhance our ability to predict certain behaviors, particularly those more likely to be socially influenced. In thinking about issues related to lead ammunition and fishing tackle, two of the primary stakeholders are hunters and anglers. Generally, hunters and anglers identify strongly with other hunters and anglers. This may be informally with friends and family members who also participate in the activities, or more formally through affiliation with hunting and fishing organizations. In either case, hunters and anglers who identify themselves as part of a social group defined by these activities may consider whether others in the group would approve or disapprove of their behavior. They may also be guided by descriptive norms, i.e. what other people do will influence their actions.

Risk communication. Risk perception and risk communication are other areas of study that have particular relevance to lead issues. The use of lead products in hunting and fishing can pose health risks to humans, wildlife, and the environment. Risk has been defined as the possibility that actions or events will cause harm to humans or to things human beings value (Hohenemser et al. 1983; Kates and Kasperson 1983; Klinke and Renn 2002). Risk assessments are used to quantify risks by way of technological analyses that evaluate the possibility and/or severity of hazards, but risk perceptions often do not coincide with actual risk potential (Wilson and Arvai 2006a, 2006b). Risk perceptions, defined as intuitive judgments of risk (Slovic 1987), can be a function of personality traits (e.g., Flynn et al. 1994), group

membership (e.g., Burt 1987; Lee 1998; Scherer and Cho 2003), and cultural influences (e.g., Slovic and Peters 1998).

Risk communication involves a purposeful exchange of information about risk between interested parties, often with the goal of providing the public with the necessary information to make informed judgments about risk (Morgan et al. 1992). In designing effective risk communication messages it is important to understand the nature of individuals' beliefs, including their current perceptions of risk, that relate to the behaviors of interest; these perceptions influence attitudes and behavior (Knuth et al. 1992). Risk perceptions can also bear upon levels of support for management actions and receptivity to educational messages.

Efforts to reduce the impacts of lead from recreational fishing

Lead fishing lures, sinkers, lead core fishing line, downrigger cannonballs, and weights used on fishing traps and nets are introduced into aquatic ecosystems by commercial and recreational anglers through accidental or intentional breakage (Goddard et al. 2008). There is a range of potential consequences from lead introduced through fishing activities, but the extent of hazards is not fully known. Lost lead fishing tackle is thought to be relatively stable, with the potential to remain intact for decades to centuries (SAAMI 1996). Very few studies have examined the dissolution of lead from fishing tackle, and these have been inconclusive. More research is needed to determine the dissolution of all types of lead fishing tackle at varying densities and water chemistry conditions (Goddard et al. 2008).

A larger body of research has examined the impacts of lost lead on fauna with somewhat more conclusive evidence. No studies have been able to link lead exposure from ingested fishing tackle to fish mortality, and there is no evidence to suggest that ingestion of lead tackle by amphibians or reptiles is a widespread problem (Goddard et al. 2008). Turtles are one exception; published and unpublished literature has documented snapping turtles (*Chelydra serpentine*) suffering from lead poisoning caused by ingesting lead fishing weights (Borkowski 1997).

Lead fishing tackle has had the greatest impact on bird species that ingest fishing tackle lost or abandoned along banks or in water bodies (Goddard et al. 2008). Birds that normally ingest small pebbles to break down food in their gizzards may mistakenly ingest fishing tackle. They typically ingest lead fishing weights that are less than 57 grams (2 ounces); for this reason, most harm to waterbirds involves smaller lead weights used by recreational anglers (Scheuhammer and Norris 1995). Once ingested, lead can poison the birds and eventually kill them.

In the 1970s, lead poisoning of birds from ingesting fishing weights emerged as a significant issue in the UK due to the decline of mute swan (*Cygnus olor*) populations (Sears 1988). This resulted in the banning of lead fishing sinkers weighing less than 1 ounce in the UK in 1986 (Pattee and Pain 2003). In 1991, studies confirmed that fewer mute swans were poisoned by lead following the ban (Sears and Hunt 1991). Swans in the Thames River Valley also showed significant declines in BLLs after the ban, but 60% of swans sampled still had elevated BLLs (Perrins et al. 2003).

The hazards of lead fishing tackle to common loons (*Gavia immer*) were reported in North America in the early 1990s (Franson and Cliplef 1992; Pokras and Chafel 1992;

Stone and Okoniewski 2001). Since that time, many studies have attempted to quantify the impacts of lead fishing tackle on common loons. In areas where there are both loon populations, and recreational fishing, lead poisoning from swallowing lead sinkers has accounted for 10–50% of recorded loon mortality (USFWS 1999). In New England, over 50% of adult breeding loon mortalities were caused by ingesting lead sinkers and jigs. Similar evidence reported in Michigan, Minnesota, Ontario, and on Lake Erie in New York has shown that 40%, 17%, 27%, and 30%, respectively, of dead adult loons were likely poisoned by lead (USFWS 1999). Loons are not the only bird species in the US to be affected by lost lead fishing tackle; more than 30 species in at least ten states have reportedly suffered mortality as a result of lead fishing tackle ingestion (Nadis 2001). These species include swans, pelicans, geese, ducks, cranes, herons, and eagles. However, while the problem affects many bird species, loons are the most heavily impacted, followed by brown pelicans (*Pelecanus occidentalis*; Franson and Smith 1999).

Notable regulatory and voluntary actions in the US

For reasons cited above, loons have been at the center of regulations and outreach efforts regarding the use of lead fishing tackle in the US. Some US federal agencies have banned the use of lead tackle on lands with loon and swan populations, such as NPS units and national wildlife refuges (Table 3). In addition, the five states with regulations in place all cite the common loon as their primary purpose for a ban, while also recognizing benefits for other waterbirds (Table 4). The prohibition on the use of lead sinkers in Massachusetts, for example, applies to the Quabbin and Wachusett Reservoirs, the two bodies of water that support the bulk of the state's loon populations. In the four other states, the regulations are

Table 3. NPS units and national wildlife refuges (NWRs) with regulations on the use of lead fishing tackle.

Unit	State(s)	Regulation
Yellowstone NP	ID, MT, WY	Leaded fishing tackle such as leaded split-shot sinkers, weighted jigs, and shot lead-weighted ribbon for nymph fishing are not allowed.
Glacier NP	MT	The use of all lead associated with fishing is prohibited within the park. This includes weights, lures, jigs, line, etc. The only exception is a fisherman who is using a downrigger; cannon ball weights of 2 to 10 pounds may be used on the down-rigger cable.
Bear Lake NWR	ID	Use and possession of lead weights or sinkers is prohibited.
Union Slough NWR	IA	Use and possession of lead terminal tackle is prohibited.
Rachel Carson NWR	ME	Lead jigs and sinkers are prohibited.
Assabet River NWR	MA	Lead sinkers are prohibited.
Seney NWR	MI	Use or possession of fishing weights or lures containing lead is prohibited.
Red Rock Lakes NWR	MT	Use and possession of lead sinkers or any lead fishing product while fishing are prohibited.
Rappahannock River Valley NWR	VA	Use of lead sinkers is prohibited.

State	Year	Sportfishing Regulation
Maine	2002	A person may not sell or offer for sale a lead sinker for fishing that contains any lead and weights 0.5 ounce or less.
Massachusetts	2001	The use of lead sinkers is banned at two reservoirs (Quabbin and Wachusett).
	2012	Lead fishing sinkers and jigs less than 1 ounce will be prohibited in all inland waters of the Commonwealth effective January 1, 2012.
New Hampshire	2000	The use of lead sinkers and jigs in all fresh water in New Hampshire, including lakes, ponds, rivers and streams is prohibited. The ban prohibits the sale and use of lead sinkers weighing 1 ounce or less and lead jigs less than 1 inch long along their longest axis.
New York	2004	The sale of lead fishing sinkers weighing 0.5 ounce or less is prohibited.
Vermont	2003	A person shall not use a lead sinker in the state of Vermont which weighs 0.5 ounce or less. It is unlawful to sell or offer for sale a lead sinker in the state of Vermont.

