LEAD POISONING OF NORTH AMERICAN WILDLIFE FROM LEAD SHOT AND LEAD FISHING TACKLE

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Abstract

Thousands of tons of lead are deposited in the environment annually through hunting, fishing, and shooting, thus exposing dozens of species birds to this toxic substance. Because lead pellets and sinkers resemble grain and grit, water birds, upland game birds, and songbirds may eat them. Raptors ingest lead when scavenging hunter-killed carcasses or preying on apparently healthy prey animals carrying shot in their tissues. While lead may pass through the digestive tract, it may be digested and absorbed into the blood stream causing behavioral and neurological dysfunction, compromising the immune system, and (sometimes) resulting in death. Indeed absorption of a single lead pellet can be lethal. Lead poisoning of waterfowl and a key predator, the Bald Eagle, resulted in a 1991 federal ban on the use of lead shot in waterfowl hunting. While the ban has mitigated lead poisoning of waterfowl, Bald Eagles, Golden Eagles, California Condors, Common Loons, and swans continue to succumb to lead poisoning at significant rates. Thus additional restrictions are being placed on lead in some National Parks, National Wildlife Refuges, state lands, and statewide in a few states. At the same time, nontoxic alternatives are becoming increasingly available. Adoption of nontoxic options has been slow however, probably because early nontoxics performed poorly in comparison with lead. But steel technology has improved substantially and the price has dropped, currently approaching that of lead. A variety of new ammunition and tackle types are being developed incorporating substances such as bismuth and tungsten which perform as well as or better than lead. While they are more expensive, this cost differential only represents a small part of sports enthusiasts' annual expenditures. Through a multi-media outreach program, HawkWatch International will seek to inform sports enthusiasts of the risks of using lead tackle and ammunition and the benefits of using nontoxic alternatives. As more hunters and anglers learn about the impact of lead on nontarget animals and the benefits of using nontoxics, they are likely to adopt those alternatives even if they are more expensive.

Table of Contents

List of Tables

Introduction

Despite a 1991 federal ban on lead shot for waterfowl hunting, lead poisoning continues to be a problem for wildlife because thousands of tons of lead are deposited through upland game hunting, fishing, and shooting sports annually. Water birds, upland game birds, and songbirds may eat lead shotgun pellets and split shot sinkers mistaking them for food or grit. Additionally, raptors may ingest lead shot embedded in apparently healthy prey animals or carcasses. Once digested and absorbed into the blood, even a single shotgun pellet or lead split shot sinker can be lethal. Sublethal levels can compromise health and cause behavioral and neurological dysfunction. Research suggests that lead poisoning is the leading cause of death in adult loons in the Northeast and a significant mortality factor in Bald Eagles, Golden Eagles, and California Condors. Because of the continued incidence of lead poisoning after the ban on lead in waterfowl hunting, lead ammunition and tackle are being further restricted on some National Parks, National Wildlife Refuges, state lands, and even statewide in some states. At the same time, a variety of nontoxic alternatives are becoming increasingly available.

To further minimize environmental lead deposition, HawkWatch International has launched its Wildlife Lead Poisoning Reduction Program (WLPRP), an outreach effort designed to inform outdoor enthusiasts of the unintended impacts of lead use on wildlife, and to encourage the use of nontoxic ammunition and tackle. This report, a review of the lead poisoning problem, is the foundation of that effort. Next, HawkWatch will work with hunters and anglers to better understand their knowledge about and attitudes toward lead and lead-free alternatives. HawkWatch will develop a multi-media approach to sensitize hunters and anglers to the unintended negative spinoffs of lead ammunition and tackle and introduce (or re-introduce) them to nontoxic alternatives. HawkWatch believes that exposure to the problem and the solutions that can be implemented relatively easily by individual hunters and anglers will appeal to the many sports enthusiasts who deeply value, and wish to help conserve, wildlife and the environment.

Lead Poisoning of Waterfowl

In the late 1800s, die-offs of waterfowl and geese were documented throughout the United States (Grinnell 1894, Hough 1894). Necropsies revealed that many of the birds had ingested lead shotgun pellets and presumably died from lead poisoning. Additional incidents of lead poisoning were described during the first half of the twentieth century involving Mallards (*Anas platyrhynchos*) (Bowles 1908), Canvasbacks (*Aythya valisineria*) (McAtee 1908), Greater Scaups (*Aythya marila*) (Van Tyne 1929), Trumpeter Swans (*Cygnus buccinator*) (Munro 1925), and various other ducks (Schillinger and Cottam 1937).

Thousands of ducks and geese in the Mississippi Flyway succumbed to lead poisoning in several die-offs during the late 1930s and 1940s. Shortly thereafter, Bellrose (1959) conducted an ambitious, and now classic, research project to gain an understanding of the extent of the lead poisoning problem. His survey of wildlife professionals from around the country revealed that die-offs had been documented in all major flyways, that Mallards, Northern Pintails (*Anas acuta*), and Canada Geese (*Branta canadensis*) appeared to be especially susceptible to lead poisoning, and that most die-offs occurred after the hunting season in late fall and early winter. Bellrose speculated that lead shot was most readily available at the end of the hunting season in areas that were heavily shot over by waterfowl hunters and estimated that over 100,000 lead pellets per acre could accumulate by the end of the hunting season. Foraging waterfowl were exposed to lead when they ate these pellets, presumably mistaking them for food or grit.

In wetlands, lead availability is determined by pellet density, soil type, water depth, and pellet size. Clearly, the most popular hunting areas accumulate the highest pellet densities (see Table 1). Conditions in wetland habitats strongly influence shot availability. Pellets that sink into soft, silty bottoms are out of reach of some waterfowl but pellets do not penetrate hard substrates (e.g. clay) and thus remain available to waterfowl. Shallow water allows waterfowl to reach the bottom and access pellets whereas deep water restricts such access. Finally, some sizes of pellets are more attractive to wildlife than others, apparently due to their resemblance to grain or gravel.

Upon examining the gizzards of 40,000 harvested waterfowl and fluoroscoping more than 5,000 live Mallards, Bellrose found that up to 6% of the waterfowl population had lead pellets in their gizzards at any one time. Because experimental data indicated that pellets were generally expelled two to three weeks after ingestion and that lead poisoned ducks died within a month, Bellrose predicted that a much higher percentage of waterfowl ingested lead shot throughout the year (~40%) and that most lead poisoning mortalities went unnoticed. Thus, although Bellrose had set out to study waterfowl die-offs, he concluded that day-to-day lead poisoning was widespread with 4% of waterfowl populations dying annually.

