Comparison of the lethality of lead and copper bullets in deer control operations to reduce incidental lead poisoning; field trials in England and Scotland

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SUMMARY

Legislative controls on the use of lead gunshot over wetland areas have been introduced in many countries, including the UK, in order to reduce lead poisoning in waterfowl following ingestion of spent shot. Effective alternatives to lead shot are widely available. However, there is evidence that the problem also affects wildlife in terrestrial ecosystems and that lead bullets are a source of contamination for scavenging birds and mammals. With this in mind, copper bullets were trialled at three varied UK sites during deer control operations undertaken to achieve nature conservation objectives. Their accuracy and killing power were recorded and compared to that of traditional lead bullets. No significant differences were found in accuracy or killing power. These results, coupled with experience elsewhere, suggest that copper bullets are a viable alternative to lead bullets. If this is confirmed in all situations, we consider further restrictions on the use of lead ammunition, designed to encourage a switch to non-toxic ammunition across terrestrial habitats, to be a proportionate response to the problems associated with lead ingestion.

BACKGROUND

The toxic effects of lead to living organisms are well known, and have led to regulations designed to minimise exposure to humans, for example by removing lead from petrol and paint products. Lead poisoning has been well documented in waterbirds across the globe (e.g. Pain 1992). In many countries, this has led to legislation banning the use of lead shot over wetlands. The use of lead shot to shoot certain species of waterfowl and the use of lead shot below the high water mark or over wetland Sites of Special Scientific Interest (SSSIs) identified for their national or international importance for waterfowl was banned in England in 1999 and in Wales in 2001. Use of lead shot over 'wetlands' was banned in Scotland in 2004 and in Northern Ireland in 2009. Although this may have caused some reduction in lead entering ecosystems via this route, compliance is believed to be poor, at least in some areas (Cromie *et al.* 2002). A global review of legislation controlling the use of lead ammunitions can be found in Avery and Watson (2009).

Recent research indicates that fragments from traditional copper-encased lead bullets and lead shot fragments in the carcasses of animals killed by hunters and pest controllers away from wetlands may be a larger hazard to wildlife than was previously thought (Pain *et al.* 2007). Furthermore, birds such as partridges and pheasants ingest spent shot from terrestrial systems (Potts 2005). At least 63 bird species have been documented to have ingested lead or suffered lead poisoning from ammunition sources, including 10 Globally Threatened or Near Threatened Species (Pain *et al.* 2009).

One of the main groups to be affected, principally through accidental ingestion of shot or bullet fragments in unretrieved game, is raptors (Miller *et al.* 2002). For example, in the Utah desert (USA), bald eagles *Haliaeetus leucocephalus* feeding on jack rabbits *Lepus* sp. may frequently ingest shot, with 71% of regurgitated pellets containing one or more pieces of shot (Platt 1976). Golden eagles *Aquila chrysaetos* have been found with lead toxicosis in the European Alps (Kenntner *et al*. 2007) and Spain, where one bird had 40 pellets in its proventriculus (Cerradelo *et al.* 1992). In Germany lead intoxication has been identified as the major cause of death in white-tailed eagles *Haliaeetus albicilla*, with 25% of carcasses examined having died because of lead toxicosis; lead from both shot and bullet fragments was implicated (Krone *et al.* 2003). Lead poisoning from ammunition is considered to be the single most important cause of mortality in this population (Krone 2009).

It was previously thought that the majority of bullets stayed in a single mass or as large fragments in a carcass, and could be easily avoided by scavenging birds. However, recent radiographic studies in the USA have shown that small bullet fragments existed up to 15 cm from the main wound channel in tissues of deer shot with lead bullets (Hunt *et al.* 2006). Ninety percent (n=20) of the deer carcasses examined contained bullet fragments which were mostly small (<2mm) and numerous (mean 160 per carcass). This suggests the probability of accidental ingestion of bullet fragments by scavengers is significantly greater than previously thought. As offal piles (grallochs in Scotland) are also traditionally left close to the site of the kill by deer hunters in the UK, these findings are clearly relevant to the UK situation.