Table 4. US states with restrictions on the use of lead fishing tackle.

statewide. The ban in Massachusetts will extend statewide in 2012. New Hampshire was the first state to ban the use of lead sinkers of one ounce or less, and according to New Hampshire Fish and Game personnel, enforcement has been done by performing random checks on anglers (Michael 2006). Violators are subject to a maximum fine of $250, but unless violators blatantly disregard the rules, they are educated about the ban and the reasons behind it rather than being fined (Michael 2006). Little information about angler compliance with the use of non-lead fishing weights is available in New Hampshire or the other areas where regulations exist. Officials in Maine, New Hampshire, Vermont, and New York have stated that regulations are too recent for compliance data to be obtained (Rattner et al. 2008). However, one study in New Hampshire has suggested that common loon mortalities due to lead toxicosis saw a 39% reduction after the ban (Vogel 2005).

In all five states where regulations have been enacted, targeted outreach has occurred prior to and following implementation. Four states (an online search turned up nothing from Maine) produced an informational brochure; displayed in all of the brochures is a picture of a loon along with the slogan "Get the Lead Out." This slogan has been used in many lead awareness campaigns, most notably to bring attention to the dangers of lead paint in residential buildings. Other common features of the brochures include information about the state's regulations; other states that have regulations; how lead fishing tackle impacts wildlife, with a focus on loons; what alternatives to lead are available; how to dispose of old lead sinkers; and ways that anglers can help prevent lead poisoning of bird species. Brochures, and a variety of other educational materials such as posters, have been distributed and exhibited through various means. For example, the Boy Scouts of America (BSA) from Massachusetts handed out materials, brochures, and sample fishing weights at local, nation-

al, and international sportsmen's events (Browne 2009). In 2001, a program sponsored by the National Wildlife Federation (NWF) in New England placed educational displays at dozens of state parks, tackle shops, and fishing events throughout the region (Nadis 2001). The Vermont Department of Fish and Wildlife (VTDFW) included a full-page description of the lead issue and specifics of the state law in the *Vermont Digest of Hunting, Fishing, and Trapping Laws* and in its 2005 *Angler's Pocket Guide* (Michael 2006).

Lead tackle exchange programs have also been implemented in these states. These programs encourage anglers to turn in lead fishing tackle to the sponsoring agency or organization to be safely disposed of, and in return anglers receive non-lead tackle. Lead exchanges often take place in conjunction with fishing events, such as fishing derbies. In Massachusetts, the lead tackle exchange program began as an Eagle Scout project with the BSA, which has collected over 65 pounds of lead through the effort (Browne 2009). Between 1999 and 2000, a campaign in Vermont and New Hampshire gathered more than 40,000 lead sinkers at fishing stores and state parks (Nadis 2001). The VTDFW has also distributed free samples of non-lead sinkers at its district offices, select state parks, fishing clinics and educational events, and at all of the state fish hatcheries (VTDFW N.d.). Exchange programs and free samples offer a way to introduce anglers to non-lead alternatives, and draw attention to educational campaigns designed to alert anglers to the toxicity of lead in the aquatic environments they use for recreation (Goddard et al. 2008).

In general, when these five states implemented their bans, they were not confronted with strong opposition or controversy. A notable exception to this was in Maine, where the Bass Anglers Sportsman Society (BASS) and people associated with youth fishing programs provided testimony against the proposed regulations during the legislative process (Michael 2006). Having donated thousands of dollars in fishing gear to kids, BASS was concerned that some of the gear would become illegal. In New Hampshire, most local sportfishing groups did not show much concern, and they did not get involved in the legislative process (Michael 2006). In New York, there was little resistance to regulations, although the ban that was passed was less restrictive than the one originally proposed; rather than banning the use of lead sinkers under one-half ounce, the ban applied only to the sale of the sinkers to allow anglers time to transition to alternative products (Michael 2006). In Vermont, where a very thorough program was directed by the legislature, the VTDFW had the support of the Vermont Federation of Sportsmen's Clubs and the NWF, and little opposition was encountered from either anglers or retailers (Michael 2006). Some small fishing-gear retailers in the different states were unhappy with the ban on sales of small lead tackle because they were left with unsellable inventory; for chain stores this was less of a concern because they could transfer stock to states where lead is legal. Contacting small retailers for purposes of implementing the bans also proved to be a bit of a challenge, whereas chain stores were easier to reach and communicate with (Michael 2006). It is unclear as to whether the level of opposition and the corresponding level of response by decision-making agencies has had an impact on the success of the such bans in terms of compliance and/or reducing negative impacts from spent lead.

Although widespread opposition was not encountered in these particular states, nationwide bans and bans on lead fishing tackle proposed in other states have not been successfully

implemented. For example, the EPA proposed a ban on the manufacture, processing, and distribution of lead and zinc sinkers in response to a citizen's proposal to require labels or warnings on lead fishing sinkers (Michael 2006). A bill containing this ban was introduced in Congress in 1994, but it was not passed. Had it become law, the economic impact of the ban was estimated to be less than $4 per year for the average angler, and an estimated 4,700,000 birds could have potentially been saved from lead poisoning. The EPA's proposed restrictions were unique in that they would have targeted all sizes and types of lead sinkers, whereas the state-level bans currently in place have only applied to sinkers of certain sizes that pose the greatest danger to waterbird species, such as loons. Another example of a failed effort at the national level was the 1999 announcement by the USFWS of its intent to establish additional lead-free fishing areas on units of the NWR system. The areas consisted of places where mortality of common loons from lead sinker ingestion had occurred, or where habitats used by loons co-existed with significant recreational fishing activities (USFWS 1999). The USFWS has yet to implement these proposed restrictions.

States outside of the Northeast region of the US have also encountered difficulties in implementing regulations. A bill before Minnesota's state legislature during the 2002–2003 session proposed a ban on the use and sale of some lead fishing sinkers and jigs; the bill was dropped due to opposition from angler groups and tackle manufacturers. Minnesota opted to change the bill from a ban to "a call on the state to encourage the use of non-lead tackle and educate the public about the potential perils of lead tackle" (Smith 2003). For nearly ten years, the Minnesota Pollution Control Agency (MPCA) has worked to raise public awareness of the need for non-lead alternatives and increase availability of these alternatives at retail stores (MPCA 2010). A variety of tools have been used by the MPCA, including lead exchange programs which collected 7,000 pounds of lead tackle from 2001 to 2008 and provision of free educational kits to members of lake associations to help them promote non-lead products. The MPCA also partnered with Minnesota's Department of Natural Resources and five Minnesota-based manufacturers to offer "Get the Lead Out" retail displays for stores; this came in response to feedback that anglers were frustrated by the difficulty of finding non-lead tackle in stores (MPCA 2010). While the regulatory actions pursued in Minnesota were opposed by many stakeholders, subsequent voluntary measures have achieved high levels of support as a result of cooperation among tackle manufacturers, retailers, lake associations, conservation organizations, anglers, and the government (MPCA 2010). Data are largely unavailable to indicate whether these efforts have been successful in reducing lead toxicosis in wildlife and if anglers are switching to non-lead alternatives. However, dead loons collected in Minnesota and Wisconsin are currently being examined in a lab in Wisconsin to determine the cause of mortality, and surveys from a recent Minnesota sportsmen's event suggest a behavioral change among some anglers (Amanda Baribeau, MPCA Electronic Waste Coordinator, phone conversation, April 12, 2010).

The Washington Fish and Wildlife Commission (WFWC) recently approved restrictions on the use of lead fishing tackle at 13 lakes with nesting common loons in early December 2010. The restrictions prohibit the use of lead weights and jigs that measure 1.5 inches or less along the longest axis at 12 lakes in Washington and the use of flies containing lead at Long Lake in Ferry County, Washington. The restrictions, which took effect on May 1, 2011,

are designed to protect loons from being poisoned by ingesting small lead fishing gear lost by anglers. The proposal was announced in early November 2009, and opponents, including the NRA, ASA, and BASS, criticized the motives behind the ban. These opponents claimed that the effects on loons are not substantial enough to support a ban. Chris Horton, BASS Conservation Director, stated that "the supporting data is ridiculously insignificant and in no way justifies, scientifically, the proposed ban on lead fishing tackle" (Robbins 2009). However, after a public hearing on the issue in October where the WFWC reviewed the findings of a Washington Department of Fish and Wildlife (WDFW) advisory group, the regulations to ban certain types of lead fishing tackle were determined to be the best way to minimize risks to loons.

