

The sociological and political aspects of reducing lead poisoning from ammunition in the UK: why the transition to non-toxic ammunition is so difficult

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ABSTRACT

A range of pressures and policy drivers exist to reduce human and wildlife exposures to the toxic effects of lead from ammunition sources, awareness of which has increased in recent years. The replacement of lead ammunition with non-toxic alternatives is widely recognised as a practical and effective solution to address the risks. As a consequence a range of users of ammunition for natural resource management are making, or have made, this transition. This paper explores a resistance to change from many in the recreational shooting community.

Compliance with the current regulations restricting use of lead shot in England in order to reduce the pollution of wetlands and poisoning of wildfowl has been shown to be poor and morbidity and mortality remains high across Britain. Unfortunately a high profile campaign run by the shooting organisations to reduce illegal use of lead shot has been ineffective.

A questionnaire survey of shooters' behaviours and attitudes was undertaken to better understand the situation, combined with a review of coverage of the subject area in the shooting media. Together with personal experiences of the authors, these highlight a number of sociological and political barriers that combine to inhibit both compliance with existing regulations and a transition to wider use of non-toxic ammunition.

These barriers to change are set within a wider context of a long held perception in the shooting and wider field sports communities that 'hunting is under threat'. The barriers are reinforced by the misperceptions that lead poisoning is not a problem for either wildlife or human health; and that non-toxic alternatives are not fit for purpose and/or too costly. There are cross-cutting issues of the regulations' unenforceability, cultural traditions within the shooting communities, as well as polarised loyalties between key stakeholder groups, and mistrust of those outside these communities. In combination, this has led to issues of biased assimilation of information and solution aversion (meaning that the evidence is immaterial if the solution to the problem remains undesirable). There has also been a popular narrative in the field sports media dismissing the evidence and discrediting the messengers. These barriers to change appear to have been supported by commercial interests and the political power of the field sports lobby including the ammunition manufacturers.

In other countries, recognition of lead's toxic impacts and transition to the use of non-toxic ammunition have been fully 'owned' by shooting communities working in combination with governments recognising joint responsibilities and interests. Within the UK, the polarisation of stakeholder groups has inhibited such ownership, and prevented constructive collaborative working and the agreement of a common solution. It is argued that the opportunity for the conservation and shooting communities to work together on resolving problems was missed in the early stages of the existing regulations. Now, the atmosphere of the debate is likely non-conducive to those within the shooting community who might like to speak out in favour of a more sustainable lead-free approach to shooting.

A range of ecological, economic and public relations benefits to making the transition to non-toxic ammunition are described. Whilst there are some costs to the shooting community, these are arguably outweighed by the costs of not changing.

Key words: *compliance, regulations, sociological aspects, political aspects, conflict, costs, barriers, lead ammunition*

Author contributions: *Wrote the paper: RC, JN. Performed the game dealer survey (including purchasing, radiography, pathology and laboratory analyses, data analyses): JR, MO, KB, MB, JN, RC. Undertook the media survey: RC.*

INTRODUCTION

As a Contracting Party to the African-Eurasian Migratory Waterbirds Agreement (AEWA), the UK has an obligation to phase out the use of lead shot over wetlands (AEWA 1999, 2002, 2008) (with the initial deadline for this being 2000). Consequently, restrictions on the use of lead shot were introduced in England in 1999 (HMSO 1999, 2002a, 2003), Wales in 2002 (HMSO 2002b), Scotland in 2004 (HMSO 2004) and Northern Ireland in 2009 (HMSO 2009). In England and Wales, the Regulations make it illegal to use lead shot for shooting wildfowl, coot *Fulica atra* and moorhen *Gallinula chloropus*, and over certain listed wetlands (Sites of Special Scientific Interest) and the foreshore. In Scotland and Northern Ireland the use of lead is not permitted over any wetlands.

Despite this UK-wide legislation, lead poisoning from ammunition sources remains a cause of significant mortality and morbidity for primarily waterbirds and likely also terrestrial gamebirds (which consume lead shot directly from the environment) and raptors (which consume lead shot and bullet fragments within prey and carrion) (Newth *et al.* 2012, Pain *et al.* 2015). Newth *et al.* (2012) detected elevated blood lead levels in a third of live wildfowl tested in Britain. Additionally they found no reduction in mortality from lead poisoning in the 11 year period following introduction of legislation in England in 1999. This ongoing problem is likely due to illegal use of lead gunshot where waterbirds feed (partial restrictions having been shown, within the UK and more widely, to be difficult to enforce (AEWA 2012)) and/or legal use of lead shot in terrestrial waterbird feeding habitats (Newth *et al.* 2012). Recently deposited lead gunshot is likely to be more readily available to waterbirds than shot deposited historically which may become increasingly inaccessible over time as it becomes incorporated into the substrate (Anderson *et al.* 2000, Newth *et al.* 2012).

The issue of the risks from the toxic effects of lead from ammunition sources (both gunshot and bullets) has prompted much discussion from different stakeholder groups in the UK and internationally, including the shooting¹ and wildlife conservation² communities as well as public health bodies³ and animal welfare organisations⁴. A number of key findings and developments related to lead in the last decade have been critical to the discourse in the UK, including:

1. A greater understanding of the degree and extent of fragmentation of lead ammunition within shot game to which the human consumer is then inadvertently exposed (e.g. Watson *et al.* 2009, Pain *et al.* 2010, BfR 2011, Iqbal *et al.* 2011);
2. Further to the 2008 Peregrine Fund conference, "Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans"⁵ and its proceedings (Watson *et al.* 2009), the subsequent increasing body of scientific reports of risks posed by lead from ammunition to the health of humans (e.g. EFSA 2010), wildlife and domestic animals (e.g. Payne *et al.* 2013), and of wider environmental contamination *i.e.* lead ammunition poses a cross-cutting One Health⁶ issue (e.g. Johnson *et al.* 2014);
3. Department for Environment, Food and Rural Affairs (Defra) funding the Wildfowl & Wetlands Trust (WWT) and the British Association for Shooting and Conservation (BASC) to undertake a study into compliance with existing regulations in England (Cromie *et al.* 2010) as poor compliance had been measured in 2002 (Cromie *et al.* 2002): the results indicating continued poor compliance and suggesting that the law had been ineffective in achieving its aim;
4. Defra and the Food Standards Agency (FSA) setting up the Lead Ammunition Group⁷ in 2010 in response to concerns about risks of lead ammunition to wild and domestic animal health and human health: in the following five years the group aimed to assess and address these risks and reported to government with its findings in June 2015⁷;
5. 'A Scientific Opinion on Lead in Food' by the European Food Safety Authority (the European Union's independent provider of scientific advice on risks from food) (EFSA 2010): with consequent food safety advice regarding game shot with lead ammunition produced by the health/food agencies of at least five European countries (BfR 2011, AESAN 2012, Food Standards Agency 2012, VKM 2013, SNFA 2014);
6. As a Contracting Party to the UN-Convention on Migratory Species, the UK adopting Resolution XI.15 (UNEP-CMS 2014a) in 2014 whose guidelines (UNEP-CMS 2014b) include a 2017 deadline for the phase out of all lead ammunition in both terrestrial and wetland habitats.

¹ Those primarily involved in recreational but also subsistence shooting (including some pest control activities as part of this). ² Those organisations whose sole remit is wildlife conservation - a label to describe e.g. WWT and RSPB, accepting overlap with the conservation work of the shooting community. ³ Those organisations or bodies with responsibility for human health e.g. in relation to food safety such as the Food Standards Agency. ⁴ Those organisations whose remit is animal welfare: may include organisations who deal with treating sick wildlife and its rehabilitation. ⁵ <https://www.peregrinefund.org/subsites/conference-lead/> ⁶ One Health: the collaborative effort of multiple disciplines — working locally, nationally, and globally — to attain optimal health for people, animals and the environment. ⁷ Lead Ammunition Group website <http://www.leadammunitiongroup.org.uk/>

The replacement of lead ammunition (both shot and bullets) with non-toxic alternatives is recognised widely as a practical solution to this One Health problem (UNEP-CMS 2014b, Group of Scientists 2013, 2014) *i.e.* one mitigation measure which would bring health benefits across the medical, veterinary and conservation sectors. Given the global drivers to reduce exposure to lead for both humans (*e.g.* WSSD 2002) and wildlife populations alike (UNEP-CMS 2014a, 2014b), this substitution would likely bring a range of benefits for the shooting community and wider society, namely:

