Background Document to the Agency Opinion on the Proposal for a Restriction

Substance name(s): Lead

IUPAC names(s): Lead

EC NUMBER(S): 231-100-4

CAS NUMBER(S): 7439-92-1

AGENCY for UK REACH:

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PROPOSAL FOR A RESTRICTION

Definitions used in the proposal

This dossier covers the use of lead projectiles as used in shotguns, firearms and airguns, all of which are as defined in the Firearms Act 1968.

The definitions of some of the common terms in this dossier are given below.

Accuracy	The ability of a weapon system to place the Mean Point of Impact (MPI) of a series of bullets / projectiles on a given aiming point.
Action	The mechanism by which a shot gun or rifle is loaded or unloaded, examples include: break-action, where the barrels are hinged in front of the trigger/ firing mechanism to expose the breech and allow loading and unloading of cartridges; and bolt-action, where a rotating bolt (comprising a metal breech-block incorporating the firing pin and extractor, and handle) is manipulated to expose the breech to allow loading and unloading.
[Gun] Barrel	A barrel is the metal tube that the projectile travels through as a result of pressure from burning gunpowder, compressed air, or other like means. The barrel also guides the projectile in the intended direction.
Backstop	A barrier behind the target capable of stopping a projectile / shot. It may be formal as in a stop-butt, or informal such as the ground, or a sufficient area of land that there is no risk of hitting an unintended target.
Bore or gauge	Bore relates to a unit of measurement used to express the inner diameter (bore diameter) of the barrel and is equivalent to the number of solid spheres of lead that will fit the bore of the firearm required to make up one pound of lead, i.e., 12-bore is equivalent to 12 x 1/12 lb lead spheres. Bore is the more common GB terminology.
Breech	The rear end of the barrel and position of loading in the case of breech-loading firearms, as opposed to muzzle-loaders which are loaded from the front (muzzle) end of the barrel.

Bullet / round	A projectile and component of ammunition fired from a gun.
Calibre	Is the measurement of the interior (the bore) of a gun's barrel and the diameter of bullet ammunition used expressed in inches or millimetres.
Cartridge	A precision made container (typically metal or plastic) comprising projectile(s), propellant and primer, designed to fit into the chamber of a breech loading firearm.
Centrefire	A metallic cartridge cased bullet, where the primer is a metal cup containing the primer compound inserted into the centre of the base of the cartridge, which on firing ignites the main propellant charge.
Chamber	The cavity at the rear of a breech loader's barrel into which the cartridge is inserted; the rear opening of the chamber is the breach.
Choke	A minute tapered constriction of the last few inches of the muzzle end of a gun barrel; typically found in shotguns, but also on some rifles, pistols and airguns. The constriction serves to shape the pattern of the shot to improve shot density, range and accuracy. Chokes may be 'fixed' or screw-in.
Choking	Referring to the amount / thickness of barrel choke in place. For example full-choke (0.040 inches) or half-choke (0.02 inches).
Clay pigeon shooting	The use of a shot gun to shoot at targets fired into the air to imitate shooting at live quarry.
Consistency	The degree of dispersion of a series of bullets / projectiles about the Mean Point of Impact.

Firearm	The Firearms Act 1968 Section 57(1B), uses the definition of a firearm as a "lethal barrelled weapon" as a "barrelled weapon of any description from which a shot, bullet or other missile, with kinetic energy of more than one joule as measured at the muzzle of the weapon, can be discharged". As such it can mean shotguns, rifles, pistols, airguns etc.
Full-bore target rifle	A rifle firearm with a larger diameter bore, generally chambered for 7.62 x 51 mm NATO or .308 inch Win centrefire cartridges.
Group / grouping	The collective pattern of impacts on a target from successive shots in a single shooting session from rifles, pistols or airguns, for example firing five bullets at the same target. The tightness of the group (i.e., how close together the impacts are to each other on the target) is an indication of the precision of the weapon and the skill of the shooter. The distance from the centre of the group to the intended point of aim (usually the centre of the target) is a measure of accuracy.
Indoor	Inside a building
Large Game, large	Quarry species that are relatively large. For example: deer, wild boar, etc.
Live quarry shooting	The use of a weapon to shoot at a living target. In the UKGB, this term is more commonly used than ‘hunting’.
Muzzle loader	Any firearm which is loaded from the muzzle end.
Outdoor	All uses that do not occur inside a building.

