Key questions and responses regarding the transition to use of lead-free ammunition

Vernon G. Thomas[1†], **Niels Kanstrup**[2] **& Carl Gremse**[3, 4]

[1] Department of Integrative Biology, College of Biological Science, University of Guelph, Guelph, Ontario N1G 2W1, Canada

[2] Danish Academy of Hunting, DK-8410, Ronde, Denmark

[3] Faculty of Wildlife Biology, Management and Hunting Practice, University of Applied Sciences Eberswalde, Alfred – Moeller – Str. 1, 16225 Eberswalde, Germany

[4] Leibniz – Institute for Zoo and Wildlife Research, P.O. Box 601103, D-10252 Berlin, Germany

[†] *Corresponding author email address: vthomas@uoguelph.ca*

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ABSTRACT

Questions and concerns about the use of lead-free ammunition in hunting were encountered during the Oxford Lead Symposium. Many originated from commonly-held, but unsubstantiated, reports that have hindered the transition to use of lead-free ammunition in the UK and elsewhere. This paper examines and answers the principal reservations raised about the use of lead-free hunting ammunition. The issue of how the evidence for lead exposure and toxicity to wildlife from discharged lead shot cartridges could be better communicated to the public to enhance adoption of lead–free ammunition is addressed. The paper presents evidence to assuage concerns about the effectiveness and non-toxicity of lead ammunition substitutes, their suitability for British shooting and weapons, and their role in wildlife health protection. Collectively, these answers to concerns could lower the public resistance to use of lead-free ammunition and thus make game shooting a more environmentally-sustainable pursuit.

Key words: *Lead-free ammunition, misconceptions, use, shooting, ballistics, toxicity, barrel damage, efficacy, shot pattern, ricochet, availability*

INTRODUCTION

Despite a large volume of scientific evidence that spent lead shotgun and rifle ammunition poses risks to wildlife and human health (Watson *et al.* 2009, Group of Scientists, 2013, 2014), there has been, with a few notable exceptions, marked reluctance across the international shooting community to adopt lead-free substitutes. Exceptions include Denmark and The Netherlands, which banned all use of lead gunshot – as long ago as 1996 in Denmark (Kanstrup 2015). Other nations, including the UK, have begun to prohibit lead use where the evidence of lead poisoning of wildlife has been, historically, most apparent. In England in 1999 this resulted in a ban on lead shot use for hunting waterfowl or over certain, listed, wetlands, with regulations following in the other UK countries. However, compliance with the English regulations still appears to be very low 15 years on (Cromie *et al.* 2015). No nation has yet to regulate the use of both lead-free shotgun and rifle ammunition for hunting, although the state of California will do so in 2019 (Thomas 2015). At the recent Conference of the Parties to the Convention on Migratory Species (COP 11, Quito, November 2014), a resolution was passed, the guidance to which calls for the replacement of all lead ammunition, in all habitats, with

non-toxic alternatives within three years (UNEP-CMS 2014 a,b). While it is for Parties (of which the UK is one) to decide how to implement these guidelines, the political imperative in the Resolution's wording is clear: countries with an established poisoning problem (of which the UK is one) are expected to act responsibly and implement the guidelines (see Stroud (2015), for this and further requirements to restrict lead shot under multilateral environmental agreements). Non-toxic shot types have long been widely available, and the international arms industry has developed effective non-toxic substitutes for bullets (*e.g.* Gremse and Reiger 2015). The primary barriers to a complete transition to lead-free ammunition use by game and target shooters in the UK now appear to be socio-political. Part of this seems to relate to the attitudes and beliefs of the shooting community, and their ability to influence government policy. The arguments used to oppose change are varied. Some of these are based on perceived wisdom and hearsay, and many myths have been perpetuated across decades. There also appears to be an anxiety that that use of lead-free ammunition would be detrimental to shooting sports (Cromie *et al.* 2015).