1. Substantial reduction in wildlife poisoning: mortality, morbidity and associated welfare concerns (*e.g.* Anderson *et al.* 2000, Samuel and Bowers 2000, Stevenson *et al.* 2005). From the shooting perspective, removal of this significant mortality factor has potential to result in greater numbers of individuals of quarry species to shoot. Indeed, replacement of lead ammunition for waterfowl hunting in the USA has been described as a key cost effective waterfowl conservation tool (Thomas 2009);
2. Reduction in environmental pollution and uptake of lead from soils into plants and lower animals (*e.g.* Sneddon *et al.* 2009);
3. Reduction in risk to humans consuming game shot with lead. Due to the particular sensitivity of the developing brain to the effects of lead (*e.g.* USATSDR 2007, CDC 2012), this is of particular importance to children, especially those most likely to be consuming such meat frequently *e.g.* children in shooting households (a BASC/Countryside Alliance survey of game-eating habits estimated that 5,500 – 12,500 children under eight years of age from their community eat game at least once a week (Lead Ammunition Group 2014)). Such levels of consumption have the potential to result in intellectual and other developmental deficits, *e.g.* BfR (2011), AESAN (2012), Andreotti and Borghesi (2012), Food Standards Agency (2012), VKM (2013), NFAS (2014), Green and Pain (2012, 2015);
4. Reduction in waste of harvested animals where substantial proportions of carcasses are recommended to be discarded to eliminate the greatest proportion of lead-contaminated meat (*e.g.* a 60 cm diameter around the wound canal for mammalian game species shot with bullets (Knutsen *et al.* 2015));

5. Reduction in potential risk to the wider public image of the shooting community as tacitly poisoning;
6. Reduction in risk of markets for game meat being affected negatively within the UK, the European Union and beyond if restrictions are introduced for food safety reasons (*e.g.* if minimum lead levels are introduced for game meat to bring in line with other meat, fish, shellfish and mollusc restrictions (EC 2006));
7. Reduction in potential risk of future economic impacts on the shooting community (particularly if societal awareness or controls on lead increase) in the case of perceptions leading to blight affecting the value of land or produce; or the principle of the polluter being asked to pay for the remediation of contaminated land where there are actual impacts such as on domestic stock or human health.

By necessity, the practicalities and technical aspects of production and use of non-toxic ammunition have been, or are being, addressed (*e.g.* Gremse *et al.* 2014, Gremse and Reiger 2015, Thomas 2013, 2015). Despite evidence of poor compliance with existing regulations in England (Cromie *et al.* 2002, 2010), there are undoubtedly some shooters who have been using non-toxic ammunition routinely since the introduction of regulations on use of lead shot for shooting wildfowl/or over some wetlands. Additionally, a number of UK organisations using ammunition in natural resources management (not for recreational shooting *per se*) *e.g.* government agencies and NGOs, have either made the transition to non-toxic ammunition or are in the process of doing so.

Although it has taken many decades of science and policy development (often associated with industry resistance), exposures of people to lead in paint, petrol and pipes have been significantly reduced at a global scale (Stroud 2015). The scene is now set for change on use of lead ammunition: the evidence is extensive and robust (Group of Scientists 2013, 2014); there are clear international and national policy drivers (Stroud 2015); ammunition users are not being asked to stop their current activities, they are being asked instead to use different ammunition, which is increasingly available; and there are a range of benefits, as mentioned above. Despite consensus between conservation (BirdLife International) and international shooting organisations (The European Federation for Associations of Hunting and Conservation - FACE - and the

⁸ This International Council for Game and Wildlife Conservation (CIC) Workshop's Resolution states that "It is now technically feasible to phase out the use of lead ammunition for all hunting" (accepting some development needs for some calibres of bullets).

International Council for Game and Wildlife Conservation - CIC) on the risks from lead ammunition to wildlife (BirdLife International/FACE 2004) as well as people (CIC 2009, Kanstrup 2010⁸) resistance to change remains firm amongst many in the UK shooting community. Why then is this transition so protracted (given that this was first recommended by the Royal Commission on Environmental Pollution in 1983 (RCEP 1983))?

The publication of the Newth *et al.* paper in the autumn of 2012, indicating a continuing problem of lead poisoning in waterbirds in Britain, gained some media coverage. This created heightened tension in the debate and was met with a strong negative reaction in the UK shooting media and shooting organisations. Since then, retaining the current *status quo* has been strongly argued for by the two main UK shooting organisations (BASC and Countryside Alliance) as illustrated by a campaign message of the latter organisation 'give your voice to keep lead' and the publication 'The Case for Lead' (Countryside Alliance 2013). As part of this, in appreciating that non-compliance with the current law related to the use of lead shot was a problem (Cromie *et al.* 2002, 2010) and could put at risk the use of all lead ammunition in other habitats, the shooting and country land management organisations came together in the summer of 2013 to launch a campaign to encourage individuals to comply with the law on the use of lead shot. This 'Use Lead Legally' campaign was subject to a high profile launch at the Country, Land and Business Association (CLA) Game Fair in July 2013 and was kept high profile in the shooting media and on the websites of the two main shooting organisations for several months. It was successful in terms of generating interest and signatories to pledge to not break the law.

The legislative *status quo*, but including significantly improved compliance with the law, would bring some gains for some waterbirds but would not address risks to waterbirds feeding in terrestrial environments, gamebirds, raptors and scavengers and wider environmental contamination (Pain *et al.* 2015), nor protect human health for frequent game consumers. In the absence of political legislative action, wider change to use of non-toxic ammunition would need to involve a willingness to change; the practicalities of change being resolved *e.g.* gun proofing for steel shot for those wanting a comparably priced shot and not wanting to buy the more expensive alternatives; and practice and shooting within acceptable ranges. The latter is an important aspect of the lead ammunition debate - ranges

acceptable for lead are analogous for ranges acceptable for steel but it is likely that judgement of shooting distance for some shooters may need honing (various shooters, *pers. comm.*). A 'sporting shot'⁹ at a bird such as a pheasant flying high is arguably out of range and would be made more difficult, and potentially additionally unethical¹⁰ to shoot at, if using steel shot. More dense non-toxic shot such as tungsten would behave in a similar way to lead.

Despite many shared conservation objectives and collaborative projects, the relationship between the field sports¹¹ and conservation communities can be problematic. Thus, the lead debate sits within this more general environment of mistrust and tension which has increased in recent years due to concerns over the sustainability of some other shooting practices (*e.g.* Brown *et al.* 2014, ECRA 2014, Avery 2015) and a perception that conservation organisations are anti-hunting (*e.g.* see results of shooting media survey below). There is also a legitimate perception among hunters in general that legislation is one-way and only leads to further restriction on their sports¹².

Appreciating this landscape, this paper provides a narrative of what will be termed 'the lead ammunition debate' (or 'the debate'), reflects on the recent chronology of events and looks at responses of the shooting community to these and the likely impacts of these responses.

The paper aims to explore some of the sociological and political barriers to change in order to help inform those involved in 'the debate' as well as interested wider society. The objectives include:

1. reviewing compliance with the law in England over time and specifically measuring compliance following the campaign by the shooting organisations to reduce illegal use of lead (the 'Use Lead Legally' campaign launched in 2013);
2. exploring the understanding and attitudes of shooters using a formal questionnaire survey; and
3. gaining an appreciation of the narrative to which the shooting community is exposed by undertaking a content analysis of the shooting media.

The paper contains both data and opinions of the authors based upon dealing with the issue for many years. It reflects on some of the other sociological and political aspects too

⁹The bird has a good chance of either being missed altogether or being hit by a small number of pellets at lower velocity but surviving. ¹⁰Ethics are personal but The Code of Good Shooting Practice says 'Guns must be competent at estimating range and shoot within the limitations of their equipment to kill cleanly and consistently.' <http://www.codeofgoodshootingpractice.org.uk/> ¹¹The total hunting/field sports community *i.e.* broader than just shooting, ¹²As an example, the 1954 Protection of Wild Birds Act had a quarry list of 33 species whilst the equivalent list of the 1981 Wildlife & Countryside Act had just 19 species.

infrequently recognised in natural science literature but of paramount importance in resolving conflicts (Redpath *et al.* 2015). A small number of lessons learned are suggested to assist in development of solutions for other conflict situations.

METHODS

'Measuring' responses of shooters to the lead issue and appraising the atmosphere of the debate has been done by a range of means of differing robustness, namely:

1. A 'game dealer survey': to measure compliance with the Regulations in England following the Use Lead Legally campaign launched in 2013.

The methods used for purchase of ducks, for pathological examination to determine recent from non-recent shot, and the shot analysis techniques used were based upon Cromie *et al.* (2010) and are provided as Supplementary Information in Annex 1.

This game dealer survey is a measure of behavioural responses of shooters following the Use Lead Legally campaign and likely reflects a range of motivations.

Measuring compliance with the current regulations on use of lead shot is complex and previously Defra contracted ADAS to undertake a project to review different compliance methodologies (ADAS 2007). That report concluded that a game dealer survey was "an absolute method of measuring compliance, which had some constraints relating to limited coverage of types of shooting and range of species. Its main strengths were seen as its practicality, ease of implementation and that it had the least chance of a biased sample when compared with other sampling methods". It is recognised that it is not necessarily a good reflection of compliance of 'coastal wildfowlers'¹³.