Bellrose's research served as the conceptual foundation and impetus for numerous subsequent studies addressing lead poisoning in waterfowl that have largely corroborated his findings (Table 2). This collective data was crucial to passage of the 1991 ban on the use of lead shot in waterfowl hunting. Also, the patterns described in the waterfowl literature are applicable to other high-risk (but less studied) wildlife such as upland game birds and raptors (Kendall et al. 1996, Locke and Thomas 1996, Kramer and Redig 1997, Miller et al. 1998).

Primary Lead Poisoning Associated with Hunting

Although lead shot was banned for waterfowl hunting, much residual lead remains in wetlands. Additionally, upland game hunting continues to add to lead loads where hunters shoot in riparian areas or marshes. A number of water birds, exhibiting different feeding strategies, are exposed to such lead (Bellrose 1959). Dabblers typically skim the bottom digging in the mud for roots, leaves, seeds, or shot resting there. Diving ducks, swans, and geese utilize deeper water but are still exposed to shot when feeding. And, shorebirds ingest lead when probing the soft soils along banks and foraging in sediments in the shallows. Their bills allow them to dig deeply in search of seeds and insects exposing them to shot that is unavailable to other species. In sum, water birds occupying different niches utilize several sediment layers. The result is that newly deposited lead is available to some species and old spent shot that has sunk into sediments is available to others.

Many upland bird species feed on seeds and grains in fields and edges. Lead pellets closely resemble these food items and occur in hunted areas where the birds feed. This is especially prevalent in fields that are planted with grains attractive to game species and that are hunted each fall after harvest. In such cases, both food and shot are readily available to large numbers of foraging birds, increasing the potential for lead exposure (see Table 3).

Symptoms of lead poisoning do not necessarily occur each time a bird consumes lead shot. Sometimes, the pellets will pass through the digestive tract within 24 hours and the bird may be exposed to lead without exhibiting symptoms of lead toxicity. At other times, the shot lodges in the gizzard where it is pulverized by the gizzard's grinding action and eroded by digestive acids. This process releases lead salts that are absorbed into the blood stream causing lead poisoning.

Birds can experience two types of lead poisoning (Bellrose 1959, Redig 1985, Sanderson and Bellrose 1986, Eisler 1988, Scheuhammer and Norris 1996). A bird with acute lead poisoning appears to be in good health but experiences massive tissue destruction and damage to internal organs, dying within a few days. A single lead pellet is enough to produce acute poisoning (Sanderson and Bellrose 1986). A bird experiencing chronic lead poisoning retains the shot in the digestive tract for several days or even several weeks until the pellets pass or dissolve (Grandy et al. 1968, Kimball and Munir 1971, Finley and Deiter 1978). A variety of symptoms ensue which may or may not be lethal. At low lead levels, the bird may experience appetite loss or anemia. If the pellets pass, the bird may recover although it is at higher risk of predation or accidental trauma while exposed. At elevated levels, anorexia, impacted gizzard or proventriculus, reproductive or neurological impairment, or immune suppression may result. At very high levels, paralysis of the digestive tract, wings, or legs occurs. The bird may be unable to eat, digest food, walk, swim, or fly, eventually starving (30-40% weight loss) or becoming subject to predation (Hohman et al. 1995).

To ascertain the prevalence of lead poisoning, a variety of researchers have counted the number of pellets present in avian gizzards by x-raying or flouroscoping live birds or examining gizzard/digestive tract contents of carcasses. However, such studies may underestimate lead prevalence, as lead pellets may be expelled or fully dissolved before a bird dies of lead poisoning (Best et al. 1992a). For example, only 14% of lead poisoned Bald Eagles (*Haliaeetus leucocephalus*) had lead shot in their digestive tracts upon necropsy (Feierabend and Myers 1984). A variety of other techniques have been applied to measure lead exposure in an attempt to correct for the deficiencies of gizzard counts (see Table 4).

While the mechanisms of lead poisoning are well understood, poisoning rates are not. Die-offs of abundant and gregarious species (such as geese or swans) are highly visible, but the daily losses are rarely observed. Poisoned birds isolate themselves, seeking dense cover where they go unnoticed (Sanderson and Bellrose 1986). In an experiment, observers were given 30 minutes to find 100 carcasses planted in a marsh; they only discovered six (Stutzenbaker et al. 1983). Predation and scavenging often occur within hours or days of the onset of severe symptoms or death, further reducing the number of poisoned birds recovered. When researchers planted carcasses in a wetland, 62% were gone in four days (Humburg et al. 1983). In a similar study, 62% of planted carcasses were gone in three days, 91% in eight days (Stutzenbaker et al. 1983). Because, it is extremely difficult to account for individual cases of lead poisoning, describing population-level effects of lead poisoning are even more problematic (Sanderson and Bellrose 1986, Washington Department of Fish and Wildlife Nontoxic Shot Working Group 2001).

Secondary Lead Poisoning Associated with Hunting

Concern over secondary lead poisoning originally coalesced around the relationship between waterfowl and Bald Eagles. Bald Eagles may gather in waterfowl hunting areas and scavenge unretrieved carcasses or prey on crippled ducks or ducks carrying embedded shot (Elder 1955, Redig et al. 1980, Pattee and Hennes 1983, USFWS 1986)[1]. To determine lead exposure in eagles, researchers examined castings found at roosting sites near waterfowl hunting areas. Up to 70% of eagle castings contained lead pellets, suggesting that lead exposure is limited by the regurgitation mechanism that evacuates shot with other undigestable materials (Pattee et al. 1981). However, not all shot is expelled and eagles have ample opportunity for re-exposure during hunting season.[2] Indeed, exposed eagles may suffer impaired hunting ability, causing them to scavenge more and increasing the chances of re-exposure (Redig 1984). Lead poisoning of raptors, like that of waterfowl, occurs seasonally with most mortalities taking place in late fall and early winter (Pattee and Hennes 1983, Feierabend and Myers 1984, USFWS 1986, Elliot et al. 1992).

In 1991, the U.S. Fish and Wildlife Service banned lead shot for waterfowl hunting to minimize lead exposure in both waterfowl and Bald Eagles. Lead shot exposure in waterfowl appears to be decreasing dramatically, but eagles are exposed to lead at pre-ban rates (Table 5) (Kramer and Redig 1996, Anderson et al. 2000). To explain these persistent exposure rates, researchers are exploring alternative lead sources, as waterfowl only comprise a portion of eagle diets. Bald eagles also feed on fish, upland birds, small mammals, and carrion (Frenzel 1985, Hennes 1985), while Golden Eagles (*Aquila chrysaetos*) feed on ground squirrels, jackrabbits, upland birds, and big-game carcasses (Ohlendorff 1976, Platt 1976, Frenzel 1985, Harmata 1990, Harmata and Restani 1995). Harmata and Restani (1995) believe that the continued use of lead shot in upland game hunting and lead bullets in plinking and big game hunting is a significant cause of lead poisoning of Golden and some Bald Eagles. Plinking involves shooting prairie dogs, ground squirrels, and rabbits. Plinkers shoot several animals in a day and typically leave the carcasses in the field, exposing Golden and some Bald Eagles to lead. Up to 30 Golden Eagles have been observed following plinkers from field to field, scavenging ground squirrels after the shooters had moved on (Harmata and Restanin 1995). Scavengers are also exposed to lead fragments from slugs used in big game hunting. Slugs are designed to shatter on impact, killing the animal instantly (ideally) by creating massive internal injuries. Scavengers may be exposed to lead slugs when consuming carcasses that are unrecovered (i.e. coyotes (*Canis latrans*) or injured ungulates) or gut piles that are left in the field.