Wisconsin has also been actively involved in educating anglers about dangers posed to wildlife from the accidental loss of lead fishing tackle. Many organizations have partnered in these outreach efforts; they include the Wisconsin Bird Conservation Initiative (WBCI), Wisconsin Society for Ornithology, Raptor Education Group, Wisconsin Wildlife Federation, Wisconsin Association of Lakes, Loon Watch, Trout Unlimited, and Gordon/St. Croix Flowage Association (WBCI n.d.). While management actions in Wisconsin have focused primarily on the promotion of voluntary use of non-lead tackle, the Wisconsin Department of Natural Resources (WDNR) has considered a ban that would phase out the use of lead fishing tackle of the sizes and weights that pose the highest risk to wildlife. Citizens voted on the proposal on April 12, 2010. Although the majority of the citizens voted "yes," 33 counties approved while 37 counties rejected. In addition, citizens in Bayfield County did not believe the result adequately reflected the wishes of Wisconsin sportsmen and proposed a citizen resolution, which revisited the topic with more specifics in the next sportsman vote. The resolution to proceed with some type of phase-out of lead tackle passed, but no one has figured out on how to proceed on this. The Natural Resources Board is currently in the process of reviewing recommendations from WDNR.

In addition to the above examples of where regulatory and voluntary measures are being pursued, many other states have engaged in outreach campaigns to reduce the impacts of lead from recreational fishing. Almost all states have at least some information publicly available regarding the hazards of lead tackle, often promulgated by the state fish and wildlife agencies. Many other organizations also disseminate information. For example, the Oregon Department of Human Services released a brochure, the cover of which reads, "Attention Fishermen, Fishing Weights Contain Dangerous Levels of Lead" (ODHS 2004). The contents of the brochure focus mainly on the threats to human health and how to avoid lead exposure; only one item suggests using non-lead fishing sinkers. While many of the messages espoused in outreach campaigns consistently focus on threats to birds, and in particular loons, there are various messages being used by different entities, and various forms of distribution. A final notable example is California's 2001 requirement that manufacturers of lures that contain lead print a warning on the packaging (Michael 2006). The warning states that lead can cause cancer, birth defects, and other reproductive harm in humans.

These outreach initiatives, which have occurred mostly at the state level, have been less controversial than regulatory bans. In fact, the ASA, one of the strongest opponents to lead bans, supports efforts aimed at encouraging voluntary use of non-lead tackle (ASA 2009).

The ASA also acknowledges that lead toxicosis of waterbirds such as loons can occur, and that areas that are "hot spots" for ingestion of sinkers should promote restrictions based on sound science (ASA 2009). Despite the increasing levels of support for voluntary action, the ASA and other groups have spoken out against bans on lead tackle based on the conclusion that there is insufficient scientific data; loon populations are stable and increasing; there are more serious threats to loons, such as loss of habitat due to shore development; alternatives cost six to twenty times more than lead; alternatives do not perform as well as lead; and bans would require significant changes from industries and anglers that aren't justified (Goddard et al. 2008; ASA 2009). A similar argument is that lead sinkers have not been shown to cause widespread population-level effects or to cause substantial changes in species distributions (Goddard et al. 2008). Many argue that population-level impacts should not be a prerequisite for corrective action (Goddard et al. 2008). The arguments over the scientific basis for bans also extend to the inconclusiveness of reports on dissolution of lead from fishing tackle in aquatic ecosystems as well as impacts on human health; these debates tend to be the most controversial and difficult to resolve.

The extent to which price factors are problematic depends on the fluctuating cost of alternative materials and general economic conditions. However, alternatives to lead fishing tackle have been available in Canada, the US, and European countries for several years, and many manufacturers already produce non-lead tackle (Scheuhammer and Norris 1995; NCM 2003). In addition, the actual cost differences may be minimal. Doug Crumrine, owner of the company Bullet Weights, says that a pack of steel sinkers costs only 10 to 20 cents more than a lead pack of comparable size (Nadis 2001). Nevertheless, some argue that the increased cost will discourage or restrict the ability of recreational anglers to use non-lead products, especially during difficult economic times. Tied to this is the argument that a decline in angler numbers could result from further restrictions, which would lead to a decrease in conservation funding partially derived from the sale of fishing licenses. No evidence exists, however, to suggest that this trend has occurred in areas where regulations have been imposed.

Another leading argument against bans on lead tackle relates to the performance of non-lead alternatives. Alternatives are not as dense as lead and therefore need to be larger to be of the equivalent weight. Many anglers believe that the increased size is detrimental because it can discourage fish from biting (Goddard et al. 2008). Although it is difficult to debate an angler's performance preferences, some claim there are benefits to using non-lead fishing tackle. For example, brass and steel alternatives are advertised as making more noise than lead as they bump over the bottom of water bodies, which is claimed to attract fish (Goddard et al. 2008). Steel sinkers are also said to be more sensitive, thus providing anglers with a better feel for what is happening at the end of their line. Steel is less malleable than lead too, so it retains its shape and holds paint longer. Both sides of the debate have developed talking points to support their positions, but those in support of non-lead alternatives recognize that the burden is on them to prove these products can provide desired performance at a reasonable cost.

A challenge of a different nature that can interfere with efforts to reduce the use of lead fishing tackle entails the manufacture of lead fishing weights by people in their homes. In 1994, the EPA estimated that approximately 800,000–1,600,000 people make lead fishing

weights in their homes, either for personal use or to sell (Goddard et al. 2008). According to the EPA, this "cottage industry" represents 30–35% of lead sinker production in the US. In areas where the sale of lead weights is prohibited, it is likely that lead product use still occurs due to availability of homemade options. This is additionally concerning due to the potential for lead poisoning in humans through lead inhalations that may coincide with the manufacture of these products in the home (EPA 2004). Moreover, it makes clear the need for well-informed communication strategies aimed at enhancing compliance with the use of non-lead fishing tackle.

As suggested by the above experiences and arguments that reveal the complexities associated with a transition to non-lead tackle, regulations alone are not likely to produce desired behavior change. In addition, regulations are likely to result in greater public controversy as compared with other alternatives such as promotion of voluntary action. Clearly, public outreach efforts will play a critical role in efforts to reduce the impacts of lead from recreational fishing and building support for management strategies aimed at addressing this issue in the future. To ensure the success of these efforts, additional research is needed to determine the effectiveness of existing outreach mechanisms, as well as to assess the diversity of stakeholder beliefs and attitudes regarding the use of non-lead products. Similar conclusions can be drawn from a review of the literature on the use of lead in recreational hunting, which we address in the next section.

Efforts to reduce the impacts of lead from recreational hunting and shooting sports

Incidents of lead poisoning of waterfowl at hunting sites appeared in the press and scientific literature in the late 1800s (Sanderson and Bellrose 1986; Friend et al. 2009). Continued investigations by leading scientists led to reports of widespread lead poisoning in the 1930s (Friend et al. 2009). Then, in the mid-1950s, attention to the issue of lead poisoning declined; it wasn't until the publication of *Lead Poisoning as a Mortality Factor in Waterfowl Populations* (Bellrose 1959) that interest in the hazards of spent lead shot was renewed. The continued decline of major waterfowl populations resulted in a sustained and heightened concern about lead poisoning (Friend et al. 2009), yet it took decades more research and contentious debate to reach scientific consensus that ingesting lead from ammunition was a significant mortality factor affecting waterfowl populations (Dolton 2008). Data during this time span estimated that the annual mortality of waterfowl in North America due to lead poisoning was between 1,600,000 and 3,900,000 birds (Bellrose 1959, Feierabend 1983).