This method has received criticism from some in the shooting community who suggest that a large proportion of the ducks sold in England are sourced in Scotland where there is a possibility of them having been shot legally with lead if they were killed when they happened to be away from a wetland. However, it seems implausible that all the game dealers in England which supplied ducks in this study, were dishonest about the English provenance of their ducks at the time of purchase and additionally improbable that a large proportion

of the many ducks shot in England do not end up being sold in England. Outlets known (from Cromie *et al.* (2010)) to source their ducks from Scotland were not approached.

Purchasing of ducks for the survey was undertaken during November 2013 to February 2014 *i.e.* some four to seven months after the launch of the Use Lead Legally Campaign.

2. A 'shooters survey': a formal questionnaire survey investigating understanding and attitudes of shooters.

This formal questionnaire survey of BASC members was undertaken between 2008 and 2010 as part of the Defra-funded compliance study (Cromie *et al.* 2010). The questionnaire explored shooters' understanding of the current regulations in England, whether they obeyed the law, their attitudes towards the regulations and surrounding issues. It would be fair to say that since the questionnaire survey was conducted the lead debate has become more polarised, however, it is reasonable to suggest that the findings are still valid. For the full methodology and results see Cromie *et al.* (2010).

3. A 'shooting media survey': analysing the message content being provided by the shooting media to the shooting community to help understand the narratives which may be influencing shooters' opinions.

To help understand the influences to which the shooting community are exposed, some of the narratives relating to lead ammunition in the shooting press were explored. A summative content analysis was used (Hsieh and Shannon 2005) *i.e.* selecting articles containing key words and then exploring the contextual usage. Some 94 articles (letters, pieces or editorials) containing the words 'lead shot' or 'lead ammunition' in the UK shooting/fieldsports printed press of nine 'popular' publications from July 2010 to July 2015 were reviewed (magazines focussed on clay pigeon shooting, target shooting and airgun shooting were not included). This was not an exhaustive review (and articles in 2011 and 2013 will be underrepresented as their collection was *ad hoc* and opportunistic rather than systematic at that time). Of the nine, two were weekly publications with an average circulation of 22,000 (range 20,000-24,000), six were monthly publications with an average circulation of 23,400 (range 11,500-31,600) and one was a bi-monthly publication with a readership of 300,000). It is not possible to calculate the total readership of

¹³Coastal wildfowlers': Shooters most likely to be in wildfowling clubs which have codes of practice, which may not allow sale of shot ducks to game dealers. In England, coastal wildfowlers should have been using non-toxic shot since 1999 so arguably are best placed to advise other sections of the shooting community on its use, even acting as advocates.

these articles as people with an interest in shooting are likely to read more than one shooting magazine, yet not necessarily read the entire publication nor consistently over time.

Events *e.g.* the holding of meetings or mere mentions of statements of fact relating to lead poisoning (other than its toxic effects) were not noted. Similarly, tone was not recorded due to its subjectivity. However, wherever an opinion of relevance to the toxicity of lead, lead ammunition or the debate more generally was provided this was noted. Of the 94 articles, 72 expressed one or more opinion (48 normal articles, 19 letters, two responses to letters and three editorials). These were noted and then grouped as appropriate into common themes, the results of which are presented herein.

It is accepted from the outset that other than the shooting media there is vast array of influences that ultimately give rise to particular belief systems and subsequent behaviours. These include heritage, social grouping, interactions on social media and so on and these deserve further investigation but are not explored within this paper.

4. Stakeholder classification

To help understand, and attempt to simplify, the lead ammunition debate (accepting the problems this may cause) stakeholders were grouped into categories. Stakeholders were identified according to the following criteria: those who are influenced by the debate, those who may influence the debate and those who have an interest in/knowledge about the debate. Stakeholders were identified, differentiated and categorised using the authors' knowledge and external expert opinion and through assessing information from a range of sources including electronic media, publications, conference proceedings and peer reviewed literature and reports (Reed *et al.* 2009).

Key segments identified included the conservation community, the shooting organisations and the shooting community. The latter includes what we are terming the 'shooter in the field' to try and illustrate an 'average' individual shooter (of whatever type of shooting), likely not involved in organisational politics, but aware of the lead ammunition debate from the shooting media, social media and shooting friends and/or family. It is fully appreciated that such categorisation can be unhelpful when analysing a debate already subject to polarisation. Furthermore, none of these segments are homogenous (for example, the

British shooting community includes a broad range of shooting types undertaken by a wide cross section of society (Cromie *et al.* 2010)).

RESULTS AND DISCUSSION

Is the current law being broken in England?

A previous game dealer survey undertaken across England in the winter of 2001/02 (*i.e.* two years after introduction of the English Regulations) found a low level of compliance with 68% of 40 ducks having been shot illegally with lead (Cromie *et al.* 2002). The larger scale study funded by Defra, undertaken over two winters (2008/09 and 2009/10) found compliance had not improved with 70% of both 253 and 239 ducks from respective winters having been shot illegally with lead (Cromie *et al.* 2010). Of particular significance for this paper is that public knowledge of the survey in the second winter did not affect compliance.

From the shooter questionnaire survey (Cromie *et al.* 2010), some 45% of 558 respondents who were legally obliged to use lead said they did not always obey this law. Although the first author has been frequently told, and knows, of wildfowling clubs that require use of non-toxic shot, the author can also recount numerous conversations with shooters who said that they, or other shooters, do not comply with the law. It is acknowledged that the extent of this practice is unknown and it is possible that these situations are more likely to occur during terrestrial bird shooting when waterbird shooting is more opportunistic.

DID THE USE LEAD LEGALLY CAMPAIGN INCREASE LEVELS OF COMPLIANCE?

The winter 2013/14 game dealer survey conducted when the Use Lead Legally campaign had been running for some four to seven months, found 77% of 84 ducks to have been shot illegally with lead (see Table 1). This level of non-compliance was worse than in the previous surveys. The ratio of mallard *Anas platyrhynchos* to other duck species was not directly comparable to the Defra-funded study but had it been (*i.e.* by adjusting the proportion of mallard to make it comparable), the level of compliance for this study would have been significantly worse than the Cromie *et al.* (2010) study (Chi-squared test $p=0.023$) (75/92)(see Figure 1).

Table 1: Proportions of 84 Mallard, Teal (*Anas crecca*), Wigeon (*A. penelope*) and Gadwall¹⁴(*A. strepera*) purchased from 32 game dealers in England shot with lead and non-toxic shot in winter 2013/14.

Shot type	Mallard		Teal		Wigeon		Gadwall		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Lead	72	84	3	50	7	47	2	100	84	77
Bismuth	8	9	1	17	7	47	0	0	16	15
Steel	5	6	2	33	1	7	0	0	8	7
Tungsten	1	1	0	0	0	0	0	0	1	1

¹⁴ It is actually illegal to sell gadwall (they are not listed on Part III of Schedule 3 of the Wildlife & Countryside Act 1981), the purchaser intended to purchase wigeon and/or teal however was offered gadwall in the absence of those species and thus they were purchased in innocence (and very possibly sold in innocence too given that it is the only common dabbling duck species *not* listed on this Schedule).

Of 32 game dealers, 31 (97%) sold ducks shot with lead (in comparison with 73% of 84 suppliers in the Defra-funded compliance study (Cromie *et al.* 2010), which was significantly more (Chi-squared test $p=0.005$).

Further results are provided in Annex 1 Supplementary Information.

COMPLIANCE OVERTIME

Figure 1 provides a timeline of compliance as measured by game dealer surveys and the shooter survey (Cromie *et al.* 2010) since the introduction of the Regulations in England in 1999 following a voluntary ban in wetlands introduced in 1995. In addition to the continued poor compliance (as measured by two methods), it serves to illustrate that various events such as the Use Lead Legally campaign or increased awareness of the issue of lead poisoning and/or non-compliance have not improved compliance.

Findings from the shooting media survey

Within the 72 shooting media articles reviewed, some 131 opinions were recorded, ranging from 1-6 opinions per article. Figure 2 illustrates the variety and number of opinions within the articles reviewed.

Overall, 87.8% of opinions ($n=115$) cited in 72 articles reflected a resistance to change (see Figure 2 for the range of opinions)

while 12.2% ($n=16$) acknowledged a problem of either the toxicity of lead for humans or wildlife, or that the law needed to be obeyed (Figure 2). A small proportion of articles (0.7% $n=5$) contained both 'resisting' and 'acknowledging' opinions.

Concern about the efficacy and costs of non-toxic ammunition was the single most prevalent theme, accounting for 15.3% ($n=20$) of all opinions cited, followed by "lead ammunition is not a problem for human health" (11.4%, $n=15$), "lead poisoning is not a problem for wildlife and "lead is a scapegoat for an anti-shooting agenda" (both 10.7%, $n=14$).

