Evaluating Non-toxic Substitutes for Lead Shot and Fishing Weights

– Criteria and Regulations –

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Introduction

Avian lead toxicosis from spent lead shot and lost fishing weights occurs throughout the world, constituting a serious risk to wildlife in both wetland and upland regions (Scheuhammer and Norris 1995; Twiss and Thomas 1998; Guitart *et al.* 1999). Concerns over the scale of mortality of waterbirds and raptors arising from lead toxicosis (Kendall *et al.* 1996; Mateo *et al.* 1997, 2001) have led to the development of lead substitutes. However, national regulatory actions dealing with this toxic risk range from total, regional and/or local bans on the use of lead shot and fishing weights to no action on the issue (Thomas 1995, 1997; Thomas and Owen 1996; Beintema 2001).

Substitutes for lead products must be non-toxic to all wildlife (in all kingdoms), which assumes that criteria exist for the evaluation of their toxicity. Since 1991, eight countries have banned the use of lead shot for hunting in wetlands. However, only the USA and Canada have regulations which define the criteria that must be satisfied before shot may be approved, legally, as non-toxic for the hunting of migratory birds (CWS 1993; USFWS 1997). These North American regulations apply only to substitutes for shot: no regulations exist in any country for determining the non-toxicity of substitutes for lead fishing weights (Thomas 1995), even though they are required by law in certain regions of Canada and the USA (Twiss and Thomas 1998).

As more nations begin to restrict the use of lead shot and lead fishing weights (Beintema 2001), it is advisable for reasons of environmental protection, regulative expediency and international trade to have regulations that define the allowable lead substitutes. At present, no initiatives exist at the international level to regulate substitutes for lead shot, and especially lead fishing weights. Nations could follow the decisions of the USA and Canada on what are legally approved substitutes, or they could introduce their own criteria of toxicity and testing protocols. The latter could result in an international mosaic of differing regulations and varying rigours of testing. That could delay a transition to use of lead-free products and impede international trade in non-toxic shot and fishing weights. Therefore, we recommend a harmonised approach to the approval process (similar to that proposed for the three North American countries by Thomas 2003) based on common international policy and regulations, including a broadly accepted definition of non-toxic shot and sinkers, which would facilitate the phase-out of lead products. The European Commission and the Organisation for Economic Cooperation and Development are examined as potential agencies for issuing such regulations.

The US Protocol for assessing lead shot substitutes (USFWS 1997) has strengths and limitations. We identify the strengths of this protocol that could be incorporated into a broader evaluation of lead substitutes and address the limitations. We propose an alternate protocol for assessing the potential toxicity of a candidate material that does not involve testing with waterfowl under outdoor winter conditions, and that is both faster and less costly. Furthermore, the extension of testing proposed substitutes for lead beyond the present narrow focus on birds is advised, to encompass better components of the natural and human environment.

Evaluation of the US Protocol for Testing Lead Shot Substitutes

The present US legally approved shot substitutes have undergone rigorous experimental evaluation as to their potential toxic impacts upon waterfowl (USFWS 2001). Any of these shot types is required for the hunting of all waterfowl (Aves: *Anatidae*) and coots (Aves: *Rallidae*) in North America. Current US regulations require the use of non-toxic shot when hunting species other than waterfowl in federally regulated reserves. It is thus assumed that types of shot approved as non-toxic to waterfowl are also non-toxic to pheasants, grouse, quail, partridges, snipe and woodcock. Within the general category "waterfowl" are species that are herbivorous, omnivorous and piscivorous, all with their own anatomical and physiological adaptations to their diets (Barnes and Thomas 1987). Also included in the list of migratory birds that may be hunted for sport in North America are cranes (family *Gruidae*), coots (*Rallidae*), woodcock and snipe (*Scolopacidae*), and doves (*Columbidae*), for which non-toxic shot has either been mandated or contemplated. Thus toxicity tests performed upon a largely herbivorous, single species of duck (*i.e.* mallard [*Anas platyrhynchos]*) in the US Protocol (USFWS 1997) to determine the non-toxicity of a type of shot have been extended to other migratory birds among which a considerable phylogenetic distance (across five avian orders) exists.