Most of the scientific research related to lead poisoning from ammunition has focused on avian species, due to the fact that the most pronounced exposures and effects have been seen in waterfowl (Sanderson and Bellrose 1986), certain upland game birds (Kendall et al. 1996), and predatory and scavenging birds (Pattee and Hennes 1983). Exposure depends on species-feeding and grit-ingestion habits, and birds that forage in areas where lead objects accumulate are more at risk (NCM 2003). Early evidence of upland bird mortality from lead ingestion was gathered in labs, and while it showed that ingesting lead ammunition was fatal to upland birds, more research is needed to determine the extent of exposure for upland species in the wild (Hunter and Rosen 1965; Westemeier 1966; Buerger et al. 1986; Stowe et

al. 1972). In predatory and scavenging species, secondary poisoning from consumption of wounded or dead prey is the most significant source of toxicosis; this has had significant effects on bald eagles (*Haliaeetus leucocephalus)* (Figure 2; Griffin et al. 1980; Pattee and Hennes 1983) and the California condor (*Gymnogyps californianus*) (Kramer and Redig 1997; Meretsky et al. 2000; Church et al. 2006). Shot, bullets, and bullet fragments have been observed in wounded prey and gut piles that hunters discard (Janssen et al. 1986; Hunt et al. 2006; Knopper et al. 2006). For California condors (Figure 3), poisoning from lead bul-

Figure 2. Bald eagle perched on branch, California. US Fish and Wildlife Service photo.

Figure 3. Upper left: Head detail of sub-adult female California condor, Pinnacles National Monument, California. Lower left: Juvenile California condor sunning in the High Peaks, Pinnacles National Monument, California. Right: Adult male California condor with 2-day old nestling at cavity nest, Pinnacles National Monument, California. All photos © 2011 by Gavin Emmons (www.gavinemmons.com). Used by permission.

let fragments in scavenged carcasses and offal piles has been identified as the greatest mortality factor for this species (Meretsky et al. 2000; Sieg et al. 2009).

The effects of lead from spent ammunition are well documented for avian species, and, more recently, the literature has focused on impacts to other wildlife. Reports have shown elevated lead concentrations in invertebrates, amphibians, reptiles, and small and large mammals in areas that are heavily hunted and/or in close proximity to shooting ranges (Rattner et al. 2008). At a small firing range at West Point in New York, for instance, lead concentrations in earthworms (*Oligochaeta* spp.) were reported to be 90 times greater than levels in earthworms at a distant reference site (Labare et al. 2004). Some evidence also suggests that lead from spent ammunition could be a challenge for the conservation of large carnivores and other scavenging mammals (Rogers et al. 2009). These include black bears (*Ursus arctos*), grizzly bears (*U. americanus*), grey wolves (*Canis lupus*), and coyotes (*C. latrans*) that scavenge on ungulate and offal piles left by hunters (Wilmers et al. 2003). Studies are ongoing in Yellowstone National Park, and the area surrounding the park, to determine the effects of the fall hunting season on carnivores in the region (Rogers et al. 2009). Grizzly bears have been shown to alter their movement patterns around the park during hunting season to feed on wounded elk (*Cervus elaphus*) and gut piles (Ruth et al. 2003; Haroldson et al. 2004), and more research is need to determine the immediate and long-term effects.

Notable regulatory and voluntary actions in the US

By 1986, the scientific research and numerous lawsuits surrounding the use of lead in hunting and shooting sports resulted in the passing of federal regulations that phased out the use of lead shot in hunting waterfowl and American coots (*Fulica americana*) over a five-year span in the US (Rattner et al. 2008). The ban, which applies specifically to hunting activities on federally regulated lands, has been in effect since 1991.

The ban on lead shot for waterfowl and coot hunting was met with resistance from the ammunition industry and sportsmen (Pokras and Kneeland 2008). Resistance took the form of lawsuits that were filed against state and federal wildlife agencies for instituting the bans, as well as noncompliance with the regulations. A lack of communication between scientists and other stakeholders was largely to blame for the contentiousness of the debate (Pokras and Kneeland 2008). One of the most poignant lessons to be learned from the events leading up to and following the 1991 ban is that strict legislation banning the use of lead for hunting that does not account for the interests of sportsmen and the ammunition industry will likely result in ardent protest, low compliance, and ultimately failure to resolve lead poisoning issues. Others cite the ban from the opposite perspective, arguing that the ban was contentious, but now people comply with the regulation without objection. While the controversy has waned over time, by learning from past situations, and acting proactively, agencies may reduce the initial level of controversy and increase the rate of acceptance.

Given that large amounts of spent lead ammunition are still deposited in the environment through a variety of other hunting, depredation control, and shooting sport activities (Scheuhammer and Norris 1995; Schulz et al. 2002), with a range of associated implications for wildlife and the environment, it is prudent for those advocating for further reductions of lead use to understand the factors that inhibited and facilitated the 1991 ban and other regulatory measures in the US. The Association of Fish and Wildlife Agencies (AFWA) conducted a survey of people who were involved in the ban in the 1990s that provides useful insight in this context (AFWA 2007). A few of the key findings are summarized in Table 5.

Many US states have taken additional regulatory actions to restrict the use of lead in hunting; these actions are specifically directed at lead shot, not all lead ammunition. Nearly half of US states have regulations requiring the use of non-lead shot that extend beyond the federal law for waterfowl hunting (Figure 4). However, these restrictions are not statewide; they have been applied in ranges where there are species of concern. Use of lead ammunition to hunt certain species was banned in some cases because their habitats coincide with waterfowl (e.g., crane, snipe rail). In Alaska, for example, the risk of lead exposure to waterbirds, including the threatened spectacled eider (*Somateria fischeri*), was an important factor leading up to additional regulatory measures (D.J. Case and Associates 2006).

In addition to these regulatory actions, several states have employed public outreach campaigns, again, aimed primarily at species of concern, to reduce the impacts of lead from hunting. In Arizona, California, and Utah, outreach efforts were initiated based on concerns about lead in the California condor's range. A report on condor–lead issues produced in 2003 by the lead mitigation subcommittee of the California Condor Recovery Team (CCRT), which found that lead poisoning from spent ammunition was the leading cause of condor fatalities (Redig et al. 2003), was influential in inciting action in this area. In the late fall of

1. More effort should have been made to obtain input from hunters prior to making policy decisions.
2. Greater attention and analysis of supply issues should have occurred.
3. Actions moved too fast; there should have been more time afforded to inform, educate, and convince agencies, nongovernmental organizations, manufacturers, retailers, media, and sportsmen of the need for the policy.
4. Sales people, especially in large stores, should have been trained to provide accurate information because they may be the main source of information for buyers.
5. Sources should have been established for reliable and accurate information.

Table 5. Suggestions about what should have been done differently for the 1990s federal ban on lead shot use for waterfowl hunting, from a survey of people involved in the ban (adapted from AFWA 2007).

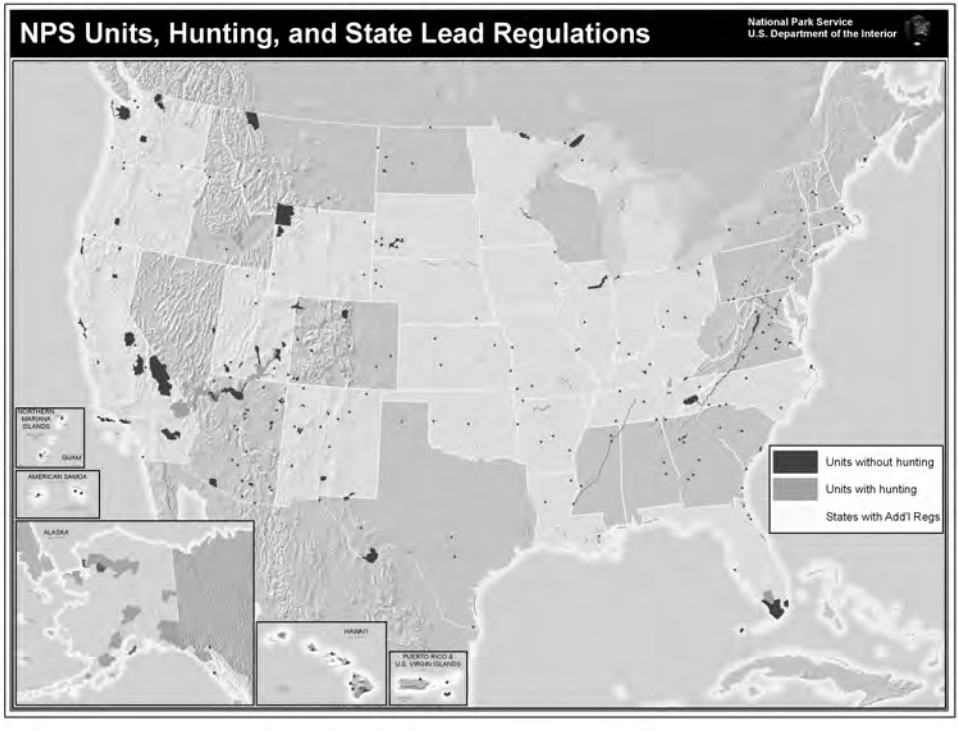

Figure 4. NPS units, recreational hunting status, and states with lead regulations. States shown in light gray have implemented lead ammunition restrictions beyond federal bans on the use of lead shot in hunting waterfowl.