From additionally looking at the two main shooting organisations' websites over time, reviewing other internet shooting media and social media on an *ad hoc* basis, the shooting papers' content reflects the broader prevalent narrative.

Dividing the survey by article type, 19 published letters on the subject were reviewed and had a lower proportion of blue 'resisting change' opinions than the average article (including editorials and the editors writing a response to a letter) (84.4% of 32 opinions vs 88.9% of 99 opinions respectively). Correspondingly the letters contained a higher proportion of orange 'accepting there's a problem' opinions in comparison with other types of article (15.6% of 32 opinions vs 11.1% of 99 opinions respectively). Although this difference is not statistically significant (Chi-squared test $p>0.05$) it may be suggestive of a greater acceptance of a problem coming from the average shooter in the field rather than the shooting media.

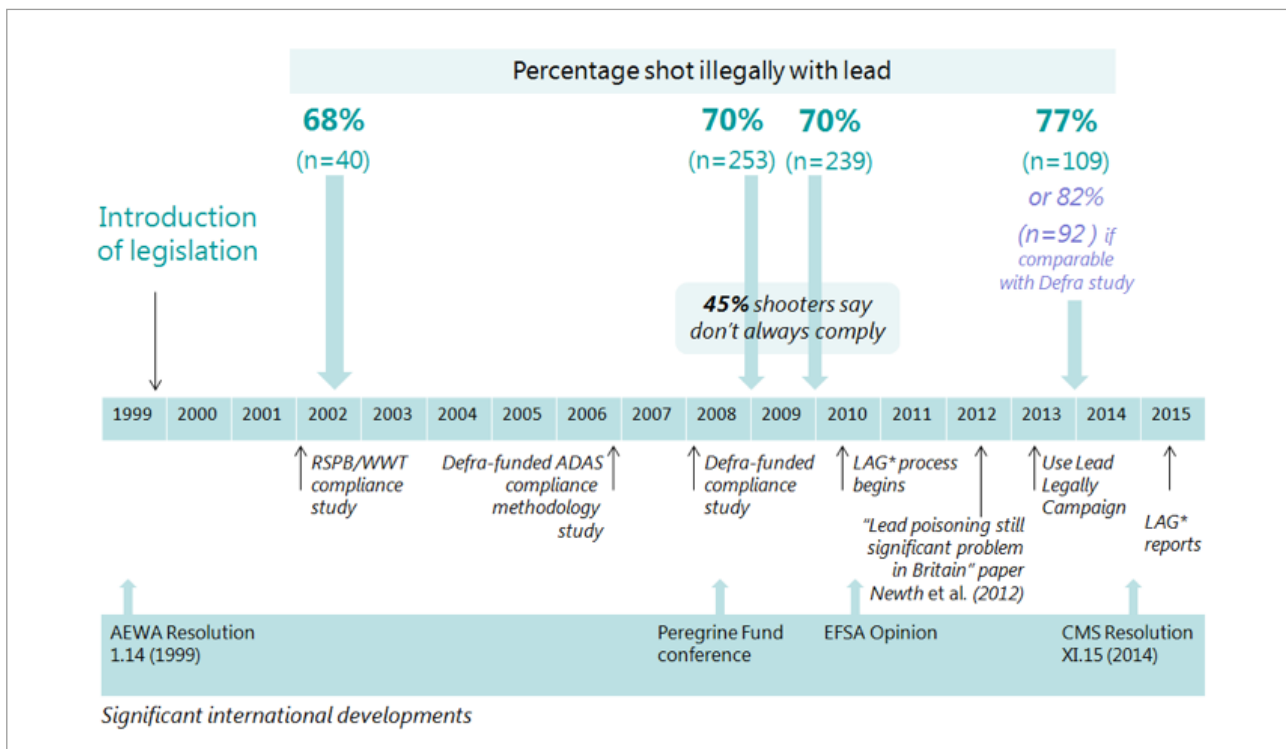


Figure 1: Timeline illustrating introduction of the lead shot Regulations in England and the four points at which compliance was monitored, plus other relevant events.*LAG: Lead Ammunition Group.

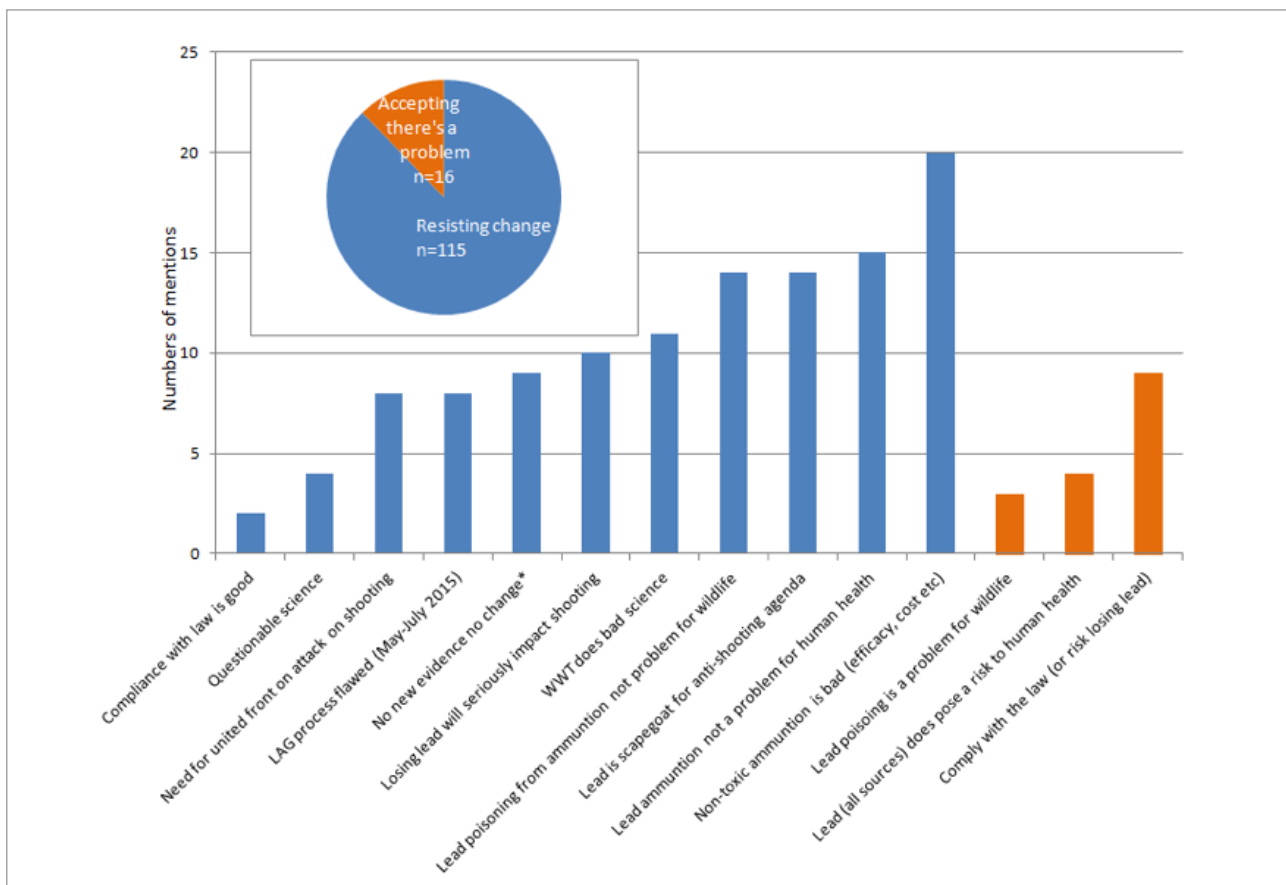


Figure 2: Opinions relating to lead ammunition cited in 72 articles in the printed shooting media between July 2010 and July 2015. Blue bars represent opinions which likely resist change or resist acceptance of a problem, orange bars acknowledge a problem. The pie chart summarises these opposing sets of opinions.*Further evidence is required before a change in approach to lead ammunition can be considered.

Printed media may not have the greatest influence on shooter attitudes but is likely to contribute, particularly those articles written by trusted commentators. The role of *e.g.* British newspapers in shaping public opinion on a range of topical subjects has been the subject of social science research and has indicated a range of influences (*e.g.* McNair 2009).

Why did the Use Lead Legally campaign not achieve its aim?

The shooter questionnaire survey (Cromie *et al.* 2010) indicated that the main reasons for non-compliance with the existing law were:

1. "Lead poisoning is not a sufficient problem to warrant restrictions" *i.e.* shooters were not convinced of the morbidity and mortality caused and thus the need for the regulations (indeed the media survey found frequent reference to 'never seeing bodies');
2. "Don't like the alternatives", shooters reporting that they felt the non-toxic alternatives were too expensive, not effective and/or not widely available;
3. "Not going to get caught" *i.e.* shooters knew that using lead would not involve penalties as the law is not enforced.