The mallard duck is used as the US government test species because it is the commonest North American waterfowl species afflicted by lead poisoning (Anderson *et al.* 2001), and because the species is commercially avail-

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able. Moreover, the American government has acted on only those species that fall under its direct federal jurisdiction *(i.e.* migratory birds), as opposed to upland game birds that come under state jurisdiction. Secondary lead poisoning (induced by the consumption of prey with lead shot in the tissues) is widely reported for birds of prey (Pain *et al.* 1993; Mateo *et al.* 1997, 2001; Kennter *et al.* 2001 for Europe: Kendall *et al.* 1996 and Wayland and Bolinger 1999 for North America), and direct lead poisoning has been reported for different upland game species (Best *et al.* 1992; Kendall *et al.* 1996).

The US government legislated the use of non-toxic shot as much as to prevent secondary lead poisoning of eagles as to reduce lead toxicosis of waterfowl (USFWS 1986). Again, lead substitutes approved as non-toxic to ducks are considered, implicitly, to be non-toxic to birds of prey. It is the implicit applicability of the results of the American testing protocol that is most useful to jurisdictions considering the introduction of lead substitutes. While different avian species may show varying effects of certain metal toxicoses, the US Protocol, by focusing on the lowest level of toxic risk, is able to assuage these concerns.

Other nations wishing to specify allowable types of non-toxic shot could agree to accept the US testing verdicts by permitting only those substitutes that have received unconditional approval by the US government. This would be the least costly, and most expedient, process. However, it would require any nation to accept both the American criteria of non-toxicity and the American testing process. There are some egregious examples of nations disagreeing on approval processes and the results for tested commodities and, consequently, restricting trade. For example, the USA allows milk to be sold from cows dosed with bovine somatotropin, and America also permits the production of beef from steers given growth-promoting hormones. The European Union (EU) bans importation of these products (National Research Council 1999), products derived from unpasteurised milk, and genetically modified organisms (Busch 2001). Given these disagreements concerning the vital issue of human food safety, a sceptic might question the Canada–USA process for evaluating lead substitutes for recreational shooting. Nevertheless, the current US Protocol (USFWS 1997) requires the most rigorous evaluation of lead shot substitutes yet devised to support any nation's policy and regulations.

Paradoxically, the US and Canadian Protocols regulating non-toxic shot for hunting waterfowl do not apply to the composition of fishing weights, despite the need to use lead-free fishing weights to prevent lead poisoning of birds in both countries (Perry 1994; Twiss and Thomas 1998). Thomas (1995) has explained how the responsibility for these two commodities falls between different federal departments and different federal laws. However, the testing that has been done could apply to the composition of fishing weights and the many species of bird that are known to ingest them (Perry 1994). The mechanisms of lead toxicosis in fish-eating birds and waterfowl are biochemically and clinically the same, despite taxonomic differences among the species affected (Lumeij 1985). If the testing of lead substitutes on a mallard duck can apply, legally, to a fish-eating duck, then the results of testing for a candidate shot could be applied to the same candidate material proposed for non-toxic fishing weights.

Although the US government has still to make this legislative leap of faith, this should not prevent other nations from doing so, especially if they are intent on introducing non-toxic fishing weight regulations. Thus weights made from approved steel, bismuth, bismuth-tin alloy and tungsten products (USFWS 2001) could be used as non-toxic substitutes immediately. Weights made from zinc should not be approved for use because they cause fatal poisoning when ingested (Levengood *et al.* 1999). This could be inconvenient for nations such as the UK, which banned the use of lead weights and, in the absence of a scientific process to evaluate alternatives, has allowed zinc weights to be used commonly as "non-toxic" substitutes. Paradoxically, zinc fishing weights may be used, legally, throughout North America, and the use of zinc shot is permitted in Europe.