2003, the USFWS and the Wildlife Management Institute (WMI), following the recommendation of the CCRT, conducted hunter surveys in the three states to understand hunters' knowledge and attitudes of condor–lead issues (Sieg et al. 2009). Information obtained from these surveys was intended to inform communication with hunters and ranchers, and it revealed that hunter awareness of lead poisoning of California condors was relatively low (D.J.

Case and Associates 2005). Awareness was highest in California; 45% of hunters there responded "yes" to the question, "Are you aware that lead poisoning is a problem currently faced by condors?" compared with 23% of Arizona hunters and 12% of Utah hunters. Despite the low levels of awareness, the majority of respondents indicated that they would be willing to take some action to help prevent lead poisoning. Arizona and California have since implemented extensive outreach programs that have many similarities, but also unique differences. In December 2007, the California Fish and Game Commission modified the methods authorized for taking big game species, nongame birds, and nongame mammals in areas designated as California condor range by prohibiting the use of lead ammunition for these purposes. The regulations became effective in July of 2008. Arizona is currently limited to voluntary participation tactics due to the status of the California condor there (i.e., its being designated as a "non-essential and experimental" population), so regulatory actions are not being considered. Utah has not implemented a formal outreach campaign, but recently began working on plans to do so (Sieg et al. 2009). Below are more detailed descriptions of existing outreach initiatives in Arizona, California, and other states where active programs have been pursued.

Arizona. The Arizona Game and Fish Department (AZGFD) began efforts to educate the public and engage hunters in voluntary lead reduction efforts in 2003 (Sieg et al. 2009). As mentioned above, results of a phone survey conducted in the fall of 2003 with 205 hunters who held tags in Arizona's condor range that year revealed that only 23% were aware of the problems posed to condors from lead use (RM 2003). Additionally, only 9% of respondents were aware of educational efforts pursued in this context, despite the fact that they would have received a letter in the mail from the agency containing details about the issue prior to the survey, and information had been published in the 2003 Arizona hunting regulations (Sieg et al. 2009).

In December 2003, focus groups were conducted in Arizona to test messages for communicating with hunters and to further investigate the barriers to reducing lead use in the condor's range. Results suggested that the best message for communication was, "Hunters and ranchers have a long history of caring for the land and conserving all kinds of wildlife. They can continue this tradition and help prevent lead poisoning in California condors by taking one or more of the following actions in the condor's range: remove all carcasses from the field; hide or bury carcasses and gut piles; remove bullets and surrounding affected flesh; or use non-lead ammunition" (D.J. Case and Associates 2005). The focus groups also revealed that hunters and ranchers wanted to be shown credible data that linked lead from spent ammunition to condor poisoning and then, if they were asked by a credible source to help condors by adopting specific actions, they would be willing to do so (D.J. Case and Associates 2005). The AZGFD and sportsmen's groups were identified as credible sources. Federal agencies and non-profit entities received much lower ratings in the Arizona surveys. This highlights the need to build partnerships. In Arizona, for example, most of the research on the impacts of lead ammunition has been conducted by the Peregrine Fund, a source with lower credibility among hunters. However, the Peregrine Fund has partnered with AZGFD, a partnership that benefits both organizations and provides a credible source for message delivery. It is especially important to partner with trusted sportsmen's groups. The NRA,

one of the most outspoken and active opponents of non-lead initiatives, is less credible than some sportsmen's groups but more credible than federal agencies. Messages coming from non-credible sources can set back progress rather than further it.

Results of the phone surveys and focus groups were used by the AZGFD to develop a strategy for communicating with hunters (Sieg et al. 2009). In 2003–2004, information was included in the hunting regulations booklet, and between 2,000 and 7,000 hunters with big game tags for the condor range were mailed information. During that time, the AZGFD also began to deliver educational presentations and lead reduction messages to the general public through such channels as wildlife fair displays, legislative contacts, the AZGFD website, the AZGFD *Wildlife Views* magazine and television programs, as well as through other general media outlets (Sieg et al. 2009). The AZGFD also sought the partnership of sportsmen's organizations in Arizona, asking them to support the agency's efforts (Sieg et al. 2009). The AZGFD has been successful in forming a coalition that includes the Arizona Antelope Foundation, the Arizona Desert Bighorn Sheep Society, the Arizona Deer Association, the Arizona Elk Society, and the Arizona Chapter of the National Wild Turkey Foundation.

In 2005, the AZGFD partnered with Sportsman's Warehouse and Cabela's to begin a voluntary free non-lead ammo program which distributed coupons good for two free boxes of non-lead ammunition to 2,390 hunters in the core condor range (Seng 2006). Hunters could redeem their coupons either at a Sportsman's Warehouse store or by mail from Cabela's. Included with the coupons was a letter outlining the issues related to lead ammunition that asked for voluntary help with the program; 65% of hunters redeemed their coupons that year (Sieg et al. 2009). Surveys of hunters who did not redeem their coupons identified the primary reasons as non-lead ammunition not being available in their caliber or preferred bullet weight; that it would take too long to sight in new ammunition; that the redemption coupon was too complicated; that they were not convinced that lead from spent ammunition was a problem for condors; and that they believed that the nature of the program was "anti-hunting" (Seng 2006). In response to some of these barriers to participation, the AZGFD provided significantly more information to hunters in 2006, but subsequently received a negative response for providing too much information that most hunters did not read (Sieg et al. 2009).

A number of additional efforts were made in 2007 to increase hunters' participation in voluntary non-lead programs. Among these efforts were lead articles about condors in sportsmen's publications, increased media coverage of how hunters were helping to recover condors, simplified outreach messages that only emphasized using non-lead alternatives, mailing of follow-up information to hunters who did not redeem their non-lead ammo coupons, and an increased number of field staff to directly contact hunters about this issue. In addition, a DVD hosted by Nolan Ryan and entitled "How to be successful in your upcoming deer hunt" was produced; it contained five minutes of information on lead exposure and asked for hunters' help. Outreach materials and the DVD were mailed to hunters along with their tags.

Since 2007, the AZGFD has continued to focus on improving its outreach and increasing voluntary non-lead program participation. Specific emphasis has been on working with ammunition distributors to increase availability of non-lead alternatives and placing

non-lead displays with educational materials in retail locations. Human dimensions surveys conducted since 2004 suggest that the agency's efforts have been successful in encouraging behaviors that reduce lead in the condor range (Table 6; Sieg et al. 2009). The AZGFD appears to be the only organization administering outreach that has comprehensively evaluated the impacts of its initiatives.

California. The hazards of spent lead ammunition to condors have long been recognized in California, and over the past few years major efforts have been taken to address this issue. As mentioned previously, only 45% of California hunters surveyed by phone in 2003 (n = 200) were aware of lead poisoning problems faced by condors (D.J. Case and Associates 2005). Around that time, some communication initiatives had been launched, but they had not been well researched or well implemented (D.J. Case and Associates 2005). Only 24% of respondents were aware of these initiatives. In 2007, the Institute for Wildlife Studies (IWS) received a grant from the National Fish and Wildlife Foundation (NFWF) to launch an outreach program to raise awareness about alternatives to lead bullets among hunter and ranchers (Theyerl et al. 2010). The program was launched in collaboration with Pinnacles National Monument (PNM), whose own effort to reduce lead available to condors began in 2006. PNM is one of five sites where California condors have been released, and with a flock of 28 condors, it hosts one of the main populations of free-ranging condors in California. Partnerships were also forged with the USFWS, Ventana Wildlife Society, Pinnacles Partnership, the Peregrine Fund, and AZGFD.