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[1] Shot embedded in tissues of apparently healthy individuals has been documented in a number of avian species. For example, 19% of Canvasbacks carried as many as 9 lead pellets embedded in their tissues (Perry and Geissler 1980). Havera et al. (1992) found a 15% imbedded shot rate for Canvasbacks and 9% rate for Lesser Scaups (*Aythya affinis*). Some 27% of Ring-Necked Pheasants (*Phasianus colchicus*) carried embedded shot (Elder 1955).

[2] Lead exposure occurs when raptors consume metallic lead as shot or sinkers imbedded in tissue or retained in the digestive tracts of prey animals. Significant exposure does not occur when raptors feed on lead that has bioaccumulated in the tissue of prey animals (Stendell 1980, Custer et al. 1984, Franson et al. 1983).

The California Condor Recovery Team (2001) concluded that lead poisoning has been the leading cause of the decline in endangered California Condor (*Gymnogyps californianus*) populations in the last 50 years. Condors, as scavengers, feed on carcasses and gut piles left in the field, seeking soft tissues and small hard objects, such as calcium-rich bone, when feeding (Snyder and Snyder 2000). This puts them at especially high risk for lead ingestion. Further, Condors do not typically regurgitate castings, a mechanism that mitigates shot exposure in Bald Eagles. Four condors died of lead poisoning after feeding on gut piles in the Vermillion Cliffs region of Arizona in 2000. An additional 35% of released condors have experienced acute lead poisoning over the past 20 years (Weimeyer et al. 1988, Risebrough et al. 2001).

Lead Exposure from Fishing Tackle

Lead poisoning due to fishing tackle has been documented in 25 species of water birds and in sensitive species including Common Loons (*Gavia immer*), Trumpeter Swans, Mississippi Sandhill Cranes (*Grus canadensis*), and Bald Eagles (see Table 6). In New England, poisoning from lead weights and jigs is the greatest source of loon mortality, accounting for 50% of adult deaths (Pokras and Chafel 1992). Likewise, in Canada, 30% of adult loon mortality is due to lead poisoning resulting from sinker ingestion (Scheuhammer and Norris 1996). Ensor et al. (1992) found that 17% of adult loon deaths in Minnesota could be traced to lead poisoning from fishing tackle. Lead poisoning, sometimes caused by sinkers, is also a significant mortality factor for the Trumpeter Swan (Blus 1994).

Lead split shot comprises 50% of the sinker market in the United States (USEPA 1994). These tiny, round BBs can be difficult to handle and anglers often lose several sinkers for each one successfully attached to the line. Further, sinkers are lost when anglers cast or break their lines to free them from submerged snags. With more than 2,700 tons of lead sinkers sold in the U.S. annually, and an additional 400-550 tons sold in Canada, accidental sinker loss results in a substantial amount of lead deposition in wetland environments (USEPA 1994, Scheuhammer and Norris 1995). There, it is available to foraging wildlife that may mistake it for grain, grit, insects, or fish.

Anglers lose lead sinkers, jigs, and lead-weighted flies in fish themselves. Hooked fish can free themselves by breaking a line or pulling tackle loose. Such fish often carry tackle in their mouths or digestive tracts. Fish are not subject to “dietary” lead poisoning (Hodson et al. 1978) and lead tackle typically dissolves. However, predators that take fish containing tackle can ingest metallic lead, becoming susceptible to secondary lead poisoning. Secondary lead poisoning due to fishing tackle has been documented in Bald Eagles, Common Loons, Common Mergansers (*Mergus merganser*), and Red-breasted Mergansers (*Mergus serrator*) (USFWS 1994). It is highly likely that Osprey (*Pandion haliaetus*), which feed exclusively on fish, are regularly exposed to lead as well.[3]

[3] The effects of lead fishing tackle on aquatic systems have not been well investigated (Scheuhammer and Norris 1995).

Lead Deposition from Trap and Skeet Shooting

Few studies exist on lead contamination associated with trap and skeet ranges. However, with pellet densities potentially numbering in the billions per acre and as much as 30 tons of lead being shot annually at a single range, contamination is a strong possibility (Scheuhammer and Norris 1995, Kendall et al. 1996).[4] At the wooded Patuxent Refuge Trap and Skeet Range, researchers found up to 4,000 pellets in soil samples ~3 inches in diameter (Vyas et al. 2000). Soil lead levels ranged from 110-27,000 ppm, more than three times the rate at toxic mine sites. For example, sediments from lead and other heavy metal mines on the Coeur d'Alene River in Idaho exhibited soil lead levels of 2,000-8,000 ppm. Songbirds feeding on seeds and earthworms (*Lumbricus rubellis*) in an enclosure at the Patuxent range exhibited high exposure levels and several died during the study (see Table 7). Earthworms at the range contained body burdens of 660-840 ppm, a toxicologically significant amount.

Many ranges occur adjacent to bodies of water. Due to lead contamination of nearby waterways, several ranges have been closed or undertaken cleanup operations. Elevated lead levels associated with contamination from ranges have been documented in aquatic invertebrates, bloodworms, clams, mussels, snails, sunfish, and bass (reviewed in Scheuhammer and Norris 1995). Rainbow trout (*Salmo gardinieri*) are susceptible to lead poisoning from water-borne lead at relatively low concentrations of 1-10 mg 1^{-1} (Hodson et al. 1978). The most severe symptom of lead toxicosis in trout is spinal curvature which depresses reproductive success, causes tail atrophy, and may result in death. Finally, aquatic plants may uptake lead from contaminated sediments. Most lead remains in the roots, although some may be transported to shoots and fruit as well (Behan et al. 1979).