During the Oxford Lead Symposium's discussion sessions, the question of how we might tackle the misunderstandings and myths surrounding lead poisoning and the options for moving to non-toxic alternative ammunition was repeatedly raised. To help address this, in this paper we have outlined some of the issues and comments raised during the symposium's discussion sessions, and have included answers, supplemented by additional information provided by symposium participants. Where appropriate, reference has been made to other papers in this symposium proceedings, which provide supplementary detail.

One of the issues raised related to possible ways of overcoming some of the barriers to change (many of which relate to people's perceptions regarding alternative ammunition types). One way of helping to overcome barriers is through providing relevant information to help dispel some of the misconceptions about the alternatives to lead ammunition. We have therefore also included a section specifically dealing with this, compiled by those symposium participants with specific shooting and/or ballistic expertise (*i.e.* the authors of this paper).

The issues below are not a comprehensive synthesis of the discussions, but include the key issues around which there was debate during the symposium.

KEY QUESTIONS COVERED

How can the problem be communicated better and the debate depolarised?

The point was raised during the meeting that the need is not to build a larger body of evidence, but rather better to communicate the evidence that already exists. The public debate surrounding the issue has become polarised in the UK, and there appears to be the perception that the current move to phase out the use of lead ammunition is some form of attack on game shooting sports. While there are always likely to be organisations and individuals both opposed to, and in favour of, game shooting sports, it is very important for all involved organisations to separate this from the issue of using toxic lead ammunition for shooting. Subject to certain restrictions, the stalking and sports shooting of many animal species is currently legal in the UK countries, and that is not an issue for debate here. Both the legal pursuit of shooting sports, and the established rural economy that derives from them, are acknowledged by all of the main stakeholders in the current debate. The drive towards lead-free ammunition for all shooting in the UK is about ensuring the shooting, where it takes place, is environmentally sustainable, and does not pose avoidable health risks to either wildlife or human health. The use of non-toxic alternative ammunition types should put game shooting on a more sustainable environmental and economic basis without its leaving a collateral toxic legacy. Science has long recognised a single problem of humans' use of lead products and their and wildlife's consequent exposure to toxic risk (RCEP 1983, Group of Scientists, 2013, 2014, Stroud 2015). Thus, the use of lead in paints, petrol, solders, and glass has been banned or heavily regulated to protect human health. The use of lead ammunition in sport shooting remains as an outstanding significant release of lead to the environment that poses risks to the health of wildlife that ingest it, and to humans who frequently eat shot game. Ending the use of lead-based ammunition in shooting would significantly lower the exposure risks to both wildlife and humans. In this way, one of the last, major, releases of lead to the UK environment would be halted. The shooting community would assume any cost (negligible for steel shot) for the transition, and would internalise this cost, rather than externalising it to the general environment and society. This is consistent with the Polluter Pays Principle. Land owners who send shot game (gamebirds and venison) to the retail market would benefit from the assured export and sale

of meat uncontaminated by elevated levels of lead to the UK and foreign public, and compliance with any food safety standards that might apply now or in future.

Lead poisoning is in many ways a 'hidden disease'; how can we address that barrier effectively?

Whilst large-scale mortality events from lead poisoning do occasionally occur (*e.g.* as reported in O'Connell 2008) this is the exception rather than the rule. Lead-poisoning mortality is usually inconspicuous, often resulting in frequent and largely invisible losses of small numbers of birds that remain undetected. Moribund birds often become increasingly reclusive and dead birds may be scavenged before being detected (*e.g.* Pain 1991). This is why lead poisoning of birds is referred to as an 'invisible disease'. Unlike cases of diseases such as botulism, where large numbers of birds often die in one place, few people find those scattered individuals that have died from lead poisoning. However, it is estimated that in the UK, as many as 50,000-100,000 wildfowl and larger numbers of terrestrial birds may die from lead poisoning each year (Pain *et al.* 2015).

The rarity of shooters observing sick lead poisoned birds is a frequently cited reason for underestimating the extent of the problem. Addressing this barrier will require good communication regarding the nature and likely extent of the problem by all stakeholder groups, not least by shooting interests. The use of visual footage of lead poisoned birds from animal recovery centres may also help to illustrate the reality and welfare impacts of the disease.

Is ingested lead shot poisonous to all animals?