The US Protocol (USFWS 1997) requires submission of published scientific evidence of non-toxicity of the candidate metal(s) to many forms of non-waterfowl wildlife in terrestrial and aquatic habitats, but supplemental testing in this area may not be required. While this Protocol ensures a rigorous demonstration of non-toxicity of a metal(s) to mallard ducks, the demonstration does not extend to other biotic components of the natural environment, such as soil-fungal and bacterial communities and soil-plant interactions.

An Amended Protocol for Testing Lead Substitutes

Reference to the periodic table of the elements indicates that most of the likely metal candidates to substitute for lead have been proposed and evaluated. In shooting, because 24–36 g or more shot are lost per discharge, issues of both ballistic performance and costs are real determinants of a material's suitability, non-toxicity excepted. In sport fishing, density of weights is the major concern to anglers, but because weights need not be lost, cost factors are less important than in shooting. This may mean that other, dense chemical elements as yet untested as lead substitutes may be presented for use as fishing weights.

The European Union presented in its 2001 White Paper, *Strategy For a Future Chemicals Policy,* the concept of testing the environmental safety of all chemicals in use (COM 2001). Although this is a draft policy, it is clear from the scientific evidence amassed that lead used in both shot and fishing weights would not receive clearance for future use in the EU and that testing of substitutes would be necessary. Although the Strategy contains provisions to accept testing performed by other authorities (COM 2001), it also exhorts industry to develop testing procedures for their products in consultation with authorities. At present no procedures have been proposed for testing lead substitutes, either by industry or governments.

The US Protocol (USFWS 1997) may entail small financial costs to a company if approval of the shot substitute is granted at the Tier 1 stage (a literature review showing that the substitute material is non-toxic to ducks and other wetland biota). Should experimental demonstration of non-toxicity to breeding ducks and their progeny be required (Tier 3 stage), total costs exceeding US$0.6 million are likely over a 2–3 year period. A substantial part of the costs is associated with keeping seasonally breeding ducks in outdoor captivity. While this mirrors the seasonal events that occur in wild populations of waterfowl, it may not be the most efficient model for testing the toxicity of a shot type to birds. We propose that use of Japanese quail (*Coturnix coturnix japonica*) as the test species would be more expedient than the mallard duck for evaluating candidate non-toxic fishing sinkers and shot.

Japanese quail have been used extensively in research. This species has a large, muscular gizzard for grinding seeds to fine particles, and resembles many other avian species that grind lead in the gizzard to fragments that are solubilised and then absorbed. As a Galliform species, it satisfies one criterion as a test animal in that both wild quail and domestic Japanese quail are known to suffer and die from lead toxicosis (Damron and Wilson 1975; Morgan *et al.* 1975; Edens *et al.* 1976; Best *et al.* 1992; Grasman and Scanlon 1995). There are no scientific studies to indicate that Japanese quail are more or less susceptible to lead poisoning than mallard ducks. Under captive conditions, young Japanese quail can be induced to breed in seven weeks, and the females are indeterminate layers, laying dozens of eggs in succession. The ratio of body mass:egg mass is such that a relatively greater proportion of the daily metabolism goes into the production of an egg compared to a mallard duck. A large body of scientific literature exists on the physiological parameters, reproductive properties, nutrition, growth (OECD 2000), cold-stress tolerance (Thomas and George 1975), and toxicology (Stone *et al.* 1977, 1979; Hill and Camardese 1986) of the Japanese quail. The Organisation of Economic Cooperation and Development (OECD) has proposed that the Japanese quail be adopted as the test species for many of its scientific assessments (OECD 2000), thus expanding the availability of scientific information related to toxicological assessment of candidate materials on this single species.