Legislation Regulating Lead Ammunition and Tackle

The 1991 federal ban on lead shot occurred for several reasons. First, the extensive research on lead poisoning of waterfowl indicated that millions of ducks and geese were dying of lead poisoning each year. Clearly, this was a concern to hunters and game managers who wanted to maximize waterfowl harvests. Endangered Bald Eagles preying or scavenging on poisoned waterfowl was further cause for alarm. Both the Endangered Species Act and the Bald and Golden Eagle Act mandated that the Secretary of the Interior must act to safeguard eagle populations (see Table 8). After 20 years of regulatory wrangling, the USFWS phased in a complete ban on lead shot for taking waterfowl during the 1991-1992 hunting season (Federal Regulation 50 C.F.R. 20). Since then, lead poisoning of loons, swans, upland game, and the continued poisoning of eagles has prompted additional restrictions on lead shot and lead fishing tackle on National Parks, National Wildlife Refuges, and on public lands in 25 states. Similar restrictions are in place on Canadian National Parks and National Wildlife Areas. Finally, Maine, New Hampshire, and New York have established statewide bans on the sale and/or use of lead sinkers and jigs in the sizes that are most likely to be ingested by wildlife.

The Clean Water Act, The Resource Conservation and Recovery Act, and The Toxic Substances Control Act have been invoked to curb lead shot use at trap and skeet ranges across the U.S. Because lead deposition can occur in the

[4] For an in-depth explanation of how lead binds with water and soils see National Shoot Sports Foundation (1996).

thousands of tons at a single range and many ranges are situated adjacent to water, concern over toxic contamination has prompted massive clean up efforts or range closures. Indeed, range closures seem to precede judicial action so that the exercise of these acts to mandate changes at shooting ranges has rarely been tested.

Waterfowl Mortalities Since the 1991 Ban on Lead Shot in Waterfowl Hunting

Overall shot ingestion rates by waterfowl have remained constant since the 1991 ban (Anderson et al. 1987). As steel has replaced lead as the prominent shot used in waterfowl hunting, birds are ingesting more steel and less lead (see Table 9). For example, Mallard lead-poisoning mortality has diminished by 64% in the Mississippi Flyway (Anderson et al. 2000). Likewise, there has been a 44% decline in lead exposure of American Black Ducks during the same period (Samuel and Bowers 2000). Other researchers have found that although nontoxics are reducing the numbers of birds suffering from lead poisoning, many continue to be exposed to lead in wetlands due to the prevalence of historic lead deposits and the continued use of lead shot in other sports (DeStefano 1995, Hohman et al 1995). This is evident from a recent Trumpeter Swan die-off in Washington (Washington Department of Fish and Wildlife Nontoxic Shot Working Group 2001).

Certainly, the risk of lead poisoning will persist as long as spent lead shot remains in the environment, potentially 100 to 300 years (Kendall et al. 1996). However, preliminary data is hopeful. Early assessments indicate the ban on lead shot has been successful in terms of reducing wildlife lead poisoning and hunter compliance with regulations, at rates ranging from 90-98% (Havera et al. 1994 , Scheuhammer and Norris 1996). It is likely that the ongoing shift to nontoxics in upland game hunting will produce similar benefits for wildlife and habitat.

Nontoxic Hunting Ammunition

The post-ban conversion to steel shot was problematic. Early tests on steel shot produced high crippling rates and scouring effects in shotgun barrels (Carmichael 2002). The results of these tests impacted public opinion tremendously. Though high crippling rates were also typical of lead shot (USFWS 1985) and many gun barrels had already been damaged by lead magnum loads (Carmichael 2002), hunters rejected steel because of beliefs about its ballistic inferiority and fear that their guns would be damaged by the hard steel pellets. For example, Szycmack (1978) found that goose hunters in Colorado believed that they were crippling many more geese with steel shot than they had with lead shot. In contrast, Szycmack's research indicated that crippling rates were actually declining with steel. Szycmack believed the hunters were responding to adverse publicity and their lack of prior experience with steel. In Ohio, hunters felt that steel crippled more birds and reduced their take and they did not support a ban on lead (Smith and Townsend 1981).

Such concerns persist despite continued improvement of steel shot technology and data acknowledging differences in ballistic properties between lead and steel yet equating their performance. Scheuhammer and Norris (1995) reviewed 16 studies conducted between 1950 and 1984 comparing steel and lead shot. They found that three tests favored lead, two favored steel, two evidenced mixed results, and eight showed no difference between the shot types. One highly publicized study in Louisiana indicated that hunters had less success and crippled more birds with steel (Hebert et al. 1984). However, because hunters had not been informed of what type of shot they were using, they had difficulty making appropriate adjustments (e.g. changing chokes and altering lead time). Further, it is unclear if the hunters had ever shot steel, let alone done so proficiently. This study was essentially a comparison of shooting performance between seasoned lead shooters and inexperienced steel shooters, rather than a comparison of shot types. Mikula et al. (1977) argued that hunters' attitudes fostered their poor performance with steel shot citing unreasonable ranges, unwillingness to hunt with retrieving dogs, and lack of shooting skills as reasons that steel shot appeared to perform comparatively poorly. This poorer performance could have yielded higher crippling rates.

Nevertheless, the search to emulate lead's properties stimulates the proliferation of other nontoxic alternatives for waterfowl hunting (Table 10).[5] Steel continues to be the most popular, and least expensive, alternative to lead. A variety of other shot types are also available. Bismuth and tungsten alloys more closely simulate lead and thus provide lead's killing power (especially at longer distances). In fact, Hevi-Shot, a new tungsten matrix, may *outperform* lead. Because of their accuracy and impact, newer alloys are gaining popularity. However, they cost at least twice as much as steel and lead shot (see Table 11). Early steel prices were quite high but increased demand helped reduce prices over time. As demand increases and subsequent production costs fall, new nontoxics are likely to become more affordable as well. Further, an ever-expanding array of gauges, sizes, and weights of nontoxic ammunition are becoming available (and occasionally required).

Certainly, the individual hunter's ammunition costs may rise with adoption of nontoxics but this increase may be comparatively small. For example, the average waterfowler only takes 6 ducks annually (USFWS 1986). Typically, 6 shots are taken per bird bagged, requiring 36 shot shells. Although nontoxics can be substantially more expensive than lead shot, the actual increase in cost of nontoxics in the field ranges from ~$2.00-$75.00 annually, a small percentage of the waterfowler's yearly hunting expenditures (Scheuhammer and Norris 1995).

Nontoxic Fishing Tackle

In 1994, the EPA proposed a ban on the manufacture, sale, and use of lead fishing tackle. The Agency found that even a single lead sinker can produce lethal lead poisoning and in sensitive species even individual mortalities can have population-level effects. The loss of thousands of tons of sinkers in the environment every year also creates ample opportunity for water and soil contamination. Finally, the Agency stated that as many as 1,600,000 people make approximately 900 tons of lead sinkers at home for personal use or for sale as part of a "cottage industry" thereby exposing themselves and their families to lead dust and vapors. Although the symptoms of lead poisoning in humans tend to be subtle, hypertension, miscarriage, and childhood brain damage may result from repeated exposure.