Lead is poisonous to all animals, irrespective of the source. Ingested lead from ammunition is particularly a problem for birds. The amount of ingested lead that will produce similar signs of toxicity may differ among individual birds, as well as species. The absorption of dissolved lead into the blood can be influenced heavily by different factors. Thus a diet rich in animal protein and calcium interferes with the absorption of lead in the blood (Snoeijs *et al.* 2005, Scheuhammer 1996). A diet low in protein and calcium, but high in starch and fibre (such as in winter), may not moderate the absorption of lead from shot. Also, if the dietary items are large and hard, they will require much grinding with grit, and this, simultaneously, increases the physical breakdown and dissolution of gunshot. Consequently, the toxic effects of lead shot ingestion may vary according to the seasonal diet of individuals, and also by species, as in herbivorous and carnivorous waterfowl (USFWS 1997).

The physical condition of an animal also influences it susceptibility to lead toxicosis. Animals that are stressed or starving, with few body reserves, are more likely to show signs of lead poisoning than animals in robust health with the same amount of ingested lead shot.

The size of lead shot may also influence the dissolution in the avian gizzard. Large lead shot are retained longer in the gizzard and are progressively broken down until they are so small that they pass through the sphincter into the intestine. Small diameter lead shot may pass through without much abrasion and ultimately exit the body in the faeces. Thus the amount of lead absorbed into the body may be different even though the same total weight of lead shot was ingested.

Some birds may ingest only one or two lead shot at the same time. This level of lead may or may not be fatal, depending upon a range of factors such as those described above. When not fatal, ingestion of small numbers of shot could result in sub-clinical signs of lead poisoning which, if more lead shot were ingested, could result in chronic poisoning or acute and possibly fatal poisoning.

Are any of the substitute shot types also toxic?

During the Symposium discussion session, panellists were asked whether any of the substitutes were also toxic. Lead shot substitutes made from iron, tungsten, bismuth and tin were developed first in the USA, and are now used internationally. In the USA and Canada any substitute for lead shot must undergo mandatory experimental testing to receive approval under federal law. To be approved, a candidate shot must first undergo laboratory toxicity testing as ingested shot in mallard ducks *Anas platyrhynchos* over two generations. This involves testing for metal accumulations, harmful effects on all of the major organ systems of the body, and any effects on all aspects of reproduction, including the ability of hatched birds to thrive. In addition, it must be shown that the shot in stipulated very high densities has no adverse effects on aquatic and terrestrial plants and animals, and the quality of soil and waters (USFWS 1997). It must also be shown that the proposed substitute would not have

a harmful effect on human health if it were eaten in cooked game meat. Shot made from iron, tungsten, and bismuth-tin alloy have been unconditionally approved for use in North America (Thomas *et al.* 2009). The same shot types can, therefore, be used in other countries without fear of environmental toxicity. Shot made from zinc failed the testing and cannot be used legally in North America, and should not be used elsewhere (Levengood *et al.* 1999). Lead shot that has been coated with plastic may degrade more slowly in the environment than uncoated shot. However, the coat can be ground down rapidly in a waterbird's gizzard exposing the lead (Irby *et al.* 1967). Similarly, damage to the coat, as when pellets strike the ground, collide with each other, or hit the target, will still allow the lead core to be exposed and corrode, releasing lead to the environment.

Is there evidence that using non-toxic shot results in reduced mortality of wildfowl?

Evidence suggests that regulations requiring the use of alternative ammunition types are very effective, if adhered to. For example, in the USA and Canada, the mandatory transition to steel shot for waterfowl hunting in 1991 and 1999, respectively, resulted in a significant reduction in the mortality of ducks from lead poisoning within a few years (Anderson *et al.* 2000, Samuel and Bowers 2000, Stevenson *et al.* 2005). Spain has required the use of non-toxic shot for hunting in its Ramsar sites from 2001, and since that time, a measurable reduction in lead–induced mortality has occurred (Mateo *et al.* 2014). In the UK, a similar situation occurred with angler's lead weights. Mute swan *Cygnus olor* mortality from lead poisoning following the ingestion of lead angler's weights decreased and their population increased following restrictions on the use of lead angling weights (Sears and Hunt 1991, Perrins *et al.* 2003).