The Use Lead Legally campaign did not seek to address any of these three issues but requested shooters to obey the law to *prevent further restriction on the use of lead ammunition* - 'use it legally or we'll lose it' *i.e.* a different reason and thus likely to involve different behavioural motivation from the above.

The main narrative from the shooting media in the one year prior to the 2013/2014 game dealer survey reinforced these first two themes above.

What are the barriers to change?

The above-mentioned reasons from the shooter questionnaire survey and themes from the shooting media survey are likely to create motivation to resist either current regulations or future complete transition to non-toxic ammunition and deserve further investigation. In this section the three known (*i.e.* from the shooter survey) and four proposed barriers are explored and potential means by which to address them are briefly described.

1. "LEAD POISONING IS NOT A SUFFICIENT PROBLEM TO WARRANT RESTRICTIONS":

i.e. shooters are not convinced that this is a significant cause of mortality: Pain *et al.* (2015) estimate in the region of 100,000s of game birds and wildfowl dying of lead poisoning annually. Lead poisoning, as a disease, suffers from the same problems of perception as other insidious (often chronic) diseases which, by their nature, are often largely unseen by most people. It is likely that the overwhelming majority of shooters have no direct experience of the deaths and illness of wildlife caused by the ingestion of lead ammunition.

Surveillance for causes of morbidity and mortality in wildlife relies to a large extent on visually detecting and then examining animal carcasses. Hence, garden bird diseases *i.e.* those seen proximate to human habitation are relatively well surveilled and studied (*e.g.* Robinson *et al.* 2010). Acute events such as oil spills or epidemics of avian botulism result in visible (to humans) numbers of carcasses with animals dying at a rate quicker than predation and decomposition remove them. However, diseases and intoxications occurring on broader geographical scales and extended timescales, or in remote areas, or where predators and scavengers abound, are usually undetected by human eyes (Prosser *et al.* 2008) hence lead poisoning is something of an 'invisible disease' (Pain 1991). The problem of lead poisoning cases not being reported may be confounded further since lead poisoning weakens affected animals and can predispose them to another cause of death *e.g.* predation, flying accident or concurrent disease (Mathiasson 1993, Kelly and Kelly 2005), and this ultimate problem may be noted in surveillance reporting without an appreciation of the underlying sub-clinical poisoning.

Indeed, some of the negative effects of lead on human health (such as diminished cognitive function, chronic kidney disease and elevated blood pressure (Lanphear *et al.* 2005, Iqbal *et al.* 2009, EFSA 2010)) might not alert the patient, nor the physician, to the cause. As an illustration, an environment and health specialist commented, with respect to lead, 'you don't take your child to the doctors due to poor exam results' (Ráez-Luna *pers. comm.*¹⁵). The prevalent narrative from the shooting media is that no-one has ever 'seen' cases of lead poisoned people or wildlife which facilitates the logical conclusion that such poisoning does not occur.

It is possible that if lead poisoning of wildlife was perceived as a problem, shooters might want to take responsibility for

¹⁵ Plenary session at the conference: <http://ecohealth2014.uqam.ca/>

the problem for reasons of: ethics of shooting¹⁰, as poisoning might be seen in a similar light to crippling or harming animals; maintaining healthy populations of birds for shooting and conservation; potential for negative impacts on the public image of shooting; and/or the problem representing 'unwise use' of a natural resource (Lecocq 2002).

To date, the conservation community has failed to persuade the shooting community (and wider public no doubt) of the substantial problem and impacts of lead poisoning. Publishing science is valuable for scientists and policy makers but may have little impact on broader societal understanding in the absence of interpretation of that science for the benefit of specific audiences (e.g. Miller 2001). Awareness-raising tools have been shown to have a beneficial role if targeted on specific weaknesses in knowledge that are most directly related to attitude and behaviour change (Bath 1998, AEWA 2009). However, with such a strong narrative within the shooting media that lead poisoning is not a (significant) problem (Figure 2), awareness-raising of the issue within the shooting community would have to firstly address the prevalent narrative which would involve politically difficult changes of organisational positioning. Thereafter, awareness-raising would rely on building communication of tailored messages using appropriate tools (e.g. video and images, infographics, facilitated workshops etc.), most importantly delivered by *trusted* and credible messengers (AEWA 2009). Exactly who these messengers may be is difficult to identify in the UK as those involved in dealing with lead poisoning are often portrayed as anti-shooting (Figure 2 illustrates the opinion that lead is used as a scapegoat for an anti-hunting agenda), and a vocal advocate from within the UK shooting community (e.g. a wildfowler who has been using non-toxic ammunition for >15 years and still enjoys his/her sport) has, to the authors' knowledge, yet to emerge and be accepted.

2. "DON'T LIKE THE ALTERNATIVES":

Including price, efficacy and availability: this has been a serious barrier in other countries (e.g. AEWA 2009), is illustrated well in the media survey (Figure 2), and is by the first author's experience the foremost concern of the shooter in the field. Techniques such as non-toxic ammunition shooting clinics/demonstrations, run by shooters, which demonstrate the efficacy of non-toxic ammunition, have been shown to work well to help change perception of non-toxic ammunition (AEWA 2001, Friend *et al.* 2009). Research such as that of Mondain-Monval *et al.* (2015) to indicate the role of hunter effectiveness rather than shot type is

also valuable (effectiveness was essentially related to practice of the shooter plus their assiduity (including judgment of distance) and was negatively related to wind strength and number of shots fired *i.e.* a lassitude effect).

Economies of scale and market forces, particularly when markets are guaranteed *i.e.* following legislative requirements (Kanstrup 2010) could potentially help to bring down the price of some of the less frequently used non-toxic ammunition types (steel, the most frequently used non-toxic shot type across the world, is currently comparably priced to lead)(Thomas 2015). It is perhaps worth noting from the game dealer surveys (above and Cromie *et al.* 2002, 2010) that bismuth, rather than steel, was the most commonly found non-toxic shot for wildfowl shooting. If there is perhaps a particular preference for this shot type, then its price may be less of a barrier for wildfowlers who would typically fire fewer shots per 'shooting event' than driven game shooters where many shots are often fired (accepting that even in these situations ammunition still remains a small part of the driven game shooting costs).

3. "NOT GOING TO GET CAUGHT":

It is a reality that non-compliance with the law in the UK is likely to go undetected with all but no enforcement. In over 15 years of the lead Regulations in England, there has only ever been one conviction and that was an offence only detected after a shooter had (seemingly by accident) illegally shot a swan¹⁶. The authors are unaware of any convictions in Scotland, Wales and Northern Ireland.

It is likely that compliance is higher in wildfowling clubs than in other shooting situations as there is some level of "oversight" of shooting activities and associated peer pressure. Stricter enforcement with a real possibility of penalty has been shown to work in some situations in the USA (Thomas 2009) and Spain (Mateo *et al.* 2014) with use of government supported enforcement officers. Given current government finances it seems unlikely that increased policing and enforcement of the current laws will be undertaken. Alternatively greater "oversight" of shooters could be created by e.g. introduction of licensing measures.

Several other barriers are proposed

These following barriers are based primarily on discussions with a broad range of stakeholders, following the narrative in the

¹⁶ <http://www.shootinguk.co.uk/news/swan-shooting-conviction-not-landmark-ruling-say-basc-25682>

shooting media as described and communications from the two main shooting organisations. These are namely:

4. "TRADITION":

Shooting and wider hunting activities are deeply traditional within the UK, with hunting being a significant element of British culture including art, literature, music, language and lore. The word "traditional" is often used by shooters to describe themselves or their pastime and likely involves a range of concepts such as fine old gun craftsmanship, inherited stories and guns, pride in maintaining tradition, and a sense of wanting to be out in the countryside and free of intrusive regulation. Persuading individuals to adopt what are seen as 'non-traditional' behaviours is particularly complex yet can be achieved if the issue becomes unacceptable to society *e.g.* changes to human rights such as voting rights (*e.g.* Stewart *et al.* 2012) and/or the benefits clearly outweigh the costs *e.g.* wearing seatbelts or not smoking in enclosed public spaces (*e.g.* Phaner and Hane 1973, Fong *et al.* 2006). The societal importance of these issues may be different to shooting but all of these examples involved great initial resistance to change.

Tackling change to the tradition of using lead ammunition is likely to involve a combination of reduction of the barriers outlined here, a clear establishment of the costs of not changing (see later section on costs), the benefits of changing (including more birds to shoot), and leadership from the shooting community and/or from influential, respected and trusted individuals from within (*e.g.* Kanstrup 2010). It is worth noting that in a country such as Denmark, the cultural acceptance/tradition of using non-toxic shot (accepting that they had no choice after a national ban on lead ammunition) has become established since their transition in 1996 (Kanstrup 2015).