While initially looking to encourage hunters to voluntarily switch to non-lead ammunition, the program's objective were slightly modified with the passing of the Ridley–Tree Condor Preservation Act, which was signed into law by the governor in January 2008 (Theyerl et al. 2010). The act, effective as of July 1, 2008, mandated the California Fish and Game Commission enact regulations requiring the use of non-lead bullets when taking big game and coyote within the historic California condor range. Recognizing that new legal requirements are often defied by a portion of the public, and/or are resisted due to encountering misinformation or a lack of information, the efforts still focused on encouraging hunters to use non-lead ammunition and offering venues for trying non-lead calibers for free, with the goal of gaining full compliance with the ban.

The California Lead Ammunition Awareness Campaign, spearheaded by the IWS in conjunction with PNM, initially set out to offer hunters and landowners opportunities to evaluate non-lead ammunition and learn about the hazards of ammunition containing lead. Outreach efforts to meet these objectives included: (1) shooting demonstration events, (2) booths at sporting equipment trade shows and county fairs, (3) meeting with local NRA chapters, (4) opportunities for hunting guides, hunting clubs, and local ranchers to field-test ammunition through visits to local ranches, and (5) presenting information about the threats of non-lead ammunition and the results of outreach efforts at professional conferences (Theyerl et al. 2010).

All of the objectives initially set forth were met or exceeded during the awareness campaign from 2007 through 2009 (Theyerl et al. 2010). A total of 14 shooting events were held, providing 319 sportsmen the opportunity to try non-lead ammunition. Over 15,000 rounds of non-lead ammunition were given out as free samples to sportsmen at the shooting events.

Year	Successful Hunters[1]	Took Lead Reduction Actions	Used Non-Lead Ammunition	Used Lead Ammunition & Packed Out Gut Pile	Took No Lead Reduction Action
2008	910	90%	72%	61%	10%
2007	767	83%	61%	54%	17%
2006	548	60%	58%	3%	40%
2005	909	50%	50%	N/A	50%
2004		<5%			

[1]Number of hunters who harvested a deer.

Table 6. Human dimensions survey results showing hunter participation in voluntary non-lead programs in Arizona's condor range, 2004–2008 (Sieg et al. 2009).

Through participation in community forums to educate community members about lead and condors, 1,900 individuals were reached. Booths were also placed at 15 county fairs and community event, resulting in contacts with 2,663 individuals. The IWS outreach coordinator also volunteered on the Hollister Friends of the NRA committee. According to the outreach coordinator, participation with the NRA helped to create better relationships with local sportspersons and countered the common misconception that the lead campaign is anti-hunting or anti-firearms (Theyerl et al. 2010).

Another important focus of the program is on educating willing ranchers surrounding PNM, encouraging them to use non-lead ammunition when hunting or eradicating animals they consider "pests" (e.g., feral pigs, coyotes, squirrels) and to educate hunters who may also use their ranchlands (PNM 2010). The IWS outreach coordinator met with 215 ranchers, vineyard operators, and other large property managers on an individual basis. Tejon Ranch Company, the largest state-licensed private hunting operation in California, became the first to voluntarily discontinue and ban the use of lead ammunition in its hunting and ranching operations (Hill 2009). Other operations have considered and/or implemented similar policies since Tejon's was implemented in 2008. In addition, US Army Garrison Fort Hunter Liggett began phasing out lead ammunition for hunting on their lands in 2007.

IWS and PNM personnel involved in the outreach efforts believe that hunters do come to understand the threats leaded ammunition can pose, and are typically convinced of the high performance of non-lead ammunition when they are provided with well-prepared information and demonstrations (Theyerl et al. 2010) Surveys distributed following shooting demonstrations have shown that hunters attending these events are accepting of non-lead ammunition and that most are surprised by the amount of lead fragments that result from lead ammunition. The outreach efforts are continuing in California and will extend to areas beyond those in close proximity to PNM.

Minnesota. Minnesota is among the states that have been active in public outreach to address the use of lead shot in hunting. In May 2006, the Minnesota Department of Natural Resources (MDNR) and Division of Fish and Wildlife (FAW) formed the Nontoxic Shot Advisory Committee (NSAC). The NSAC comprised representatives from the manufacturing and retail industry, hunting constituencies, environmental groups, and technical ex-

perts from other state and federal agencies (NSAC 2006). The goals of the committee were to develop recommendations for future restrictions on lead shot in Minnesota, a time frame for implementation, and a public communication/education plan, and to identify gaps in understanding and potential research needs. Based on several meetings held throughout 2006, accompanied by a thorough investigation of lead issues, the NSAC reached a consensus that the MDNR should (1) regulate lead shot on managed dove fields (which was implemented in 2006) and for shotgun hunting in general, and (2) implement regulations that are more restrictive than current state and federal legislation (NSAC 2006). The committee did not, however, reach consensus as to what the extent of these regulations should be.

A cooperative human dimensions investigation was conducted in 2007–2008 by the Minnesota Cooperative Fish and Wildlife Research Unit and MDNR to provide information about small-game hunter perceptions and knowledge of non-toxic shot and to help identify appropriate messages for communication programs (n = 927; Schroeder et al. 2008). The study was very context-specific and focused on attitudes and norms about a potential ban on lead shot in the Minnesota farmland zone. Results indicated that over half of the respondents believed that a ban on lead shot would help protect wildlife from lead poisoning, benefit the quality of the environment, prevent the spread of lead in the natural environment, and improve awareness about lead contamination issues. Half of the respondents also believed that such a ban was likely to increase crippling and wounding losses for small game hunting and would require the use of less effective shot. Over 75% believed the ban would require hunters to use more expensive ammunition, and over 40% thought the ban was unnecessary government regulation that would make it more difficult for some people to hunt. Much of the data suggests that many hunters perceived both positive and negative impacts. Over 70% of respondents felt that it was good to protect wildlife from lead poisoning, and most thought that hunters would adjust to the ban after a few seasons. Respondents' intent to support or oppose the ban was fairly evenly split, indicating the potential for high controversy; 44% said it was unlikely that they would support the ban, and 42% said it was likely (Schroeder et al. 2008). The likelihood of supporting the potential ban was positively correlated with respondents' trust of the MDNR.

Building on the results of this investigation, the MDNR's website currently contains many examples of outreach aimed at educating hunters about the hazards of lead to wildlife and human health. Along with the Minnesota Department of Health, the MDNR also has been very active in raising awareness among hunters about the specific risks associated with lead in venison. Informing these efforts are recent studies conducted by the agency to determine levels of lead bullet fragmentation and deposition in white-tailed deer (*Odocoileus virginianus*) and domestic sheep (*Ovis aries*; Grund et al. 2010). Results indicate that using copper bullets or bullets with no exposed lead can significantly reduce or eliminate lead exposure that would otherwise occur with lead bullets. This research was conducted in response to findings from investigations conducted in North Dakota which we discuss in more detail below.

North Dakota. In 2008, a study of lead in venison showed that, much like wildlife species, humans can be exposed to lead by consuming deer harvested with lead ammunition. Concerns arose after a study by a Bismarck physician found that, out of 95 packages of

ground venison donated to food pantries, 53 contained lead fragments (NDDoH 2008a). Following this discovery, the North Dakota departments of Health, Agriculture, and Game and Fish advised food pantries to stop the distribution of ground venison (NDDoH 2008b). A few weeks later, tests in Minnesota also discovered lead in venison donated to food pantries. As in North Dakota, Minnesota's departments of Health, Agriculture, and Natural Resources issued similar advisories to halt the distribution of venison. In addition to removing venison from food banks, public advisories were issued to the hunting community about the dangers of lead exposure, especially for children and pregnant women. Other Midwestern states, such as Wisconsin, also began to study venison and to issue letters of caution to food pantry managers (Warzecha and Thiboldeauz 2008).

The measures taken in North Dakota and Minnesota were highly controversial, and the NSSF emerged as the most outspoken opponent to the agencies' actions. The initial scientific evidence to support pulling venison was minimal and, in North Dakota, gathered very informally. Subsequent studies have been conducted to determine whether people who eat wild game harvested with lead bullets have higher BLLs than those who don't. A study of 738 North Dakotans showed a link between eating wild game shot with lead bullets and higher BLLs (NDDoH 2008b). However, while the correlation was statistically significant, other sources of lead exposure were not controlled for, and results were considered inconclusive. In fact, the results revealed that individuals who consumed game harvested with lead ammunition had lower BLLs than average Americans exposed to other sources of lead. Additionally, only a 0.3 microgram per deciliter difference was shown between participants who consumed game harvested with lead and those who did not.