Use of this species would greatly expedite testing of lead substitutes, whether under short-term cold exposure conditions, as required under Tier 2 of the US Protocol, or under the longer-term reproductive conditions specified in Tier 3. Any of the physiological, toxicological and pathological variables required to be measured from mallard ducks can be readily generated from Japanese quail. Several generations of quail could be produced in one year, allowing testing to be completed in a shorter period of time, and, in theory, across more than one generation of young. The current North American protocol extends across only one generation of young birds. Most importantly, the vital experimental conditions and testing parameters required in the US Protocol (exposure to a nutritionally deficient diet under cold exposure, and no impairment of breeding and chick development) should be retained in full in any new protocol using Japanese quail.

Extra considerations not related to direct poisoning of birds could be included in a revised evaluation. An example could be analysing lead substitutes in organic anaerobic (oxygen deficient) sediments, where bacterial methylation might create organic derivatives from metals that posed toxic risks (Bull *et al. 1983;* Lorowitz *et al.* 1992). The solubilisation and uptake of metals by soil biota and plants, and their impact(s) on physiological processes (e.g. Doncker *et al.* 1994; Jones and Muelchen 1994) could also be given greater emphasis in a new protocol, unlike in the current US Protocol. Last but not least, human health aspects should also be taken into account. It has been reported that game killed with toxic shot (Johansen *et al.* 2001), or the consumption of animals poisoned from ingested lead (Guitart *et al.* 2002) can potentially threaten the health of human consumers. Tsuji and Neiboer (1997) questioned the use of bismuth shot (fully approved in North America) as the best substitute for lead shot in the presence of published medical studies that show that certain bismuth compounds can be toxic to human beings when ingested. Thus testing for non-toxicity of shot to captive ducks may not satisfy criteria of non-toxicity for human beings, especially northern, native people who rely on shot birds for a large proportion of their annual meat supply.

International Harmonisation of Agreements on Lead Substitutes

Lead is an ubiquitous and cheap metal that is made into shot and weights using simple technology. Consequently, there is much manufacture of shot and sinkers in countries where labour costs are low, and the products are exported to North America and Europe. Automation of ammunition manufacture has also made Europe and the USA major producers and exporters of sporting ammunition. Some countries do not have shotgun cartridge manufacturers, but import their ammunition from a variety of producing nations.

The practices of recreational hunting over wetlands and uplands differ little among nations. Similarly, the causes and nature of lead poisoning from shooting and angling do not differ internationally, nor do the steps to reduce the prevalence of this disease (Guitart *et al.* 1999; Beintema 2001). Moreover, the ammunition used in these types of hunting must already conform, legally, to an internationally approved series of production standards and ballistic specifications established by the International Proof Commission for Europe (British Proof Authorities 1993), and the Sporting Arms and Ammunition Institute (SAAMI 2002) for the USA. These agencies have regulated the standards for ammunition manufacture to ensure human safety and to promote the multinational sale of ammunition.

Because this international precedent has been set to ensure human safety, the same precedent could be used to regulate the nature of the shot to achieve environmental/ wildlife protection. Regulating at the international level the definition of non-toxic shot and fishing weights would ensure common standards of non-toxicity of shot and sinkers in all countries that banned lead. This would prohibit the use of zinc shot and zinc weights, and preclude the development of types of shot where a lead centre were coated with some material to reduce (in theory) shot abrasion in the gizzard of birds. Levonmaki and Kairesalo (2002) reported that some commercial brands of steel shot sold in Scandinavia contain high levels of chromium (contrary to American and Canadian laws) that could pose a toxic risk to soil organisms in areas where accumulation of that shot occurred. It is in the interests of wildlife, anglers and hunters that proven non-toxic types of shot and sinkers be readily available for use, even if they must be imported from other nations. Hence the importance of a creating a mechanism that recognises a single definition of "non-toxic" internationally.