In regions of California inhabited by condors *Gymnogyps californianus*, a ban on the use of lead-core rifle ammunition has been in effect since 2007. Consequently, there has been a significant decline in the blood lead levels of golden eagles *Aquila chrysaetos* and turkey vultures *Cathartes aura* that would, otherwise, be exposed to secondary lead poisoning from scavenging the gut piles from shot game (Kelly *et al.* 2011). Thus the regulations of the 2007 Ridley-Tree Condor Preservation Act (California state law requiring hunters to use lead-free ammunition in condor preservation zones) are having the desired effect.

However, regulations do not work if they are not complied with. In England lead gunshot has been banned for shooting wildfowl or over certain listed wetlands since 1999. Three consecutive studies of compliance with the regulations (Cromie *et al.* 2002, 2010, 2015) have shown that about 70% of ducks, shot in England and sourced from game providers and other commercial outlets, were shot illegally using lead gunshot. The proportion of wildfowl dying of lead poisoning did not change following the introduction of legislative restrictions on the use of lead (Newth *et al.* 2012) and large numbers of birds continue to suffer lead poisoning in England.

While legislation that is complied with has been effective at reducing lead poisoning in birds, in the UK evidence suggests that partial restrictions (dealing just with certain taxa or habitats) are unlikely to be effective.

Effective transition to non-toxic ammunition for all shooting would both remove the majority of the risk to wild birds, and also substantially reduced risks to the health of humans that frequently consume game meat.

How do we deal with lack of compliance with the existing regulations?

As described in Cromie *et al.* (2015), compliance with the 1999 regulations requiring the use of non-toxic shot for shooting wildfowl and over certain listed wetlands in England remains very low. This is despite long-standing efforts on the part of shooting organisations to encourage compliance, including a campaign to this effect in 2013. There may be many reasons behind this, but the difficulty of policing partial regulations, which in England require the use of non-toxic shot for shooting some species/in some areas, but allow the use of lead for shooting other species/in other areas, is likely to play an important part. Under current circumstances in England, it seems highly probable that many people will continue to use lead gunshot illegally in the absence of a ban on its use (and possibly also sale, possession and import) for all shooting.

It is also notable that even where there is a high degree of compliance with the current regulations, the problem of lead poisoning would not be solved for the wildfowl species that graze terrestrial habitats, for terrestrial birds, or scavenging and predatory birds. Nor would this tackle potential risks to the health of frequent consumers of game, as most game eaten comprises terrestrial gamebirds which are currently legally shot with lead.

How can we enhance shared learning and speed up implementation of the use of non-toxic alternatives?

Legislation requires the use of non-toxic ammunition for some (or in a few cases all) shooting with shotguns and/or rifles in many countries, although we have heard that compliance can be very poor (especially with partial restrictions as in England). There exist other politically binding imperatives to replace lead ammunition with non-toxic alternatives, *via* multilateral environmental agreements such as the Convention on Migratory Species and the African-Eurasian Migratory Waterbirds Agreement (see Stroud 2015). In addition, an increasing number of national food safety authorities are publishing advice recommending that women of pregnancy age and young children eliminate or significantly reduce the consumption of game shot with lead ammunition from their diet (see Knutsen *et al.* 2015). The science around the toxicity of lead at low levels of exposure is extremely compelling and agreed upon by all major authorities, but there appears to be little awareness of the issue more broadly, including across the general public, medical practitioners, retailers and restaurateurs. For example, the food safety advice published by the UK Food Standards Agency (FSA) in October, 2012 (FSA 2012) was not included in National Health Service advice on a healthy diet in pregnancy when they revised their guidance either in 2013 or January, 2015[1].

It appears that a concerted communication effort will be needed across all stakeholders, including the shooting community and the general public, to increase awareness of the problem, and to share knowledge on and facilitate the implementation of possible solutions, including the use of non-toxic alternative types of ammunition.