As obligate scavengers, vultures are vulnerable to the ingestion of lead shot and bullet fragments. Examples include Eurasian griffon vultures *Gyps fulvus* poisoned in Spain (Mateo *et al*. 2003) and turkey vultures *Cathartes aura* in Canada exhibiting bone lead levels indicative of elevated lifetime exposure, most likely as a result of scavenging hunter-shot carcasses (Martin *et al.* 2003). Reintroduced populations of the Critically Endangered California condor *Gymnogyps californianus* suffer markedly from lead toxicosis. Lead poisoning remains the leading cause of death among free-ranging birds, having caused 60% of deaths in the last five years (Watson, 2009). Ammunition residues in rifle- and shotgun-killed animals are the principal source of this contamination (Parish *et al*. 2009, Chesley *et al*. 2009). In the absence of current intensive efforts to treat birds in order to reduce lead-induced mortality, levels of exposure to lead from fragments of spent ammunition are incompatible with the establishment of a self-sustaining condor population in Arizona and Utah (Green *et al*. 2009).

Although differences exist between the North American and UK situations, there appears to be sufficient similarity to suggest these results are broadly transferable, especially as several species of UK conservation concern have been recorded as suffering from lead poisoning. Of these, four are red-listed and therefore of highest concern (grey partridge *Perdix perdix*, herring gull *Larus argentatus*, white-tailed eagle and hen harrier *Circus cyaneus*), while a further four are amber-listed and of medium concern (red kite *Milvus milvus*, western marsh-harrier *Circus aeruginosus*, honey buzzard *Pernis apivorus* and golden eagle) (Eaton *et al*. 2009). Clearly, any mortality that can be avoided for these species is of key conservation importance.

As already highlighted, lead is also poisonous to humans. Injurious effects of lead on humans are numerous and can be caused by sustained low levels of exposure. For example, there is evidence of permanent adverse effects of lead on cognitive function in children with blood lead levels below 10 μg dL-1 (Canfield *et al*. 2003). Exposure of humans to lead occurs by several routes including dietary exposure. Meat from game animals shot using lead ammunition is a potential source.

Many of the small lead fragments found in shot game are sufficiently small and distant from obviously injured tissue that professional butchers do not remove them when trimming venison for human consumption. A recent study found 80% of 30 deer shot with lead bullets (each processed by a different butcher) gave rise to at least one 0.9 kg package of minced venison containing one or more lead fragments; 34% of all venison packages produced from these deer contained fragments (Hunt *et al*. 2009). Similar bullet fragment contamination of red deer *Cervus elaphus* and wild boar *Sus scrofa* meat has been reported from Poland (Dobrowolska & Melosik 2008).

Recent studies have also raised concerns about lead contamination of the meat of game animals killed using lead shot and of gamebirds which had ingested spent lead shot. Breast muscle tissue from some seabirds killed for food using lead shot in Greenland was sufficiently high for sustained consumption to be potentially hazardous to human health, even though all visible shot were removed from the tissues before analysis (Johansen *et al*. 2004). Presumably this arises because of the presence of small fragments which are difficult to see. It has also been shown that the southern European practice of marinading game meat in vinegar increases the concentration of lead in the edible tissues, when lead pellets are present (Mateo *et al.* 2006).

Adult Inuit people in arctic Canada showed elevation of blood lead levels, the degree of which was positively correlated with the quantity of hunted waterfowl in the diet (Dewailly *et al*. 2001). Analysis of stable isotope ratios of lead in blood samples indicates that exposure to ammunition is the main cause of elevated blood lead in indigenous people in Canada (Tsuji *et al*. 2008).

Waterfowl are not the only game species for which contamination from lead shot is a potential hazard. Liver lead levels in 40% of a sample of Canadian birds of several widely hunted non-waterfowl species (wild turkey *Meleagris galloparvo*, ring-necked pheasant *Phasianus colchicus*, grey partridge *Perdix perdix*) exceeded health guidelines (Kreager *et al*. 2008). The main source of lead in these species is thought to be spent lead shot ingested by the birds, having been mistakenly identified as grit.

With this increasing evidence of negative effects on both wildlife and humans from consumption of game species shot with lead ammunition, there is a need for more testing of alternatives. Adequate alternatives to lead shot (primarily steel) have been developed for use over wetlands where lead shot has been regulated against. These types of shot should also be effective for the shooting of gamebirds and pigeons. However less is known, at least in a UK context, about the efficacy of alternatives to lead bullets. Non-toxic alternatives to lead bullets exist, with copper being the most widely used. In the USA, schemes to discourage the use of lead ammunition have resulted in excellent uptake of copper bullets as an alternative, both in Arizona (where a voluntary approach was used) and California (where a regulatory approach was taken) (Hill 2009). In Arizona and Utah, modelling indicates that extension of the existing voluntary scheme for the replacement of lead bullets by copper would be sufficient to allow the re-introduced population of California condors to become self-sustaining (Green *et al*. 2009). More recently, the US National Parks have announced a total ban on the use of lead ammunition, precipitating a switch to copper bullets.