[5] Toxicity tests on bismuth and tungsten alloys indicate that these substances are nontoxic to wildlife (Sanderson et al. 1992, Ringelman et al. 1993, Kraabel et al. 1996, Sanderson et al. 1997, Kelly et al. 1998, Risebrough et al. 2001)

Although no actions have been taken on the EPA's proposed ruling, the National Park Service and the National Wildlife Refuge System have begun to ban the use of lead fishing tackle on some parks and refuges. Most notably, it is illegal to use lead sinkers in Yellowstone National Park, an important breeding site for the Trumpeter Swan. Likewise, Canada has prohibited the use of lead tackle on all National Parks and National Wildlife Areas. And Maine, New Hampshire, and New York have recently banned the sale/use of some sinkers.

To meet growing demand, an increasing number of nontoxic alternatives are available.[6] Water Gremlin, the leading sinker maker in the U.S., has established the Gremlin Green line of nontoxic sinkers. BulletWeights produces an array of steel sinkers and jigs. Tungsten, bismuth, and antimony work as well or better than lead for weights and weighted eyes. And Dinsmore's reusable tin split shot sinkers, which can be clamped onto the line and reused, are proving effective (and, for some, easier to handle than lead split shot). Another option is putty (e.g. Loon Outdoors Deep Soft Weight) that is malleable as it is applied to the line, hardening when it is submerged. Other, less widely used materials include recycled glass, ceramics, and plastic.

The economic impact of the switch to nontoxic sinkers will be nominal (see Table 12). The EPA (1994) reports that the average angler spends $1.50-$3.50 on sinkers annually. Nontoxic sinkers could increase that cost by up to $4.00 (the price of three flies, two spoons, or two spinners), which is still a small fraction of the anglers' equipment costs and an even smaller fraction of total costs. Similarly, when the National Wildlife Refuge System implemented "Lead-Free Fishing Areas," they acknowledged that nontoxics sometimes cost more than lead weights but stated that as sinkers only comprise 3% of yearly equipment costs, the increase did not create a burden for anglers (Federal Regulation 50 CFR 32 and 36, proposed rule).

Lead Management at Shooting Ranges

The National Shooting Sports Foundation range management guidelines (1997) strongly encourage range managers to mitigate the impacts of lead and avoid lead contamination of soils and ground and surface water. A number of design elements can minimize the possibility of lead dissolving in water and binding with soils particles. Directing runoff, adding clay layers to create impermeable soil surfaces, mixing phosphate or lime with soils, and landscaping with plants that bioaccumulate lead all minimize lead mobility at shooting ranges. Perhaps the most cost-effective approach is recovering and recycling lead shot. Finally, range managers are encouraged to protect wildlife by creating undesirable habitat, removing edible vegetation, and protecting water supplies. The National Rifle Association, Amateur Trapshooting Association, National Skeet Shooting Association, and National Sporting Clays Foundation encourage range managers to design and manage ranges according to these guidelines.

[6] Zinc, copper, and brass sinkers are not viable options as they are toxic themselves. Brass is composed of lead, zinc, and copper, all of which are toxic to wildlife when ingested (USEPA 1994).

Conclusion

Hunting and fishing result in the deposition of thousands of tons of lead into the North American environment every year. While foraging, wildlife species can be exposed to lead and may die of lead poisoning. Such mortalities have been documented in a wide array of birds including waterfowl, shorebirds, piscivores, songbirds, and raptors. Poisoning of California Condors, Common Loons, Trumpeter Swans, and Bald Eagles is of special concern because it may have population-level effects. Recent research reveals that legislation banning the use of lead shot in waterfowl hunting has reduced the amount of waterfowl lead poisoning and the extent of Bald Eagle lead poisoning. Such declines demonstrate that switching to nontoxic shot can protect wildlife populations and improve the environment. Similar regulations are being established to minimize lead deposition associated with upland game hunting and fishing. Available alternatives provide hunters and anglers with options that allow them to perform well, to excel at their sport, and to minimize lead exposure to wildlife. Because hunters and anglers cherish the outdoors and value wildlife, they may find that the increased cost of ammunition and tackle is offset by the knowledge that they are helping to protect wildlife from lead poisoning. This recognition may begin to fuel voluntary shifts to nontoxics in areas without regulatory restrictions. To facilitate such shifts, HawkWatch will engage in an outreach effort to expose sports enthusiasts to the dangers of lead tackle and ammunition and to the benefits of using nontoxic alternatives.

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Table 1: Estimates of pellet deposition in hunting and shooting areas

Location	Mean pellet densities	Source
North America	68,900 pellets/acre in waterfowl hunting areas	Bellrose 1959
United States	~3,700,000,000 pellets/acre at trap, skeet, and sporting clay ranges	Kendall et al. 1996
New Jersey	87,817,000 pellets/acre in a meadow adjacent to a trap and skeet range	Roscoe et al. 1989
Maine	40,000 pellets/acre in bay sediments	Longore et al. 1982
Tennessee	11,000 pellets/acre pre-season 43,600 pellets/acre post-season in a field managed for dove hunting	Lewis and Legler 1968
Missouri	122,800 pellets/acre in uncultivated fields 26,100 pellets/acre in cultivated fields near duck blinds	Fredrickson et al. 1977
Illinois	6,000 pellets/acre pre-season 44,000 pellets/acre post-season in a field managed for goose hunting	Esslinger and Klimstra 1983
Indiana	1,300 pellets/acre pre-season 11,000 pellets/acre post-season in fields managed for dove hunting	Castrale 1989
New Mexico	40,100 pellets/acre in seasonal marsh (minimum)	Shrank and Dollahan 1975
New Mexico	67,000 pellets/acre pre-season 344,100 pellets/acre post-season at stock tank frequented by dove and quail hunters	Best et al. 1992a
Washington	344,000 pellets/acre at Skagit Wildlife Area pheasant release site	Washington Fish and Wildlife Nontoxic Shot Working Group, 2001
	188,000pellets /acre at Voice of America pheasant release site	

Table 2: Examples of lead exposure and lead poisoning in waterfowl due to hunting