Human food safety and environmental safety are major areas where data are required in all countries for approval of pesticides, for example. The regulations may differ in the approach from nation to nation, but the final objective is the same. In addition, the guidelines of the International Conference on Harmonisation for human drugs are followed by most developed countries (National Research Council 1999), and could be used as a prototype for approval of alternatives to lead in recreational sports. In other international operations, for example civil aviation, the European Joint Aviation Authorities and the Federal Aviation Administration of the USA have committed to harmonise the development and implementation of common safety regulatory standards and procedures for aircraft and aircraft engines, including environmental aspects, such as noise and emissions (JAA 2002). Thus several international policy and regulatory processes already exist that could be adapted for regulating lead substitutes.

Canada and the USA have a common standard for shot because their testing protocols are virtually identical (Canadian Wildlife Service 1993; USFWS 1997). The next step for these two countries is to involve Mexico in a similar requirement for non-toxic shot. This is because Mexico shares several migratory flyways with both the USA and Canada, Mexico is a party to the Migratory Birds Treaty with the USA (Lyster 1985), Mexicans hunt waterfowl, and because Mexico is involved with the USA and Canada in major waterfowl wetland restoration. While this approach could take care of North American interests, it does little to resolve the issue elsewhere.

In Europe, a common EU standard could be developed and applied to all shot and sinkers sold as non-toxic to wild life. This would effectively regulate the composition of lead substitutes made within the EU, and, simultaneously, regulate the composition of imported products. At present, not all member nations of the EU require the use of non-toxic materials, but the number is growing (Beintema 2001), and at some point in time, a harmonisation of the standards for non-toxic shot and weights may become necessary. This will happen when the EU's 2001 *Strategy for a Future Chemicals Policy* becomes law among all member States. Such a set of standards could still allow individual member nations to impose extra criteria on shot and sinkers that were deemed necessary. Article 130(t) of the Maastricht Treaty already grants such a provision to member States. Such a case would be Denmark requiring that any type of non-toxic shot be proven to be non-corrodible when embedded in the wood of hardwood trees. This criterion was implemented to protect the value of trees used in the veneer industry. A second potential rationale for harmonisation would be the situation in which most of the EU members that practiced migratory waterfowl hunting (but not all of which required that proven non-toxic ammunition be used) agreed to accept a rigorous standard of non-toxicity, simply to protect birds from needless mortality. Then the goal of the EU standard would be to secure the *entire continental flyway* and prevent continuing metal toxicosis (Thomas and Owen 1996).

The OECD could play a significant part in this harmonisation process for alternatives to lead shot and sinkers, especially since the EU and the USA proposed an OECD Council Act on lead reduction (OECD 1995). This Organisation is all the more appropriate given its 1996 Declaration on Risk Reduction for Lead (OECD 1996), in which it endorsed restricting the use of lead shot for hunting in wetlands, and encouraged the development of substitutes for lead fishing weights. Most importantly, the OECD comprises 30 nations across several continents, and provides a broader mechanism to embrace North America, Europe and SE Asia in a single regulatory process. Coincidentally, these are the regions of the world where most hunting and recreational angling is practiced, and where most trade in ammunition and weights occurs. The OECD would be an appropriate body to regulate the composition of shooting and angling commodities that are going to be traded extensively on international markets because of its mandate for economic cooperation and development, and especially its commitment to sustainable use of the environment (OECD 2002). Both the EU and the OECD are free to devise their own testing criteria for lead substitutes and the process adopted, but they should be highly complementary. They could draw liberally from the US Protocol and add new testing conditions, where appropriate.

The trend to remove more forms of lead from the human environment will necessitate evaluation processes to approve their substitutes, whether they be lead wheel balance weights or lead shielding around radiation machinery. The US Protocol is legislatively based, and was introduced to fulfil a specific need, i.e. the approval of substitutes for lead shot in waterfowl hunting. The legislative constraints on this Protocol in the USA preclude its use in other forms of testing and granting of approval. This is the rationale for the EU, and especially the OECD, to develop a new protocol that is intercontinental in scope, that is expedient to apply by industry and governments, and that caters to variety of lead substitutes, not just one specific type of shot. The US process (USFWS 1997) is a very good place to begin.

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