5. "POLARISED ENHANCED LOYALTIES":

The opportunity for the conservation and shooting communities to work together to address the above issues following the introduction of the Regulations across the UK was missed. Although there had been wide stakeholder involvement leading up to this point (Stroud 2015) and collaborative initiatives thereafter *e.g.* a jointly owned public relations strategy, there was likely a sense of the job having been completed and that the law would be obeyed. Despite good information about the law and the use of non-toxic alternatives provided primarily on the BASC website (Cromie *et al.* 2010), with hindsight, hearts and

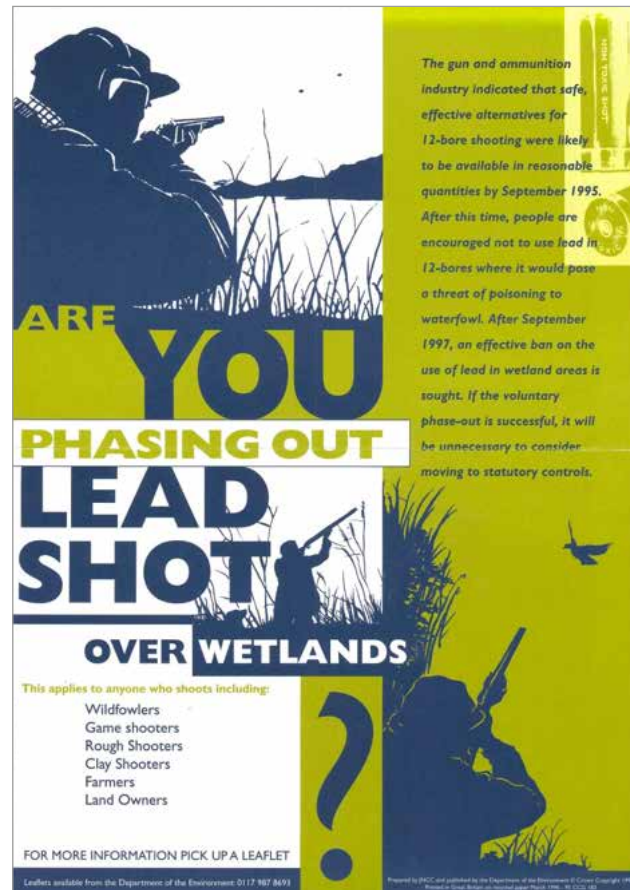


Figure 3: **Information poster produced ahead of the voluntary phase out of lead in wetlands in 1995** (note the industry assurance of the availability and efficacy of non-toxic shot).

minds of the wider shooting community had probably not been won. It would have been valuable at that time to have prioritised development of collaborative persuasive resources concerning the actual problem of lead poisoning as well as the efficacy of the non-toxic shot. For historical interest Figure 3 is a poster produced as a joint government and shooting and conservation community resource prior to the voluntary phase out of lead shot in wetlands in 1995.

Since that time there has been the aforementioned range of other developments, including wider understanding of risks of lead ammunition to wildlife, livestock, humans and the wider environment, plus the associated calls and policy drivers for its substitution with non-toxic alternatives (*e.g.* Watson *et al.* 2009, EFSA 2010, UNEP-CMS 2014a, 2014b). As the "threat to lead ammunition" has emerged and change has become more likely, the discourse has become more polarised (as exemplified by the shooting media analysis) with a recurring narrative of this being "an attack on shooting". This has been likely fuelled by leaked organisational position documents (Balmain 2010, Gray 2010,

Finch 2012), the shooting media coverage, issues of trust and inter-organisational politics. Again, all this is set in the broader context of tensions between the field sports and conservation communities on a range of issues of sustainability of some hunting practices and the suspicion that conservation concerns are actually motivated by an anti-hunting agenda.

The shooting media survey illustrates a prevalent theme as being the 'evidence for needing change is absent or invented/exaggerated'. Social scientists may term this mistrust as 'biased assimilation' where, in polarised debates, either side may seek and assimilate evidence that reinforces their current beliefs and existing attitudinal position and reject the contradictory counterargument (McCright and Dunlap 2011, Corner *et al.* 2012). From the shooting perspective, Ali (2015) suggests that the lead scientists may suffer from 'white-hat bias' whereby they select the evidence that supports their own understanding of the situation.

This current debate may well be subject to what is termed 'solution aversion' whereby an objection to the possible solution (in this case transition to non-toxic ammunition) results in the scepticism about the seriousness of the problem even if it is based on sound science (Campbell and Kay 2014). These authors reflect on the motivated disbelief that this creates. If the debate is being framed within this context, although there is often a call from the shooting community for more evidence (*e.g.* Ali 2015), it would suggest that further evidence is unlikely to be accepted by the shooting community if the solution to the problem remains undesirable.

6. "DISCREDITING THE EVIDENCE, THE MESSENGERS AND THE PROCESS":

Those, in particular scientists and researchers, involved in work which is controversial and/or contentious to industry can find themselves in invidious positions. Needleman and Gee (2013) reflect on this, for example, regarding the removal of lead from petrol and EEA (2001, 2013) provides other examples.

For the lead ammunition debate, likely related to the model of biased assimilation (McCright and Dunlap 2011, Corner *et al.* 2012), it would seem that a practice has developed of discrediting both the providers of evidence and the messengers of unpalatable messages. The portrayal of the chair of the Lead Ammunition Group, provides a good example of this. As the ex-Chief Executive of BASC (a position he held for 25 years), he is

from the heart of the shooting community. This position likely facilitated his ability to keep the complex and polarised Lead Ammunition Group process together through its five years of deliberations (indeed senior personnel from the shooting community expressed confidence in the process (Douglas 2014)) and the minutes of the meetings, which were observed by both Defra and FSA, indicate the extent of the procedural approach¹⁷). Only once his final report was drafted, which both highlighted the problem and the possible solution, did the shooting stakeholders resign (Lead Ammunition Group 2015). Since then both he and the process he led have been widely criticised in the shooting media (Figure 2)(*e.g.* Walker 2015, White-Spunner 2015).

The process of scientific investigation involves peer review and evaluation by independent experts usually involving open and thorough critiques (Spier 2002) thus few scientists can afford not to be resilient to criticism. The media survey, and wider narrative, however indicates a dismissal of the evidence and particular criticism of some of the key scientists. In 2009 Friend *et al.* wrote "Little of what we have presented here reflects the bitterness that characterized much of the struggle to transition to the use of non-toxic shot for waterfowl hunting in the US. Nor does it reflect the heavy personal costs to those who championed the use of nontoxic shot, among them state and federal employees, outdoor columnists, members of the general public, academicians, researchers, and others." Friend's words could have been written about the UK yet the situation here is surely even more polarised as within the USA the conservationists and hunting community are far more integrated and often the same thing. Personal costs in the UK situation no doubt include academics and personnel from the conservation community and also those in the shooting community who have had to deal professionally with lead over the years, finding themselves criticised and unpopular with colleagues from both poles of the debate.

7. "WHERE THE ECONOMIC AND POLITICAL POWER LIES":

Following a five year ineffective voluntary phase-out, restrictions on the importation, sale and use of practically all sizes of lead angling fishing weights in the UK in the 1980s (Stroud 2015) to prevent poisoning of species such as mute swans *Cygnus olor*, were met with dismay by many anglers (M. Brown *pers. comm.*). However, the change was accepted and non-toxic alternatives were quickly seen as the norm (Cromie *et al.* 2010). The shooting

¹⁷ Lead Ammunition Group website <http://www.leadammunitiongroup.org.uk/>

community and organisations have arguably a stronger political and lobbying voice than the angling community. Like many membership organisations, the two main shooting organisations are in the position to both provide leadership as well as reflecting their memberships' views. Driven grouse and pheasant shooting is big business in the UK (Public and Corporate Economic Consultants (PACEC) 2006, 2014) and is seen as 'quintessentially British' (White-Spunner 2012). Whilst those from this industry fear that a transition to non-toxic ammunition may have negative economic impacts - with a perception that range for shooting will need to be restricted *i.e.* fewer shots at 'high birds' (White-Spunner 2012, and see Introduction), or is an unwelcome challenge, an incentive will remain to support the shooting organisations in their resistance to change. Similarly the ammunition manufacturers, with economic imperatives, have often been influential in their resistance to change away from lead ammunition particularly at the European level¹⁸ (Gremse 2015).

Overall, the current polarised debate and its powerful players create significant barriers to change.