Species	Location	N	Exposure rates	Source
Various Species	North America 1938-1953	5,148 Mallards captured	10% gizzards contained lead shot 25% ingested lead annually 4% mortality in Mississippi Flyway annually	Bellrose 1959
		39,610 harvested	2-3% mortality for U.S. annually	
	North America 1930-1964	1,873,970 various studies	4% of waterfowl succumbing to disease died of lead poisoning	Sout and Cornwell 1976
	United States 1973-1984	171,697 harvested	5% gizzards contained shot 40% ingest shot annually	Sanderson and Bellrose 1986
	Maine 1976-1980	1,246 harvested	4% gizzards contained lead shot	Longcore et al. 1982
	Illinois 1972	±1,500 die-off	75% gizzards contained lead shot and equally high toxic liver levels	Anderson 1975
	Louisiana 1980-1981	1,038 die-off	74% gizzards contained lead shot and equally high toxic liver levels	Zwank et al. 1985
	Iowa 1985-1986	449 captured	53% Canvasbacks exposed 39% Lesser Scaups exposed 31% Ring-necked Ducks exposed	Havera et al. 1992
Mallards	Illinois 1979	3,389 harvested	8% gizzards contained shot	Anderson and Havera 1985
Black Ducks	Nova Scotia 1987-1988	117 harvested	6% gizzards contained lead shot	Schwab and Daury 1989
Canvasbacks	Louisiana 1991-1994	172 captured	50% lead exposed 16% mortalities caused by lead toxicosis (and may have contributed to predation)	Hohman et al. 1995
Ruddy Ducks	Pennsylvania 1973-1977	1,213 collected (oil spill)	1% gizzards contained lead shot	Perry and Artmann 1979
Canada Geese	Colorado 1974	1,522 die-off	65% gizzards contained lead shot	Szymczak and Adrian 1978
	Illinois 1977	3,500 die-off	Unknown	Esslinger and Klimstra 1983
Trumpeter Swans	North America 1976-1992	231 various mortality studies	42% died of lead poisoning	Blus 1994
Tundra Swans	North America 1942-1990	303 various mortality studies	73% died of lead poisoning	Blus 1994

Table 3: Examples of lead exposure and primary lead poisoning in game birds due to hunting and fishing

Species	Location	N	Exposure rates	Source
American Woodcock	Eastern Canada 1995-1996	1,588 harvested	40% exposed (bone)	Scheuhammer et al. 1999
Bobwhite Quail	Illinois 1966	1 dying	4 lead shot in gizzard	Westemeier 1966
	New Mexico 1985-1987	111 collected	15% exposed 6% sublethal poisoning (liver)	Best et al. 1992b
Scaled Quail	New Mexico 1950	1 dead	13 lead shot in gizzard	Campbell 1950
	New Mexico 1985-1987	226 harvested	7% exposed 4% sublethal poisoning (liver)	Best et al. 1992b
Ring-necked Pheasant	California 1965	1 dead	29 lead shot in gizzard	Hunter and Rosen 1965
Mourning Dove	Maryland Early 1960's	62 collected	16% gizzards contained lead shot	Locke and Bagley 1967
	Tennessee 1967	1,949 harvested	1% gizzards contained lead shot	Lewis and Legler 1968
	New Mexico 1985-1987	420 collected	8% exposed 4% sublethal poisoning (liver)	Best et al. 1992a
Sora Rail	Maryland 1965-1974	767 harvested	12% gizzards contained lead shot	Artmann and Martin 1975
	Missouri 1966-1967	167 harvested	2% gizzards contained lead shot	
	Maryland 1976	229 collected	7% gizzards contained lead shot	Stendell et al. 1980
Mississippi Sandhill Crane	Mississippi 1992	1 dead	1 lead object liver lead level 70 ppm	Franson and Hereford 1994
Wild Turkey	New York 1972	1 dead	4 lead shot in gizzard	Stone and Butkas 1972

Table 4: Tests for lead exposure in wildlife

Test	Lead Exposure level	Source
	Indications of recent lead exposure	
Blood lead levels Measures recent lead exposure in live or dead birds. However, blood lead drops dramatically within 24 hours of death.	<.20 ppm Background .20-.59 ppm Exposed—indicative of recent, acute exposure with no symptoms but may be more vulnerable to accidental injury .60-1.0 ppm Clinical lead toxicity—chronic exposure resulting in some symptoms, possibly mild depression and anemia, require chelation therapy >1.0 ppm Acute lead poisoning-critically ill, requiring immediate and effective therapy	Redig 1984, 1985, Havera et al. 1989
Protoporphyrin (PP) levels in the blood Increases in PP due to ingestion of even a single lead pellet inhibits delta-aminolevulinic acid dehydratase (ALAD) enzyme activity in blood. Thus test indicates ALAD activity levels.	Species-dependent ranges	Hoffman et al. 1981, Anderson and Havera 1985, Scheuhammer 1989
Liver lead levels measures recent lead exposure at necropsy.	Species-dependent ranges	Scanlon et al. 1980, Buerger et al. 1986, Franson 1996, Wayland et al. 1999, Vyas et al. 2000
Kidney lead levels measures recent lead exposure at necropsy.	Species-dependent ranges	Pattee et al. 1981
Gizzard Visual inspection determines number of pellets present.	Researchers visually inspect gizzard contents for shot. To differentiate, apply a magnate to which steel shot is attracted. This approach detects 75-80% of pellets in gizzard.	Montablano and Hines 1978, Anderson and Havera 1985
Gizzard Radiology/ Flouroscopy determines number of pellets present.	Researchers x-ray or fluoroscope gizzards (or gizzard contents) to detect the presence of shot. This approach detects 72% of pellets in gizzard.	Anderson and Havera 1985, Montablano and Hines 1978
Gizzard Inspection/Radiology/ Flouroscopy determines number of pellets present.	Researchers combine methods in an attempt to detect all pellets. This approach detects 92-100% of pellets.	Montalbano and Hines 1978

Indications of lead exposure over the lifetime			
Bone analysis used to measure lifelong lead exposure. Because lead uptake in bones occurs within a few hours, bone can be appropriate for recent exposure too. This body burden measure is especially useful for harvest studies and when carcasses are scavenged or decomposed.	Species-dependent ranges		Scheuhammer 1987, Elliott et al. 1992, Wayland et al. 1999
Feather analysis used to measure external contamination rather than dietary exposure.	---	---	Scheuhammer 1987

Table 5: Examples of lead exposure and lead poisoning in raptors due to hunting and fishing