The RSPB prefers to use habitat management and non-lethal techniques to reduce the impact of vertebrates on nature conservation objectives. However, in a small number of cases, where these methods are not practicable and where a major problem exists, vertebrate control may be required. Deer control operations are therefore carried out on a small number of the RSPB's nature reserves, where high numbers are causing detrimental impacts to habitats of conservation importance or the specialist species which depend on them. Lead bullets are currently used in these operations. It was decided to trial copper bullets on several reserves in order to test their efficacy compared to traditional lead alternatives.

ACTION

Initial investigations were made into the legality, toxicity, cost, availability and safety of using copper bullets, prior to lethality being tested:

Legality: Use of copper bullets is legal across the UK providing they have a hollow or soft point, designed to ensure the bullets deform in a predictable manner on impact.

Toxicity: Metallic copper is not toxic if ingested, so any fragments of copper bullets remaining in, for example, deer carcasses, do not pose a threat to wildlife or humans. 98.5% of copper ingested is excreted, so minimal build up is possible in living organisms (Kenntner 2009). In large quantities copper can be toxic to trees, but the quantity contained in a stray bullet would be not be sufficient to cause damage. Copper bullets therefore pose no secondary poisoning risk to wildlife, humans or the wider environment.

Safety: Some practitioners have expressed concerns that, because copper bullets do not fragment as much as lead bullets on impact, the risk of ricochet will be greater, particularly if the target is missed. These concerns have led to a moratorium on the use of copper bullets in Germany. While this concern is valid, the German decision was based on a single incident, where there is at least the suggestion that health and safety precautions were poorly observed. In practice, any bullet can ricochet under certain conditions and, while it has not been quantified, the increased risk of ricochet from copper bullets appears small and managing that risk should not significantly affect operations. The available evidence shows no increase in reports of accidents caused by ricochet in areas where copper bullets have been widely distributed and used. In a study carried out by the German Research Centre for Environmental Policy (FFU) of hunter attitudes to copper bullets, where 89% of hunters were aware of the relative merits of copper and lead bullets, only 1.3% of respondents mentioned safety concerns (Schuck-Wersig 2009). We are also not aware of any evidence of safety concerns in California or Arizona. Practitioners involved in our trial were made aware of the potentially slightly greater ricochet risk, and lines and angles of fire were set accordingly. Although a small number of shooting points were not used for this reason, overall operations were not significantly affected. In practice, as long as practitioners pay particular attention to health and safety guidelines, there appears to be no additional safety risk associated with the use of copper bullets.

Availability: An increasingly wide range of copper bullets is available from manufacturers' websites and most UK ammunition dealers, although availability in smaller calibres such as .243 is more limited. However, remaining gaps in UK supply are being rapidly filled. For example, at the start of our trial, no .22 calibre copper bullets were readily available. There are now at least two options. Copper bullets are currently available in almost all relevant calibres, and it is predicted that any remaining gaps in supply will be rapidly met.

Cost: On average, copper bullets are currently more expensive than traditional lead bullets, but not prohibitively so. As of July 2009, lead bullets cost approximately £115+VAT for a box of 100, while the copper bullets used in our trial cost £170+VAT for the same number. However, online retailers in the US sell boxes of 50 copper bullets for $34.64, with an equivalent box of lead bullets costing $36.95. The difference currently seen in prices in the UK is likely to be due simply to lower demand for copper bullets. Further, this differential is likely to decrease as more UK suppliers begin to stock copper bullets.

Lethality: Between August 2008 and March 2009, experienced stalkers involved in deer control at two RSPB reserves, one in Scotland and one in the south of England, were asked to rate standard lead bullets, recording accuracy and outcome on a scale of one to five. For 'accuracy', a score of 1 was assigned if the intended part of the animal was hit precisely, while a score of 5 represented a miss. For 'outcome', a measure of killing power, the following classification was used:

1 = animal killed cleanly;
2 = animal killed but ran a short distance;
3 = animal mortally wounded but had to be searched for;
4 = animal required a coup de grace;
5 = animal wounded and had to be followed up or not found.

These two components (accuracy and killing power) are the two main bullet factors in determining the lethality of a shot. The rifleman, calibre, bullet make, bullet weight, target species and approximate range were also recorded for each shot taken.