These results added fuel to the controversy. The NSSF issued statements claiming that the study proved traditional ammunition poses no threat to humans. Those on the other side of the issue used the findings to claim that lead ammunition should be banned because humans are exposed to some amount of lead, and no amount is safe. Due to the study, and similar ones that followed, the agencies in North Dakota and Minnesota revised their initial advisories. New advisories stated that lead is a harmful substance, firearm ammunition used for taking deer contains lead, and venison processed by hunters and commercial processors has been shown to contain lead particles (Bihrle 2008). But, they also note that no incidence of human lead poisoning has been documented in the US and make recommendations for limiting the possibility of exposure. One of the recommendations is to use non-lead ammunition, but the rest focus on precautions to take when using lead bullets. As this situation suggests, more research is needed to determine if the exposure to lead from consuming game harvested with lead ammunition is detrimental enough to the health of humans to warrant regulatory action, or to be perceived as a high enough risk among hunters to prompt voluntary use of non-lead alternatives. (Following NPS internal policies, Theodore Roosevelt National Park in North Dakota now requires volunteers who are chosen to participate in elk reduction efforts to use non-lead ammunition.)

Wyoming. In 2009, officials in Grand Teton National Park (GTNP) and the National Elk Refuge (NER) began encouraging hunters to use non-lead ammunition during the elk and bison seasons (Skaggs and Iverson 2009). This came in response to a series of studies, beginning in 2004, that were conducted by Craighead Beringia South (CBS), a non-profit

science and education organization (CBS 2009). The studies found that BLLs of ravens (*Corvus corax*), bald eagles, and golden eagles (*Aquila chrysaetos*) in the Jackson Hole valley were highest during the fall hunting season. GTNP and the NER also cite the recent findings of research on potential lead contamination in humans, stating that one of the goals of the non-lead program is to raise awareness about the risks to hunters so that hunters can make informed decisions when choosing ammunition (Skaggs and Iverson 2009). To begin to monitor program participation, GTNP and the NER asked hunters to report their use of non-lead ammunition for the 2009 season; hunters were able to record their responses on their hunting permits. This baseline information will not only be used to track hunter behavior in the context of lead use but also to inform possible incentive strategies that can be used in the future to increase use of non-lead products. GTNP and the NER have stressed the voluntary nature of their program and are not pursuing regulatory bans in those areas.

CBS also recently began its own outreach program targeting hunters in the Jackson Hole area (CBS 2009). The focus of the program is on educating hunters about the hazards of lead and distributing non-lead rifle ammunition. In 2009, 194 boxes of ammunition were distributed. However, follow-up research to help determine the effectiveness of the program did not detect lower BLLs in eagles, and the drops in raven BLLs were minimal. The CBS has acknowledged that its program needs to be expanded, and future plans are to provide non-lead ammunition to more hunters while educating them about the positive impacts of voluntarily switching to non-lead alternatives. Future research on the impacts of these initiatives in the Jackson Hole valley may prove valuable in facilitating comparisons with other programs, such as those in Arizona's California condor range.

Emerging efforts in other states: The case of dove hunting. The use of lead for hunting mourning doves (*Zenaida macroura*) has attracted attention in states across the nation in recent years. Efforts aimed at reversing declines in hunter numbers in the US have prompted many states to provide more dove hunting opportunities (National Mourning Dove 2010). However, this has raised concerns about the potential for mourning doves and other wildlife to be exposed to significant quantities of lead shot in the future, particularly given that large amounts of lead have been shown through prior research to accumulate in relatively small areas from dove hunting (Lewis and Legler 1968; Best et al. 1992; Schulz et al. 2002). To inform future management decisions on this issue, several states have conducted human dimensions investigations. In Missouri, small-game hunters were surveyed to determine their attitudes toward regulations requiring the use of non-lead shot for hunting small game, specifically mourning doves (Schulz et al. 2007). The survey found that most hunters (72–85%) opposed additional regulations. Surveys were also recently administered in Illinois and Texas, but due to differences in study design, the results of these investigations are not comparable (National Mourning Dove Hunter Survey 2010). The need for a national survey to assess dove hunters' current awareness of lead issues and levels of support for the use of non-lead ammunition, which would be comparable across regions and states, has been identified. Results could also help in determining what information is needed to better inform and communicate with hunters about lead issues. Plans, including survey development, are currently underway to implement such an investigation in 2011 (National Mourning Dove Hunter Survey 2010).

WAFWA and AFWA activities. In June 2009, the Western Association of Fish and Wildlife Agencies (WAFWA) established an ad hoc work group charged with making recommendations to WAFWA with regard to lead use in hunting and fishing (Elicker 2010). Recognizing the sensitivities surrounding this issue, and its complexity, the work group members were drawn from multiple disciplines, including chairs of the Wildlife Health, Human Dimensions, and Resource Information and Education, Wildlife, and Fish Chiefs committees, and is chaired by the director of the Washington Department of Fish and Wildlife. The work group believes that fish and wildlife agencies should help lead efforts to address this issue due to the potential impacts on hunters, anglers, industry, retailers, and fish and wildlife management (WAFWA 2010). The work group focused on developing practical, realistic, and science-based recommendations and ultimately developed ten recommendations for WAFWA (Elicker 2010): (1) coordinate with other WAFWA committees; (2) develop consistent messaging; (3) utilize human dimensions research to develop messages; (4) monitor research on lead and wildlife; (5) collaborate with industry, partners, and public agencies; (6) seek consistent federal policy; (7) monitor state efforts; (8) encourage manufacturers to make non-lead products available and affordable; (9) address funding issues; and (10) identify further research needs regarding impacts on wildlife. The ad hoc work group will continue for an additional year and work towards reaching some of the objectives set forth in their recommendation (WAFWA 2010).

In September 2010, AFWA passed a resolution to adopt a number of principles regarding future regulation of lead ammunition and fishing tackle. These principles stated a belief that future regulation was best addressed by individual states and should focus on population-level impacts to wildlife that are substantiated by the best available science (AFWA 2010). However, they also noted that state fish and wildlife agencies should proactively coordinate with state health agencies, industry, conservation organizations, and hunting, angling, and shooting sports interests. In addition, they called for the development of effective human dimensions strategies, as well as the use of public education and voluntary programs where appropriate in lieu of regulation.

Lead ban petition to the EPA. On August 3, 2010, conservation groups petitioned the EPA for a nationwide ban on the production and sale of lead bullets, shotgun pellets, and fishing sinkers (EPA 2010). The petition was filed by the Center for Biological Diversity, American Bird Conservancy, Public Employees for Environmental Responsibility, Association of Avian Veterinarians, and the hunters' group Project Gutpile. The petitioners want the EPA to act under the auspices of the Toxic Substances Control Act (TSCA) which gives the EPA the broad authority to regulate chemical substances that pose a risk to the health of humans or the environment. The EPA is prohibited from regulating ammunition or firearms under the TSCA, but if non-toxic alternatives are commercially available, toxic elements of ammunition can be regulated (EPA 2010). There are no such restriction for regulation fishing sinkers. As with previous moves to impose regulations, the petition generated much debate and roused both those who support a ban and those who do not. On November 4, 2010, the EPA denied the petition, stating that the petitioners had failed to demonstrate that such a ban was necessary to protect against an unreasonable risk of injury to health or the

environment as required by TSCA. Following the denial of the petition, the groups sued the EPA in late November 2010 and further action is pending.

Partially in response to the petition, the chairs of the Congressional Sportsmen's Caucus—Senators Jon Tester (D-MT) and John Thune (R-SD) and Representatives Jeff Miller (R-FL) and Mike Ross (D-AR)—introduced the Hunting, Fishing and Recreational Shooting Sports Protection Act (S. 838 and H.R. 1558) on April 14, 2011. The bill would amend TSCA to deny the EPA authority to outlaw lead bullets, shot, and fishing tackle. In addition, Representative Paul Braun (R-GA) introduced two bills that would prohibit the EPA from regulating any type of firearm ammunition or fishing tackle based on material composition (H.R. 1443 and H.R. 1445). H.R. 1445 would also prohibit the Department of the Interior and the Department of Agriculture from newly prohibiting or limiting, based on material content, the use of traditional hunting implements on federal lands.