Limited space in the landscape for having a different voice

It would appear that defending the use of lead ammunition and maintaining the *status quo* have become an economic issue for the main shooting organisations. A weakening public stance from either of the two main organisations has the potential to be financially damaging in the short term through potential losses to both various supporter funding streams and membership. In the late 2000s, BASC, being aware of both the science and the policy direction of the issue, began to suggest internally that the use of lead ammunition (both bullets and shot) was no longer sustainable and that the shooting community should prepare itself for change (*e.g.* Balmain 2010, Gray 2010). Perhaps had they been the single shooting membership organisation they could have dealt with the subsequent reaction and provided leadership on the issue (as was the case in Denmark (Newth *et al.* 2015)).

It is the authors' opinion that the debate has since become so polarised that it would indeed have to be a confident advocate from the shooting organisations or wider community who would speak up in defence of the evidence on lead and promote non-toxic ammunition. This sort of leadership was present in Denmark at the beginning of their lead discussions and from the

outset the shooting community owned both the problem and led the solution (Kanstrup 2006, Newth *et al.* 2015).

SO WHAT MESSAGE IS THE SHOOTER IN THE FIELD RECEIVING?

Away from organisational politics, the commercial interests of driven game shooting and ammunition manufacturers, what should the average man or woman who enjoys shooting make of the debate? It seems from the outside that they are in an unenviable situation of being provided with a narrative that the evidence is non-existent or exaggerated and promoted by those with an anti-shooting agenda, and that the much lauded Lead Ammunition Group process was flawed after all.

If, being concerned about the problem of lead poisoning, they were to support a change to non-toxic ammunition this could be perceived as disloyal to fellow shooters and contribute to some sort of collective weakening of field sports in the UK. Indeed, this is a prevailing message that lead ammunition represents 'the thin end of the wedge' and that all attacks on shooting should be resisted collectively, a theme illustrated from the shooting media survey. In the authors' experience there is an apparent defensiveness from many shooters as they feel that their pastime and activities are being eroded. This is reflected in a resistance in British conservation and wider society to flexible sustainable harvesting practices and indeed, once a hunting right has gone it is rarely returned¹².

The costs of changing and not changing

It is beyond the scope of this paper to put an economic value on the current costs of the impact of lead ammunition vs the cost of making the transition to non-toxic ammunition.

Overall, a transition to non-toxic ammunition would reduce costs (as in resourcing or negative impacts) for:

1. Government: although resourcing would be greater in the short term for extending current regulations to all habitats and species, there would be no need for longer term awareness raising, enforcement, monitoring *etc.*
2. Conservation community: as they would no longer need to keep undertaking expensive research and surveillance work to feed into advocacy work.

¹⁸ Various processes outlined on the website of Association of European Manufacturers of Sporting Ammunition (AFEMS) <http://www.afems.org/>

3. Welfare organisations: who, over time, would need to intervene and treat fewer poisoned individual animals.
 4. Those at risk of lead poisoning: fewer health impacts for frequent game consumers, including children and pregnant women; and wildlife.
 5. Wider environment: less lead getting into soils and subsequently plants/invertebrates *etc.*
2. Ensuring the sound evidence base is shared and interpreted and tailored for specific audiences;
 3. Insufficient effort has been made to maintain healthy channels of communication between the shooting and conservation communities with a dedication to openness and constructive discourse and development of trust and mutual understanding;

The main costs of the transition would be borne by :

1. The shooting community *e.g.* if necessary, proofing of existing shotguns for steel shot, or possible new shotguns or more expensive shot types for very old valuable guns; increased cost of non-lead bullets or possibly new rifles in some circumstances. Arguably these costs are partially offset by the costs of not changing on risks to public image, game markets and potential of the polluter being asked to pay for contamination.
4. Trusted voices from the middle ground with an understanding of both aspects of the conflict have been largely missing from the issue;
5. Addressing one area of conflict within a landscape of other tensions is particularly complex.

Costs to ammunition manufacturers of a reduction in sales of lead ammunition are likely to be offset by income from sales of non-toxic ammunition.

The Lead Ammunition Group represents an ambitious participatory stakeholder process which judging by the minutes of the meetings¹⁹ managed to cover a broad range of issues in great detail and provided an opportunity for responding to a number of the lessons learned. It is perhaps unfortunate that some of the stakeholders have left that process prior to the arguably more important government-determined next steps (Lead Ammunition Group 2015, Swift 2015).

CONCLUSIONS AND LESSONS LEARNED

Given the evidence from human and ecosystem health science on impacts of lead ammunition, possible restrictions on the sale export/import of game meat containing elevated lead levels, and further policy developments on lead ammunition (including CMS Resolution 11.15), it is clear that the direction of travel of this issue is leading to a phase out of lead ammunition. To date, however, attempts by the conservation and shooting communities respectively to persuade shooters of the problem of lead poisoning and to comply with the existing law have not worked (as illustrated in part by the results contained herein). The issue of the risks from lead ammunition has been lost to some extent in the complexities of various sociological barriers and the politicisation of the problem. Indeed, the lessons learned probably differ little to other conflict resolution situations (Newth *et al.* 2015, Redpath *et al.* 2015) and include:

Although the shooter may deposit the lead, this is in many ways not the actual root of the issue. It would be more than patronising to paint the shooter in the field as some sort of innocent in this piece (given the strong feelings lead often/ usually produces) but behind them lie powerful sources of resistance to change. In addition to issues of tradition and politicisation, these include perceived or real financial impacts for ammunition manufacturers, the driven game shooting industry and the funding and economics of the shooting organisations.

1. A need for facilitated processes beginning with a focus on shared objectives - in this case broader conservation goals of healthy (numerically and physiologically) populations of native British quarry species;

At the time of writing the Lead Ammunition Group has reported to government and decisions are now political (Swift 2015). Perhaps the debate is so polarised that the shooting community knows that imposition of restrictions is more likely than an acceptance of change and leadership from within. It is hoped that leadership from the shooting organisations or wider community (or another as yet unidentified trusted third party) may emerge yet. This is arguably preferable to the alternative of the issue shifting into a broader public debate.

¹⁹ <http://www.leadammunitiongroup.org.uk/meetings/>

By whatever means it happens, resolving the lead ammunition problem once and for all would ultimately result in one less area of tension for the shooting and conservation communities. This could bring a range of benefits and is important given that there are many shared conservation objectives. In summary, the lead ammunition debate in the UK may have its basis in the natural science of toxicology in a range of hosts but is defined by a range of political and sociological barriers.

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ANNEX 1

Supplementary Information

METHODOLOGY OF GAME DEALER SURVEY FOR 2013/14 STUDY

For the sake of brevity, more detailed methodologies *e.g.* full *post mortem* examination protocols, or diagnostic decision trees, are not presented herein but are presented in Cromie *et al.* (2010).

TIMESCALE

Ducks were purchased during the period of late November 2013 to February 2014.

PURCHASE OF SHOT DUCKS

Using the database of game suppliers in England created during the Defra-funded compliance study (Cromie *et al.* 2010), plus identifying new outlets *via* internet searches, WWT staff and colleagues purchased shot wild ducks from suppliers that fell into three main categories, namely: game dealer/butcher outlets (which may also have web-sales); internet game dealers; and farm/estate shops.

Purchasing was undertaken by either opportunistic walking into retail outlets to purchase birds, placing orders directly on the internet or more commonly by placing an order by telephone with subsequent collection in person or postal delivery of birds. An assumption was made that this is how ducks are normally purchased and thus it did not affect normal supply to game dealers.

Birds were labelled according to their order number and stored frozen at -20°C until further analysis.

Region and provenance of birds

Purchasing was carried out in eight of the nine Government Office regions of England (Figure S1) (London being omitted, as per the Defra-funded compliance study, as birds were unlikely to be locally sourced).

There was no intention in this study to investigate regional compliance due to the relatively small sample sizes from each region. The 'across the country' purchasing was undertaken to



Figure S1: **Government Office regions of England** from which ducks were purchased with the exception of London.

try to provide as unbiased a sample as possible.

Suppliers were asked at the time of enquiry about the geographical provenance of the ducks they sold, and were given no reason to suggest that provenance would influence the likelihood of a sale. There was consequently no financial or other incentive for those from whom we purchased game to be anything other than honest about the provenance of the ducks. If suppliers said the birds were, in effect, not locally sourced *e.g.* they came from Scotland²⁰ or likely came from outside the Government Office region²¹ (as determined by the shopper), they were not ordered. The purchasing conversation at ordering and/or collection often involved the supplier telling the shopper about their duck-supplier, some naming the local estates or wetland areas from which they'd been shot. Anecdotal comments supported this *e.g.* through indicating that they had several more ducks should we need them as Mr X or Mr Y local hunter/shoot had been successful over the previous few days. Where labels were attached to purchased ducks, these were examined to try to gain further information about provenance.