The same stalkers then used copper bullets of equivalent calibre and recorded all variables in the same way. In addition, they recorded a subjective 'comparison' score of satisfaction with performance compared to traditional lead bullets on a scale of one to five, where 1 was 'very satisfied' and 5 was 'not satisfied'. A third RSPB reserve, also in Scotland, also trialled a small number of copper bullets. The deer target species, calibres, bullet types, weights and ranges at each site are summarised in Table 1.

CONSEQUENCES

At Scotland 1, red deer and roe deer *Capreolus capreolus* were shot with lead or copper bullets to compare their accuracy and killing power. Of 34 deer shot with lead bullets, 27 (79%) were assessed as having been killed cleanly, with seven (21%) recorded as having run a short distance before dying. All but one of the shots (n=33, 97%) were considered to be highly accurate. Of 62 deer shot with copper bullets, 48 (77%) were assessed as having been killed cleanly, with 12 (19%) recorded as having run a short distance before dying and two (3%) being mortally wounded but having run further and needed to be searched for. All but three (n=59, 95%) of the shots were placed in the highest category of accuracy. All but two (n=60, 97%) of the shots taken were scored as 'very satisfied' on the subjective scale, in comparison to lead bullets.

Table 1. Bullet types, weights and calibres, deer target species and range at each of the three RSPB reserves involved in trial, 2008-2009.

Site	Lead bullet type	Copper bullet type	Calibre	Target species	Max. range (m)	Min. range (m	Ave. range (m)
Scotland 1	Norma, 130 grain (n=34)	Barnes Federal Vital Shok, 130 grain (n=59)	.270 (n=93)	Red deer (n=38) Roe deer (n=55)	200	35	107
South England	Nosler BT, 95 grain (n=17); Norma, 130 grain (n=3)	Barnes Federal TSX (n=32)	.243 (n=49); .308 (n=3)	Sika deer (n=52)	130	20	82
Scotland 2	not reported	Barnes, 130 grain (n=5)	.270 (n=5)	Red deer (n=5)	130	130	130

Five red deer were shot with copper bullets at Scotland 2, using Barnes TSX bullets and the normal .270 calibre rifle. All shots taken were considered highly accurate. The stalker involved suggested results were comparable to those found with lead bullets, although no formal comparison was carried out.

At the southern English site, sika deer *Cervus nippon* were shot with either lead or copper bullets. All shots taken with both bullet types (n=20 for lead, n=32 for copper) were considered highly accurate. Of 20 deer shot with lead bullets, 15 (75%) were killed cleanly, while the remainder ran a short distance. Of the 32 deer shot with copper bullets, 26 (81%) were killed cleanly, one (3%) ran a short distance before dying, two (6%) were mortally wounded but had to be searched for, one (3%) required a ‘coup de grace’ and two (6%) were wounded, but had to be followed up. The five deer that had to be searched for, followed up, or required a coup de grace were all shot in the chest. Although this ‘heart and lung’ shot placement is recommended by the British Association for Shooting and Conservation (BASC) for deer under most conditions, local factors can make alternative shot placements the best option. At this site, head shots are the preferred practice, due to the nature of the site. The initial problems are believed to be a result of copper bullets not expanding as much as lead bullets of the same calibre. This led to a greater risk of the bullet passing straight through the body of the deer and not causing sufficient damage to kill the animal instantly. Such problems may be addressed either by using more recently developed Barnes MRX bullets, specifically designed to expand more than the bullets used in our trial, or by using a larger calibre weapon. Having reverted to taking head shots, all deer shot with copper bullets were killed cleanly (n=23).

When all shots were combined across sites, the mean accuracy score was 1.04 for lead bullets and 1.04 for copper bullets, while the mean outcome score was 1.22 for lead bullets and 1.38 for copper bullets. However, when ‘heart and lung’ shots at the southern English site were excluded (as these are not the normal practice at the site), the mean outcome score across sites improved to 1.22 for copper bullets and 1.13 for lead bullets (Fig. 2). Mean accuracy was not affected by excluding these shots. The mean comparison score was 1.05, indicating a high degree of satisfaction with the copper bullets’ performance compared to that of traditional lead bullets.

Discussion: The results of this trial suggest that there is no difference in the accuracy of copper and lead bullets. Furthermore, it suggests that differences in killing power between the two are small, especially when normal practice is followed. Using newly available copper bullets designed to expand to a greater degree than the bullets used in our trial may further erode this difference.

These conclusions should be treated as indicative rather than definitive. The number of stalkers involved was small and some desirable aspects of experimental design, such as blinding of the stalkers to the type of ammunition, were not practical.