In 2010 the Department for Environment, Food and Rural Affairs (Defra) and the FSA invited key organisations to form an independent strategic group to advise Government on the impacts of lead ammunition on wildlife and human health. The purpose of this group (the Lead Ammunition Group - LAG) was to bring together relevant stakeholders and experts to advise Defra and the FSA on:

(a) the key risks to wildlife from lead ammunition, the respective levels of those risks and to explore possible solutions to any significant threats;

(b) possible options for managing the risk to human health from the increased exposure to lead as a result of using lead ammunition.

The Lead Ammunition Group's report [subsequently submitted in June 2015] will provide much needed information and guidance.

This symposium enabled an open examination of the evidence and stimulated and facilitated debate both around the health risks of lead ammunition to wildlife and humans and solutions available including those already implemented elsewhere. These proceedings should provide a helpful 'one stop shop' for information on the issue in the UK, along with examples of how others have effectively dealt with this.

However, increased public awareness and good communications should ideally come from within the shooting community. Regulation requiring the use of non-toxic ammunition would of course solve the problem, and there would need to be a sensible phase in time to enable adaptation.

While all of the information is accessible to facilitate and enhance shared learning, implementation of the use of non-toxic alternatives ultimately requires political will for change.

Are there economies of scale for non-toxic ammunition production?

Steel is widely available and is by far the most commonly used alternative to lead shot. Prices of lead and steel shot are currently comparable, and depending upon world metal prices, steel shot may be slightly cheaper or slightly more costly than lead, but differences are small. The more expensive shot types are tungsten and bismuth, which are sold and used in far lower volumes. Tungsten is a strategic material and is always likely to be more expensive than lead. With bismuth, if the market is large enough, the price could come down somewhat. For bullets, an economy of scale effect is predictable. In the USA, where a larger demand for lead-free bullets exists, the prices for lead-free and lead-core equivalent bullets do not differ much when sold in large retail stores (Thomas 2013a). Knott *et al.* (2009) indicated

[1]http://www.nhs.uk/conditions/pregnancy-and-baby/pages/healthy-pregnancy-diet.aspx

that the price of lead-free rifle cartridges sold in the UK would likely decline as the size of that market increased.

COMMON QUESTIONS CONCERNING ALTERNATIVE AMMUNITION TYPES

The following questions have been raised variously across many countries, including in the UK, and over many decades. These are relevant to the UK situation and to broader communication of the issue.

Is there evidence that the use of lead-free ammunition regulations may reduce participation in shooting sports or significantly affect its economic viability?

While the use of lead bullets has not been restricted in many areas or countries, several examples exist of countries or regions where the use of lead gunshot has been prohibited for all shooting. An example relevant to the UK is that of Denmark, where alternatives to lead have been used for almost 20 years (since 1996). As outlined in these symposium proceedings (Kanstrup 2015), non-toxic shot use by Danish hunters has not been accompanied by a change in the number of hunters. Game shooting is a relatively expensive sport, and the costs of non-lead ammunition are a small part of the total costs of shooting game with rifles and shotguns (Thomas 2015). For the individual shooter, steel shot of similar quality to equivalent lead shot is of broadly comparable cost (this fluctuates with world metal prices). Other alternative shot types are more costly, perhaps by up to about five times, but these are less frequently used and still represent a small proportion of the costs of sports shooting. The use of lead-free ammunition on shooting estates has many benefits. In addition to reduced environmental contamination, this reduces the exposure of wildlife and livestock to spent lead shot and its health effects. In addition, for both large and small game animals sold in national and international food markets, a low-lead status of the meat will ensure that consumers are not exposed to unnecessarily high levels of dietary lead, which have the potential to put at risk the health of frequent consumers of game meat. Proposals to restrict the use of lead ammunition will help to give shooting sports a more sustainable future without the toxic footprint of lead contamination, and this should help to secure both the environmental sustainability and long-term economic viability of shooting estates.

Are alternative shot types as effective as lead in killing birds?