Overall findings for outreach to reduce the impacts of lead from hunting and fishing

Many important lessons have come out of the work being done by various states, agencies, and organizations that can inform development of effective outreach strategies and messages for addressing issues related to the use of lead in recreational hunting and fishing. While there are more examples to draw upon for hunting, many of these lessons would also be applicable to communicating about lead use in recreational fishing. Additionally, while recommendations stem largely from context-specific outreach efforts—e.g., efforts applied to condor conservation (Sullivan 2009) and lead shot use in Minnesota's farmland zone (Schroeder et al. 2008)—many are relevant for considering how the NPS might address lead issues on its lands in the future. The following lists are an attempt to synthesize key lessons learned from our review of the relevant literature.

Some general findings

- Surveys of hunters in Arizona and California showed that, depending on the nature of the request and the source, most hunters are willing to take some action to help prevent lead poisoning of wildlife (D.J. Case and Associates 2005).
- Many hunters may be unaware of the impacts of lead ammunition on wildlife, suggesting the need for strategies that can help raise basic awareness among sportsmen about lead issues (D.J. Case and Associates 2005).
- Voluntary measures typically require less concrete evidence ; i.e., they allow for more uncertainty than regulatory bans would. However, this should not be seen as an invitation to offer scientific evidence that is not rigorous or to avoid providing scientific evidence altogether (Sullivan 2009).
- Negative media has been a challenge in many cases, and researchers have found that a single negative media article can nullify the impacts of providing factual information (AFWA 2007). This indicates the need to develop good ties to the media and accurately disseminate information through media outlets.
- In states such as Washington, where proposed bans on lead fishing tackle have been controversial, it is recommended that agencies work to promote the use of non-lead

alternatives and the proper disposal of lead products until regulatory legislation can be enacted (Gumm and Poleschook n.d.).
- Tools used by many states to eliminate lead in the environment from fishing are: lead sinker exchanges (promoting proper disposal), brochures educating anglers about the hazards of lead, warnings for children and pregnant women about their susceptibility to detrimental effects of lead exposure, and promotion of responsible fishing practices such as retrieval and disposal of fishing line and tackle.

Outreach-specific findings, including tactics for message creation and delivery

- Many states have emphasized the importance of knowing one's audience, and educating oneself about hunters, hunting, and ballistics expertise to be well received and seen as credible by hunters (Sullivan 2009).
- Hunters in Arizona and California stated that they would be more supportive of non-lead alternatives if they were given credible scientific evidence of the detrimental impacts of lead on California condors (D.J. Case and Associates 2005). However, when the AZGFD responded by providing hunters with detailed information on the topic, they found that fewer hunters read the information and that it was therefore less effective than if the communication delivery had been less in-depth (Sieg et al. 2009). It is important to find the right balance of adequate information and home in on the key points in an appropriate communication style, given that the public may not have the time or level of interest to process large amounts of information.
- Providing hunters with incentives, such as free non-lead ammunition, has proven to be a powerful tool to enhance the success of outreach initiatives (Sieg et al. 2009). The AZGFD also points out the necessity of partnerships to implement this type of program, as some government and non-governmental organizations cannot distribute ammunition directly.
- Photos of x-rayed ballistics gel and wildlife carcasses have made a huge impression on hunters in Arizona and California (Petterson 2009). Many hunters are unaware of the amount of lead lost through fragmentation; a visual display is one of the most effective ways to portray this information.
- Participatory outreach mechanisms—e.g., demonstrations with ballistics gel and water jug testing—have been effective ways to engage the public on issues of lead use in California (Petterson 2009). They provide an opportunity for hunters to experience firsthand the degree to which lead bullets fragment compared with non-lead bullets. They also provide hunters a chance to test non-lead ammunition, which can help dispel negative misconceptions regarding non-lead products. For example, many hunters may believe that non-lead ammunition is less effective, but when non-lead bullets are shot into ballistics gel, participants can witness the hydraulic shock and compare it with that of leaded bullets.
- The Ad Hoc Mourning Dove and Lead Toxicosis Working Group has emphasized the importance of training salespeople—i.e., the people from which hunters buy their ammunition—as they are often the main source of information for hunters (AFWA 2007).
- Messages that highlight the importance of conservation heritage to hunters were rated

highly by focus groups in Arizona (D.J. Case and Associates 2005). These messages focus on deeply held core values for many hunters. Hunters are rightfully proud of the hunting tradition and its contributions to wildlife conservation in this country; using non-lead products can be seen as an extension of this tradition (Sullivan 2009). It is worth noting, however, that some research (Schroeder et al. 2008) has suggested that other message points may be more effective.

- The AZGFD has stressed in some of its communications that using non-lead ammunition makes hunting more beneficial to wildlife (e.g., the endangered California condor), which, again, invokes the conservation ethic of hunters (Sullivan 2009). Certain species depend on hunting for survival, and wildlife carcasses and offal piles (without lead fragments) can enhance survival of these species. This approach demonstrates that agencies are not blaming hunters, but rather asking for their help.
- Persuasive messages from credible sources may help generate support for bans on lead shot. More specifically, Schroeder et al. (2008) found that basic, factual, first-person narratives that mention a social group hunters identify with (e.g., Ducks Unlimited) may be more persuasive than other alternatives, including declarative statements from the state agency, counterarguments, value-expressive messages about hunting heritage, and third-person narratives.
- Tied to the above point, credible sources are needed to deliver messages aimed at promoting voluntary lead reduction measures. Surveys in Arizona identified sportsmen's groups as the most credible source (D.J. Case and Associates 2005).
- Hunter education instructors have been suggested by some researchers as important sources for getting messages out to new hunters (AFWA 2007).
- In Arizona, research found that references to endangered or rare species should not be used at the outset of communication messages (Sullivan 2009). This is important supportive information, but it is not the first topic that should be presented or emphasized.
- Focusing on one-to-one communication whenever possible has been an important strategy in outreach efforts in California and Arizona (Petterson 2009). The opportunity to do so occurs oftentimes in the field where agency staff can interact with hunters on a less formal basis. An important consideration in this context is the need to ensure field staff, concessionaires, interpreters, law enforcement, etc., are aware of, and on board with, the agency's agenda with regard to lead issues.
- Adding to the previous point, it is important for recipients to receive one unified message from all sources (AFWA 2007). Mixed messages from various organizations can decrease the credibility of all involved and confuse hunters as to what is fact or opinion.

Conclusion

Management decisions about the use of lead ammunition and fishing tackle are needed to mitigate further impacts of lead on wildlife, wildlands, and humans. Unfortunately, these decisions will have to be made in an environment of uncertainty and controversy. Despite the significant body of literature on lead poisoning caused by spent lead ammunition and fishing tackle, there are still gaps in scientific understanding that create an environment of scientific uncertainty, making lead product bans difficult and expensive to implement.

Previous efforts to reduce the amount of lead introduced by hunters and anglers in the environment are valuable for understanding the current issues surrounding lead bans and efforts to increase voluntary use of non-lead alternatives. However, most of the research aimed at informing these efforts thus far has been very context-specific, and the attitudes and beliefs of hunters and anglers regarding lead issues are still largely unknown. We do know that in areas with key species of concern, hunters and anglers are often unaware of the lead-related impacts of their activities, even though they may be more aware than in areas where there has been less attention paid to such impacts. There is a definite need for more thorough evaluation of existing communication strategies, as well as a need to understand the beliefs and attitudes of the diverse array of stakeholders, in order to inform more targeted outreach initiatives. While the political will at individual state levels, and at the national level, appears to be lacking to support a broad-scale ban on lead products in hunting and fishing, this has not been fully explored, and those who oppose such a ban have been more unified and vocal in their objections. Exploring the full range of beliefs and attitudes is an important next step to take if policy and outreach to reduce impacts from lead are to be considered viable options in the future.

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