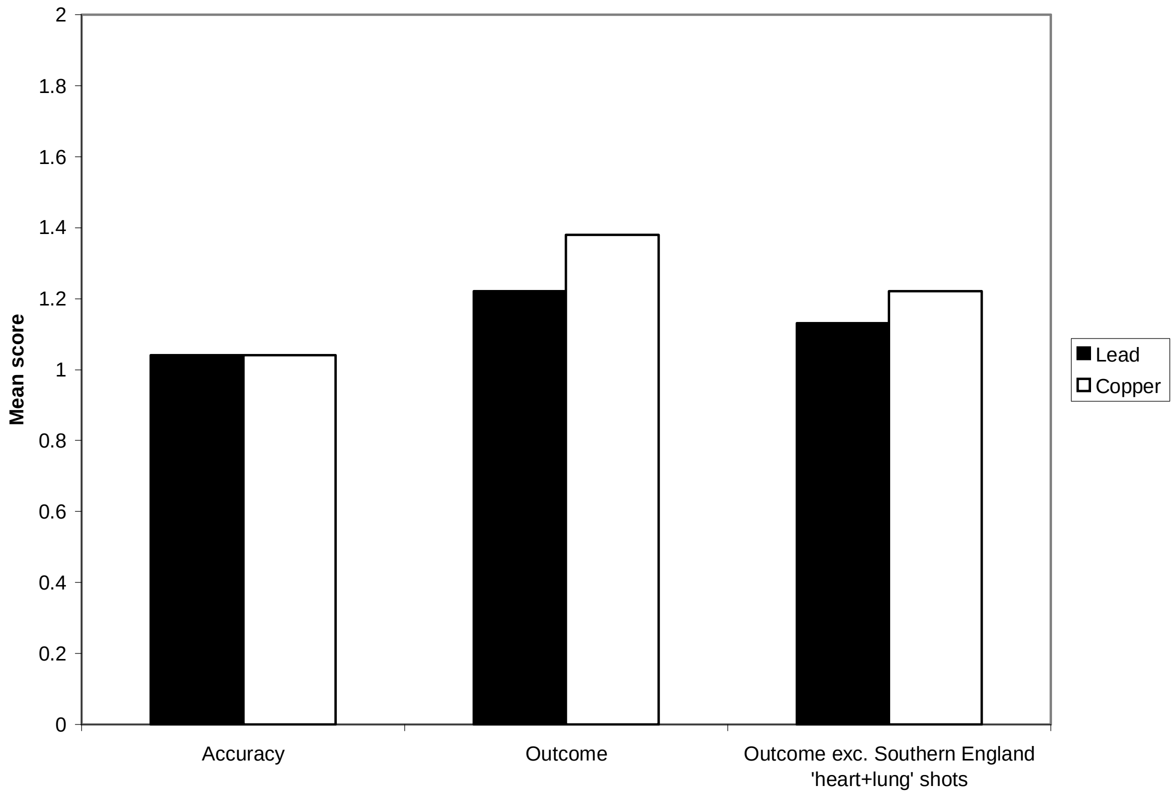

Figure 2. Mean accuracy and outcome scores for all shots across sites. High values represent lower accuracy or outcome (=killing power). Outcome scores are presented with and without the 'heart and lung' targeted shots from southern English site excluded, as these are not normal practice at this site (this exclusion does not affect accuracy scores).

Results from other studies support the conclusions reached in our trial. A recent study carried out in Germany, using various calibres and makes of copper bullet, (Spicher 2009) found 95% of animals (n=260) were killed with a single shot. 48% of animals did not run and the average distance managed by those that did was only 14 m. Of the 12 hunters in the survey, eight (66%) were satisfied that copper bullets were as suitable as traditional lead bullets, and four (33%) considered that the copper bullets performed better. Only one individual was not satisfied that copper bullets performed as well as lead alternatives.

A separate study into the attitudes of German hunters to copper bullets found 27% had no reservations about switching to copper bullets and 67% were prepared to switch, after taking into account all available evidence and experience (Schuck-Wersig 2009).

Given the apparent effectiveness of copper bullets, and their general acceptability to those stalkers whose opinions have been canvassed, the only short-term barrier to widespread use of non-toxic bullets for deer control is likely to be cost. Further work is needed to ensure efficacy of non-toxic bullets for other forms of vertebrate management and under different environmental conditions. If this is confirmed in all situations, we consider further restrictions on the use of lead ammunition, designed to encourage a switch to non-toxic ammunition across all terrestrial habitats, to be a proportionate response to the problems associated with lead ingestion.

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