In the USA, concern arose, initially, in the 1980s over the ballistic efficiency of early types of steel shot for waterfowl hunting in the USA (Morehouse 1992). This issue was investigated early on in the USA, because it was among the first to end the use of lead shot for wetland shooting, and because it had the capacity to investigate hunters' use of this shot type.

Concern largely related to a perceived potential for increased "crippling loss" of waterfowl shot with steel. The term "crippling loss" refers to birds that have been shot but are unretrieved, either because they have not been killed outright, or because they have been killed but the carcass cannot be found. In the former case, birds are generally wounded due to poor shooting skill and/or errors in distance estimation.

Crippling rates of birds can be high (generally in the range of 10-50%), irrespective of the shot types used (*e.g.* Haas 1977, Nieman *et al.* 1987). Morehouse (1992) reported a slight increase in waterfowl crippling rates in the USA during the early steel shot phase-in years of 1986-1989, but that the rates for both ducks and geese declined towards early 1980s levels in 1991. A large-scale European study on the effectiveness of steel shot ammunition indicated similar performance levels with lead shot when hunting waterfowl (Mondain-Monval *et al.* 2015). Mondain-Monval *et al.* (2015) also showed that hunter behaviour and judgement, the abundance of birds, and strong wind conditions played significant major roles in determining the effectiveness of hunters' ability to bring birds to bag. Noer *et al.* (2007) indicated that the wounding of geese by Danish shooters could be reduced by hunters' confining their shooting to a maximum distance of 25 m, a practice that requires awareness and determination.

A definitive, large-scale, comparative study of the effectiveness of steel and lead shot for shooting mourning doves *Zenaida macroura* was conducted in the USA (Pierce *et al.* 2014). The study revealed that hunters using lead shot (12 gauge, with 32 g of US #71/2 shot) and steel shot (12 gauge, with 28 g of US #6 and US #7 shot) produced the same results in terms of birds killed per shot, wounded per shot, wounded per hit, and brought to bag per shot. Hunters in this double-blind study wounded 14% of

targeted birds with lead shot, and 15.5% and 13.9% with #7 and #6 steel shot, respectively. Hunters missed birds at the rate of 65% with lead shot, and 60.5% and 63.6% with #7 and #6 steel shot, respectively. Pierce *et al.* (2014) concluded that *"... (shot) pattern density becomes the primary factor influencing ammunition performance"*, and this factor is controlled by the shooter.

Steel Shot Lethality Tables have been compiled by T. Roster[1] of the (then) US Co-operative Nontoxic Shot Education Program (CONSEP). These data are invaluable for hunters to gain proficiency in the use of steel shot. The critical point of the tables is emphasizing shooting within the effective range of the shotgun cartridge at which pattern shot density and pellet energy are, together, capable of producing outright kills. It would be advisable to reproduce the same tables in UK hunter information packages.

In summary, crippling of birds is related to the shooter rather than the ammunition, and the evidence suggests that while shooters may need to adapt to using different ammunition, steel shot can be used as effectively, without increased wounding of birds.

Does non-toxic shot deform in the animal's body like lead shot?

The lethality of gunshot is not a function of its ability to "mushroom" in the body. This is a common confusion with expanding rifle ammunition. Soft lead pellets that hit large bones in animals' may lose their round shape, often fragment, and remain in the carcass. The lethality of shotgun shot relates to the number of pellets that penetrate the vital regions of the animal and cause tissue disruption. It is accepted that a minimum of five pellets hitting the vital regions are required to produce rapid humane kills (Garwood 1994), *i.e.* it is the pattern density of shot rather than the energy in a given shot that defines lethality (Pierce *et al.* 2014).

Very soft pellets that may deform during passage along the gun barrel also contribute to poorer quality patterns. Gunshot makers will use up to 6% antimony to harden the shot to ensure that lead shot does not get hit out of roundness during firing and fly away from the main shot pattern and not contribute to the shot pattern's density. Another process involves plating lead shot with nickel to harden the pellet surface, prevent deformation, and generate better killing patterns at distant ranges. Steel shot patterns well because of its relative hardness, and if delivered accurately, kills effectively from multiple hits without the need of deformation.

Are lead-free shotgun cartridges made in a broad range of gauges and shot sizes?