Species	Location	N	Exposure rates	Source
Bald Eagles	United States 1960-1965	45 collected	7% died of lead poisoning	Coon et al. 1969
	United States 1975-1977	168 collected	5% died of lead poisoning	Kaiser et al. 1980
	United States 1960-2000	4,300+ collected	8% died of lead poisoning	Franson et al. 2002
	Northwest U.S. 1979-1981	120 captured	23% exposed	Wiemeyer et al. 1989
	California & Oregon 1979-1982	17 captured	41% exposed	Frenzel and Anthony 1989
		10 dead	90% sublethal poisoning 10% acute lead poisoning	
	Western U.S. 1985-1992	252 captured	56% detected Fall and winter detection levels 89-100%	Harmata 1993
	Idaho 1977-1986	6 dying or dead	83% acute poisoning (liver)	Craig et al. 1990
	Montana 1982-1984	unknown captured	80% exposed	Harmata 1990
	Montana 1985-1992	37 captured	73% exposed 8% clinical lead toxicity 5% acute lead poisoning	Harmata and Restani 1995
	Montana 1990-1994	81 captured	16% exposed 2% clinical lead toxicity 3% acute lead poisoning	Miller et al. 1998
	Minnesota Early 1980's	25 captured	48% exposed 16% clinical lead toxicity 32% acute lead poisoning	Hennes 1985
	West Coast Canada 1988-1991	27 injured, dying, or dead	23% sublethal poisoning 14% acute poisoning (liver)	Elliott et al. 1992
	Canadian Prairies 1990-1996	96 dead	2% sublethal poisoning 12% acute poisoning (liver)	Wayland and Bollinger 1999
	Canadian Prairies 1992-1995	66 captured	9% digestive tracts contained lead shot	Miller et al. 2000
	Saskatchewan 1992-1995	103 captured	8% exposed	Miller et al. 2001

Golden Eagles	Western U.S. 1985-1992	84 captured	80% detected	Harmata 1993
	Idaho 1977-1984	16 dying or dead	13% sublethal poisoning 44% acute poisoning (liver)	Craig et al. 1990
	Idaho 1989-1994	178 captured	42% exposed	Craig et al. 1994
	Montana 1982-1984	13 captured	44% exposed	Harmata 1990
	Montana 1985-1992	86 captured	43% exposed 11% clinical lead toxicity 2% acute lead poisoning	Harmata and Restani 1995
	California 1985-1986	162 captured	30% exposed 3% clinical lead toxicity 3% acute lead poisoning	Pattee et al. 1990
	Canadian Prairies 1990-1996	31 dead	10% sublethal poisoning 13% acute poisoning (liver)	Wayland and Bollinger 1999
Bald & Golden Eagles	Midwestern U.S. 1980-1995	654 dead	12% exposed 3% clinical lead toxicity 6% acute lead poisoning	Kramer and Redig 1997
California Condor	California 1980-1986	5 dead	60% died of lead poisoning	Weimeyer et al. 1988
		14 captured	36% clinical lead toxicity	
	California 2001	5 captured	1 died of lead poisoning 4 others recovered from acute lead poisoning with chelation therapy	Risebrough et al. 2001
	Arizona 2000	17	4 died of lead poisoning 13 others recovered from acute lead poisoning with chelation therapy	California Condor Recover Team 2001
Red-tailed Hawks	Unites States 1975-1992	163 collected	1% diagnosed as lead poisoned 2% died of emaciation which may have been caused by lead poisoning (not tested for presence of toxins)	Franson et al. 1996

Table 6: Avian species poisoned by lead fishing tackle

Sensitive Species	Common Loon, Trumpeter Swan, Bald Eagle, Mississippi Sandhill Crane
Waterfowl	Canada Goose, Mallard, American Black Duck, Ring-necked Duck, Redhead, Wood Duck, Greater Scaup, Common Merganser, Red-breasted Merganser, White-winged Scoter
Wading Birds	Sandhill Crane, Great Blue Heron, Common Egret, Snowy Egret, White Ibis, King Rail, Clapper Rail
Gulls	Herring Gull, Laughing Gull, Royal Tern
Pelicans	Brown Pelican, American While Pelican, Double-crested Cormorant
Sources: USFWS 1994, Schuehammer and Norris 1995, Smrchek 1996.	

Table 7: Examples of wildlife lead exposure at trap, skeet, and shooting ranges

Location	**Species**	**N**	**Lead exposure**	**Source**
Tidal meadow adjacent to trap and skeet range, New Jersey	Northern Pintails	40 collected	100% experienced acute lead poisoning. 33% dead of lead poisoning upon submission. Average number of lead shot in gizzard was 38 pellets.	Roscoe et al. 1989
Patuxent Research Refuge Trap and Skeet Range, Maryland	Song birds	20 captive	85% experienced acute lead poisoning.	Vyas et al. 2000
Federal Law Enforcement Training Center, Georgia	Various avian and mammal species	72 collected	33% exposed 17% subclinical toxicity	Lewis et al. 2001
		10 found dead	Animals found dead diagnosed as lead poisoned.	

Table 8: Current regulations relevant to lead and nontoxics for hunting, shooting, and fishing

United States	
Migratory Bird Treaty Act	Provides Secretary of Interior authority to regulate how migratory birds are hunted.
Endangered Species Act	Secretary of Interior must act to ensure survival of threatened or endangered species.
Bald and Golden Eagle Act	Secretary of Interior must act to ensure survival of Bald and Golden Eagles.
National Wildlife Refuge System Administration Act	Conservation of wildlife is top priority at refuges, therefore hunting is permitted only if it is compatible with sound wildlife management practices.
National Park Service Act	Ensures protection of scenery and wildlife within National Parks for future generations.
Clean Water Act	Prohibits "point source" discharging pollutants in waterways of the U.S.
Resource Conservation and Recovery Act	A substance is defined as hazardous waste due to its toxic environmental impacts and is subject to regulation and remediation.
Toxic Substances Control Act	Toxins subject to regulation if they pose environmental risks that outweigh the burden of potential regulations.
Federal Regulation 50 CFR 30	United States Fish and Wildlife Service prohibits using lead shot for taking waterfowl, coots, and certain other species beginning in 1991-1992 hunting season. Establishes U.S., Puerto Rico, and Virgin Islands as nontoxic zones for hunting waterfowl. Revises procedures for approving nontoxic shot materials (must contain <1% lead) to ensure that spent shot does not impose a significant danger to migratory birds. Approves bismuth-tin, tungsten-iron, tungsten-polymer, and tungsten-matrix shot.
Federal Regulation 50 CFR 32	National Wildlife Refuge System prohibits use or possession of toxic shotgun pellets for upland game hunting on Waterfowl Production Areas and other areas beginning in 1996-1997. Establishes "Lead-Free Fishing Areas" thereby prohibiting use of some lead sinkers and jigs on National Wildlife Refuges and National Parks inhabited by loons (i.e. AK, MI, MN, ME, MT, WI, FL, WY).
State Regulations AR, CA, DE, FL, IA, IL, IN, KS, KY, LA, ME, MI, MO, NC, NE, NH, NM, OH, OK, OR, SD, TN, UT, WA, WY	Some nontoxic upland game hunting and/or fishing zones established. In particular, Maine, New Hampshire, and New York have banned the use and/or sale of high-risk sinkers and jigs (1/2 – 1 ounce).