Although suppliers from whom ducks were purchased gave assurances that birds were locally sourced, there is no foolproof way to ascertain exact provenance and it is possible that some may have been sourced outside England (where they may have been shot legally or illegally with lead). A large game dealer is reported to supply Scottish shot ducks to English outlets

²⁰ One supplier only ²¹ A small number of suppliers

(Stephen Crouch, *pers. comm.*). The possibility was therefore suggested that some of the birds purchased in England may have been sourced from Scotland, where ducks can be legally shot using lead ammunition if in terrestrial environments²². To reduce this possibility those suppliers identified in the Defra-funded compliance study as sourcing birds from Scotland were not approached, and ducks were not purchased from the one supplier contacted within this study who said his ducks were sourced from Scotland.

Given the above discussion on efforts made to identify provenance of birds and appreciating the number of ducks both shot *and* purchased in England, it seems unreasonable to unduly suspect that the information provided by game dealers concerning the ducks in the present study (and that of the Defra-funded study (Cromie *et al.* 2010) whose methods were replicated here), is anything other than honest.

While 100 per cent proof of provenance is not available, the weight of the evidence provided by the game dealers points towards the ducks being shot in England.

Sample size and species

The previous English game dealer surveys (Cromie *et al.* 2002, 2010) indicated that ~70% of purchased ducks were shot with lead. With an assumption that compliance would have improved since then an *a priori* power analysis to give a 95% confidence of detecting birds shot with lead indicated at least 30 ducks needed to be tested. Suspecting that this sample size may attract criticism, a larger sample size of 100 birds containing shot, purchased from across England, was aimed for.

As the majority of ducks sold are 'oven-ready' with feathers, head, wings, legs and viscera removed, shot are sometimes no longer present in carcasses. Thus, knowing the proportion of birds likely to be carrying shot at purchase (77% from Cromie *et al.* 2010) a sample size of at least ~15 were purchased per region to ensure ~12 birds would be carrying shot and in total shot from some 100 birds could be analysed. These ~15 birds were purchased from between three to six game dealers per Government Office region.

As supplied mallards may be disproportionately shot by inland duck shooters, significant efforts were made to purchase widgeon

and teal as these *may* represent the coastal or other wildfowlers to a greater extent – accepting that both species use inland waters too.

RADIOGRAPHY AND *POST MORTEM* ANALYSIS

Radiography

To quickly eliminate birds without shot and to aid recovery of shot by pathologists, all carcasses were subjected to X-raying to reveal the embedded radio-dense pellets.

Post mortem examination

Free-living wildfowl may contain embedded shot which proved non-lethal from previous exposure to shooting (e.g. Noer and Madsen 1996, Hicklin and Barrow 2004, Newth *et al.* 2011, Holm and Madsen 2013). The provenance of such embedded shot is impossible to obtain so it was important to ensure that only shot that had most recently entered the bird at time of death were analysed.

Pellets were determined to be 'recent'²³ and 'non-recent' depending on the *post mortem* examination findings.

Shot were judged to be 'recent' when they were:

1. found at the site of fractured bones (ensuring that these are fractures that occurred at the time of death and not those caused thereafter) or within the bones themselves;
2. present within vital organs such as heart and lungs;
3. present within large areas of haemorrhage and bruising showing that they entered the bird at, or very shortly before, the time of death and the bird would have been unable to fly far with the damage inflicted;
4. present at the end of shot tracks containing feathers that had not been 'walled off' by the body in any way showing that they had recently occurred;
5. found at the back of the bird (or opposite side of entry) having been tracked through the rest of the body including vital organs.

²² The law in Wales is analogous to that of England however in Scotland there are restrictions on use of lead over all wetlands and as mallards are predominantly birds of wetlands, if the law is adhered to in Scotland, one would expect the majority of ducks shot there to be shot with non-lead ammunition.

²³ The word 'recent' was decided on during the Defra-funded compliance study (Cromie *et al.* 2010) and means entered bird at or shortly before time of death. The word 'lethal' could be used instead (accepting that not all shot entering the duck's body are necessarily lethal if they do not cause significant injury e.g. a shot breaking a wing bone is not in itself lethal although it results in the death of the bird).

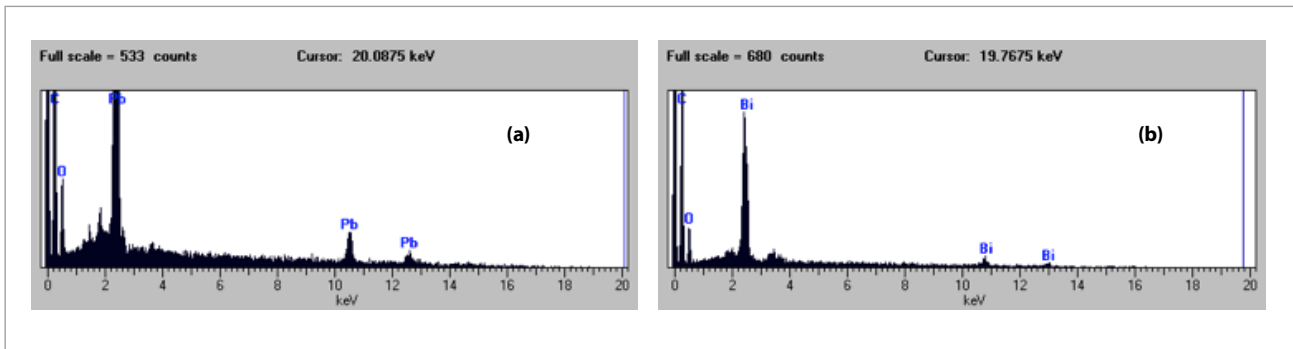


Figure S2: The 'X-ray output' from scanning electron microscopy showing both a shot originally classified as 'lead with inconsistencies' (a) and a bismuth sample (b). The peaks indicate the shot to contain oxygen (O), carbon (C) and lead (Pb) (a) or bismuth (Bi) (b), peak height illustrating relative abundance.

Shot were judged to be 'non-recent' when they:

1. had been 'walled off' by the body showing they have been present for some time;
2. showed no sign of bruising or haemorrhage around them;
3. were found in non-vital areas such as loose in the coelomic cavity (accepting that they may or may not have been 'recent' but were likely to be non-lethal).

SHOT ANALYSIS

Shot type was identified using the methodology employed during the Defra-funded compliance study²⁴. In brief, these were based on their physical, chemical and additionally atomic properties *i.e.* aspects of appearance and malleability, ferromagnetic properties, reaction to nitric acid and potassium iodide, and, for a sub-set of shot (32/109), including those for which there were some inconsistencies in other methods²⁵, examination under scanning electron microscope which produces definitive characteristic X-ray "profile" of the elements present²⁶. These techniques readily identify steel, bismuth and lead, and distinguish them from each other. From a brief review of types of shot available on the market, lead, bismuth, steel and tungsten matrix shot types were used as positive controls throughout the analyses. Provisional diagnosis of shot type was made using results of appearance, malleability and ferromagnetism. Results of chemical analyses and scanning electron microscopy were considered conclusive.

FURTHER RESULTS OF THE 2013/14 GAME DEALER STUDY

Of 159 ducks purchased from 32 game dealer outlets, 109 contained recent shot. Overall, 77% of these 109 ducks had been shot with lead. Bismuth was the most commonly used non-toxic shot (15%) followed by steel (7%). Figure S2 illustrates the outputs of a lead and bismuth sample from scanning electron microscopy.

Table S1 summaries the numbers of birds purchased regionally, the number containing recent shot and the proportion of these that had been shot with different shot types.

²⁴ Melting point was omitted as it was extremely onerous and time consuming, difficult to measure and provided no additional confidence to the results.

²⁵ Five of the lead samples (including one copper coated lead shot) had slight inconsistencies *e.g.* not looking obviously like lead in all characteristic or the precipitate changing colour during the chemical analysis. Two samples, which were ultimately non-lead, had been described as "unsure" prior to scanning electron microscopy analysis. ²⁶ A high energy beam of electrons scans the sample surface and interacts with the sample atoms to produce characteristic x-rays which identify the elemental composition, the areas under each peak provides a measure of relative abundance of elements in the sample.

Table S1: **Proportion of birds shot with lead and other shot types according to region purchased**, including, for information only, birds with non-recent shot and birds containing no shot (as 'oven ready').

Government Office Region	Recent shot						Non-recent shot		No shot	Total purchased
	Lead	Bismuth	Steel	Tungsten	Total	% lead	Lead	Bismuth		
East	9	6	1		16	56		1	8	25
East Midlands	11	2			13	85			1	14
North East	9	7	1		17	53			5	22
North West	15		3		18	83	1		7	26
South East	6	1	3		10	60	1		11	22
South West	9				9	100	1		4	14
West Midlands	11				11	100			3	14
Yorkshire & Humber	14			1	15	93			7	22
Total	84	16	8	1	109	77	3	1	46	159



Driven game shooting is big business in the UK and a perception of threat to this represents a barrier to transition to non-toxic ammunition.

Photo Credit: Gail Johnson/Shutterstock.com