Manufacturers in Europe make and distribute cartridges according to hunters' demands, which, in turn, are driven by regulations. Given that the main requirement is currently for wetland shooting, the main types of lead-free cartridges produced are suited for this type of shooting (*i.e.* 12 gauge cartridges in shot size US #5 and larger). If regulations were in place requiring hunters to use lead-free shot for upland game shooting, industry would make and distribute them for this purpose. Pressure constraints prevent steel shot being loaded into cartridges smaller than 20 gauge. Cartridges containing steel, Tungsten Matrix, and Bismuth-tin shot are already made in 12 gauge 2.5, 2.75, and 3.0 inch, and 20 gauge 2.75 and 3.0 inch cartridges but at production levels consistent with current market demand. Cartridges in 16 ga and 28 ga and .410 bore can be made easily with Tungsten Matrix or Bismuth-tin shot, but a strong reliable market is required to make them widely available.

Can gun barrels be damaged by using lead shot substitutes?

Barrels comprise three regions: the chamber, the barrel bore, and the terminal choke. Steel shot is much harder than lead shot and does not deform during the initial detonation in the cartridge chamber, unlike soft lead pellets. There is no damage to the chamber because the pellets are still inside the cartridge case. As steel pellets travel down the barrel, they are contained inside a protective cup that prevents the pellets contacting the walls of the barrel. The *only* point along the barrel where some risk *might* arise is when the steel shot pass through the choke. The chokes of different makes of shotguns are not made in a consistent, uniform manner. Concerns pertain to abruptly-developed, as opposed to progressively-developed, chokes in barrels. It is *possible* that large steel shot (larger than US #4 steel, 3.5 mm diameter) passing through an abruptly developed, tightly- choked (full and extra-full), barrel could cause a small ring bulge to appear, simply because the steel shot do not deform when passing through the constriction. This does not occur if the barrels are more openly choked, such as "modified" or "improved cylinder". This is the essence of the concerns. Ring bulges are also known to occur in shotgun barrels when large hard lead shot are fired through tight chokes. A gun barrel with a

[1] T. A. Roster, 1190 Lynnewood Boulevard, Klamath Falls, Oregon 97601, USA.

ring bulge can continue to fire steel shot. It is a cosmetic change, and not related to safety or the risk of exploding barrels.

For shooters with interchangeable, removable, chokes, the solution is to use a more open choke when shooting such steel shot, as when shooting waterfowl or "high" pheasants. For shooters with gun barrels (single or double) having "fixed" full and extra full chokes, the choke, if necessary, can be relieved readily by a gunsmith to a more open choke. The shooting of steel shot of diameter *smaller than* US #4 (< 3.5 mm) does not cause concerns when fired through tight chokes. The same caveat about shooting large steel shot through fixed choke barrels also applies to large Hevi-Shot pellets, which are also much harder than lead shot.

This concern about ring bulges does not apply to Tungsten Matrix or Bismuth-tin shot, both of which perform similar to lead shot during firing and passage through the barrel.

Do lead shot substitutes pattern like lead shot?

The lead-free shot, Tungsten matrix and Bismuth-tin, have ballistic properties and densities similar to lead shot. Both types are fired from the barrels at approximately the same velocity as lead shot, and in the same shot containers. Both shot types respond to barrel choking as lead shot, and have similar shot string lengths. Manufacturers give steel shot similar muzzle velocities as lead shot, so there is no perceptible difference to shooters. Steel shot, by virtue of their spherical shape and hardness, do not contribute as many fliers (mis-shaped or deformed pellets) to the fringes of shot patterns, and so add more shot to the main killing region of the patterns. Steel shot strings are slightly shorter than lead shot strings. Steel shot cartridges produce slightly tighter patterns than lead shot with a given barrel choke, so do not need to be fired through barrels with much choking.

Can my gun be used with non-toxic shot cartridges?