Canada	
Environment Canada, Guidelines for Nontoxic Shot Approval	Guidelines regarding toxicity tests required for the approval of candidate non-toxic shot.
Migratory Birds Convention Act	In 1996, non-toxic shot required for all hunting within National Wildlife Areas. In 1997, non-toxic shot required for all migratory game birds (except Woodcock, Band-tailed Pigeon, Mourning Dove) in wetlands. In 1999, non-toxic shot required on a national level for migratory birds (with the exceptions listed above).
Canadian Wildlife Act & National Parks Act	These Acts are designed to safeguard wildlife. Under their authority, lead fishing sinkers and jigs weighing less than 50 grams banned in National Wildlife Areas and National Parks in 1997.

Table 9 Comparisons of shot ingestion rates in waterfowl since 1991 ban on lead shot in waterfowl hunting

Species	Location	N	Those gizzards with shot (by type): Lead	Nontoxic	Source
Limited bans on lead shot for waterfowl hunting in place					
Various Waterfowl	U.S. 1974-1975	2,734 harvested	73%	27%	White and Stendell 1977
	Mississippi Flyway 1977-1979	74,365 harvested	Mallards 78% 10 other species combined 83%	 22% 17%	Anderson et al. 1987
	Midwest 1977	1,246 harvested	87%	13%	Trost 1979
Canada Geese	Eastern Prairies 1986-1988	53 harvested	44%	66%	DeStefano et al. 1995
1991 federal ban on lead shot for waterfowl hunting in place					
Various Waterfowl	Mississippi Flyway 1996-1997	16,651 harvested	Mallards 32% Canvasbacks 29% Lesser Scaups 56% Ring-necked ducks 55%	 68% 71% 44% 46%	Anderson et al. 2000
Trumpeter Swans	Washington 2000-2001	300 collected	Die-off caused by lead shot ingestion		Washington Department of Fish and Wildlife Nontoxic Shot Working Group 2001

Table 10: Available Nontoxic Ammunition

Material	Brand	Gauges	Sizes	Game species
Steel	Cabela's Xtreme Steel	12	T, BBB, BB, 2, 4	Ducks, geese
	Estate Steel Game and Target Loads	10, 12, 20	1, 2, 3, 4, 6	Ducks, geese, upland game
	Estate High Velocity Magnum Steel Loads		4, 6, 7	Ducks, upland game
	Kent Cartridge Company Fasteel	12	BB, 1, 2, 3, 4	Ducks, geese
	Federal Classic High Velocity Steel	10, 12, 16, 20	T, BBB, BB, 1, 2, 3, 4	Ducks, geese
	Federal Premium Steel Magnum	12	T, BBB, BB, 2, 4	Ducks, geese
	Federal Duck and Pheaseant Steel	12	BB, 2, 4	Ducks, geese, pheasant
	Fiocchi USA Steel Shotshells	12, 20	T, BBB, BB, 1, 2, 3, 4, 6, 7	Ducks, geese, upland game, turkey
	Remington NitroSteel High Velocity Steel	10, 12, 20	T, BBB, BB, 1, 2, 3, 4	Ducks, geese
	Remington Sportsman Steel	12, 20	BB, 2, 4, 6, 7	Ducks, geese, upland game
	Remington Express Steel Extra Long Range	12, 16, 20	BB, 1, 2, 3, 4, 6	Ducks, geese, upland game
	Remington Steel Game Loads	12, 20	7	Doves, quail
	Winchester Super-X Drylock Steel	10 12, 20	T, BBB, BB, 1, 2, 3, 4, 6	Ducks, geese, upland game
	Winchester Supreme Xpert Steel	12, 20	BB, 2, 4, 6, 7	Ducks, geese, upland game
Bismuth	Bismuth Cartridge Company No-Tox	10, 12, 16, 20, 28, 410	BB, 2, 4, 5, 6	Ducks, geese, upland game, turkey
	Eley Hawk Ltd. Impax Bismuth	10, 12, 16, 20, 28, 410	BB, 3, 4, 5, 6, 7	Ducks, geese, upland game
Tungsten-Iron	Federal Premium Tungsten Iron Loads	10, 12, 20	BBB, BB, 2, 4	Ducks, beese
Tungsten-Iron-Steel	Federal Premium Tungsten Iron Steel Loads	10, 12	2, 4	Ducks
Tungsten Polymer	Federal Premium Tungsten Polymer	10, 12, 20	4, 6	Ducks, upland game
Tungsten-Nickel-Iron	Hevi-Shot	12, 20	2, 4, 6, 7.5, 9	Ducks, geese, upland game, turkey
Tungsten Matrix	Kent Cartridge Company Impact	12, 16, 20	1, 3, 5, 6	Ducks, upland game

Table 11: Price comparison on a sample of pheasant loads (≅1 ¼ oz. 2 ¾" Size 4 shells)*

Material	Product	Toxicity	Number of Shells	Cost
Lead	Cabela's Xtreme Lead	Toxic	25	$9
	Golden Pheasant Lead	Toxic	25	$11
Steel	Federal Duck and Pheasant Steel	Nontoxic	25	$8
	Winchester Super-X Steel	Nontoxic	25	$12.50
	Fasteel	Nontoxic	25	$15
	Cabela's Xtreme Steel	Nontoxic	25	$18
Nontoxic Alloys	Federal Premium Tungsten-Iron-Steel	Nontoxic	10	$12
	Bismuth No-Tox	Nontoxic	10	$15
	Impact Tungsten Matrix	Nontoxic	10	$16
	Hevi-Shot Tung-Nickel	Nontoxic	10	$16

*Prices drawn from Cabela's (www.cabelas.com), April 2002. Although prices may vary by retailer, the percent differences between shot types remain fairly constant.

Table 12: Price comparison on a sample of sinkers and weights*

Products	Toxicity	Number	Cost
BassPro Lead Split Shot	Toxic	210	$5.00
Cabela's Lead Shot	Toxic	±100	$3.00
BassPro Tin Split Shot	Nontoxic	210	$5.50
Cabela's Nontoxic Shot	Nontoxic	±100	$4.25
Dinsmore Tin Shot	Nontoxic	±100	$5.00
XPS Diamond Drop Weights (lead)	Toxic	10	$3.00
XPS Tungsten Drop Weights	Nontoxic	6	$5.00
Loon Outdoors Deep Soft Weight (tungsten putty)	Nontoxic	1 oz.	$6.00

* Prices drawn from BassPro Shops (www.bassproshops.com) and Cabela's (www.cabelas.com), April 2002. Although prices may vary by retailer, the percent differences between sinker types remain fairly constant.