Any gun that can fire lead shot cartridges safely can also fire non-toxic shot cartridges safely, provided that they are the same length, and of an equivalent shot weight. Thus Tungsten Matrix shot cartridges or Bismuth-tin cartridges can be used confidently in any European gun with any choke constriction. One would not fire 2.75 inch lead shot cartridges in a gun proved for 2.5 inch cartridges, or 3.0 inch lead shot cartridges in guns proved for 2.75 inch cartridges simply because they were not made and proved to handle these larger cartridges. The same considerations apply to the use of Tungsten Matrix and Bismuth-tin shot cartridges. The only possible concern about the use of steel shot pertains to the choke region of the barrel (as addressed in the previous points). Any UK-made gun can shoot steel shot safely provided the cartridge length matches the chamber length, and provided that the shot sizes are consistent for use with a given choke boring. The cartridge makers have made enormous progress in the development of more progressively-burning gunpowders to make their steel shot cartridges compatible for use in older guns. Shooters are always advised to ensure that the cartridges, whether lead shot or non-toxic shot, are of the same size as the chambers of their guns. The European Proof Commission will add a special proof mark (a Fleur de Lys) mark on the actions and barrels of guns to indicate that they have been proved safe for magnum-size steel shot loads.

Can non-toxic shot be used with biodegradable wads?

Tungsten Matrix cartridges and Bismuth-tin cartridges are made with shot contained in degradable fibre wads for use in areas where plastic wads are not allowed, whether on wetland or upland sites. Steel shot requires containment in a hard wad that is released to the environment. However, the UK company, Gamebore, has begun to make a biodegradable wool felt wad that protects the shotgun barrel, and provides an environmentally-friendly material for shooting steel shot in sensitive areas.

Is ricochet a problem with lead-free ammunition?

All types of shot and bullets can ricochet (*i.e.* deflect) from a hard surface such as water, rocks, or the surface of tree trunks, if they hit the surface at an acute angle. Shot made from soft lead, Tungsten Matrix and Bismuth-tin may break up on direct contact with rocks. Steel shot will bounce off hard surfaces, and is not so prone to fracture. Bullets made from pure copper or gilding metal can ricochet as readily as lead core bullets, especially if they have a pointed meplat (*i.e.* spitzer points). It is the responsibility of shooters to be aware of the backdrop to

each shot, regardless of the type of shot or bullet used. The issue of richochet of lead-free bullets or gunshot has not arisen as a serious concern among US hunters, and has not been raised to prevent a transition to their use.

How long would it take for industry to ramp up production of lead-free shot?

UK cartridge companies (Gamebore and Eley) currently make two proprietary brands of non-toxic shot cartridges, Tungsten Matrix and Bismuth-tin. At least five UK companies currently make steel shot cartridges, and more distributors import steel shot cartridges from European and American companies (Thomas 2015). This array of steel shot is available for both game and clay target shooting (Thomas 2013b). The majority of cartridges made in the UK are made for clay target shooting, rather than game shooting.

The UK companies already have the technology in place to produce all the non-toxic cartridges that UK shooters will demand. What is presently limiting production is the assured market demand from the shooting community. Voluntary measures to adopt lead-free cartridges do not create a strong market demand that companies can rely on. Also, a lack of compliance with existing non-toxic shot regulations for shooting over UK wetlands (currently about 70+% non-compliance) does not encourage companies to make more non-toxic shot than is ordered.

Any regulations that would require greater use of lead-free cartridges would require an appropriate phase-in time. The vast majority of steel shot incorporated into cartridges originates in China, and the Chinese companies would need adequate time to increase projected production. The same consideration applies to tungsten originating from Chinese mines and refiners. The cartridge cases and shot cups designed for steel are not the same as those used for lead shot cartridges, and so increasing their production volume takes time. It also takes time for UK makers to make, test, advertise and distribute their cartridges, and for the wholesalers to stock and prepare their products for sale. Given the experiences of the USA, a transition time of three years to the date of entrance of legislation appears reasonable, for both UK and European makers. This is also the timeframe suggested in the guidance to the CMS (November 2014) Resolution recommending a phase out of the use of lead ammunition.

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Current partial UK regulations do not protect birds feeding in terrestrial environments such as these pink-footed geese *Anser brachyrhynchos*.

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