Pellet	Small spherical or 'tube' shaped projectile. Typically comprising shot or airgun ammunition.
Precision	The ability to place a bullet / projectile on the point of aim.
Primer	A chemical compound that ignites the propellant (e.g. gunpowder) when struck by a firing pin. Primer may be placed either in the rim of the case (rimfire) or in the centre of the base of the case (centrefire).
Projectile(s)	Object(s) expelled from the barrel of a gun. Examples of relevant types of projectiles are bullets, gunshot, shotgun 'slugs', air gun pellets and BBs.
Raptors (predatory or scavenging)	Predatory birds (birds of prey) that have keen vision, powerful talons with claws and strong curved beaks, including owls. These birds can also scavenge carrion, either occasionally or as their main food source.
Rifle	Firearm incorporating a barrel marked with spiralling grooves causing the bullet to spin to improve the bullet's range and accuracy.
Rimfire	A metallic cartridge cased bullet, where the primer is located within a circumferential rim protruding from the base of the cartridge case. When firing, the firing pin will strike the rim (hence rimfire), sparking the primer compound within the rim, and igniting the main propellant charge
Scavenging birds (non-raptor)	Other bird species that typically scavenge carrion, e.g. vultures, corvids, gulls.
Shot	A mass of small spherical projectiles. In breech-loading shotguns these are usually contained in a cartridge. For muzzle-loading shotguns the shot is poured loose into the barrel from the muzzle end.

Side-by-side	A double-barrelled shotgun where both barrels are placed horizontally beside each other, as opposed to 'over-and-under' where the barrels are placed one above the other.
Small game, small	Quarry species that are relatively small. For example: ducks, pheasants, partridges, hares, squirrels, rabbits, foxes, etc.
Smallbore target rifle	A rifle firearm with a narrow bore, generally .22 inch calibre (5.6 mm bore) rimfire chambered for cartridges such as the .22 Short, .22 Long, or .22 Long Rifle cartridges.
Stop butt	Engineered bank, berm, wall or other device, behind and around the target on a shooting range, intended to stop all misdirected shots that may reasonably be expected to be fired.
Target shooting	The use of a weapon to shoot at an inanimate (non-living) target. Includes practice, or other shooting, performed in preparation for 'hunting'. Examples of relevant types of targets are 'clay pigeons', paper targets, biathlon targets, silhouettes, etc.
Waterbird	Used in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) to refer to birds that are ecologically dependent on wetlands for at least part of their annual cycle. This definition includes many species of divers, grebes, pelicans, cormorants, herons, storks, rails, ibises, spoonbills, flamingos, ducks, swans, geese, cranes, waders, gulls, terns and auks.
Waterfowl	Typically species from the avian family Anatidae, i.e. ducks, geese and swans. These birds are adapted for surface water swimming (i.e. having webbed feet and oily feathers). However, a broader interpretation to include other waterbirds (e.g. Common Snipe) that are hunted is not uncommon. Hunted waterfowl and waterbirds can be referred to as game waterfowl.
Welfare	The physical and mental state of an animal in relation to its environment. Welfare can be considered in terms of whether an animal is suitably fed and housed, in good health and exhibiting normal behaviours.

Wildfowl	Principally associated with the hunting of waterfowl, although can refer to any hunted (game) bird, such as waders, grouse, pheasants, or partridges.
Wildfowling	The hunting of wildfowl, particularly ducks, geese and waders.

1 Introduction

Lead has been used in ammunition for live quarry and target shooting for centuries. The Department for Environment, Food and Rural Affairs (Defra) Secretary of State, with the agreement of the Scottish Government and the Welsh Government, asked the Agency under Article 69(1) of UK REACH to prepare an Annex 15 restriction dossier for lead ammunition on the basis '*that the use of lead in ammunition raises concerns related to both human health and the environment. The harm of lead ammunition to wildfowl is of particular concern – poisoning from ingesting lead ammunition causes long-term suffering and slow painful deaths for animals. The health of humans, particularly children, may also be adversely affected from eating meat killed using lead ammunition*.'

In GB, each of the devolved administrations has already enacted a ban on the use of lead shot over wetlands in response to the African-Eurasian Waterbird Agreement (AEWA, 1999). These bans were introduced between 1999 and 2004 with the aim of protecting waterbirds from the impact of lead poisoning.

The English and Welsh regulations are similar and use of lead shot is prohibited:

- on or over any area below the high-water mark;
- on or over certain Sites of Special Scientific Interest;
- for the shooting of ducks, geese or swans of any species, coots or moorhens on or over both wetlands and terrestrial habitats.

In Scotland, the use of lead shot is prohibited on or over all wetland areas (but excluding peatlands with no visible water) but the ban does not extend to waterfowl outside of wetlands. Compliance with these regulations is not monitored, but is thought to be low based on data from England investigating ammunition types used to kill ducks.

There is currently a ban on the use of lead shot in wetlands in Northern Ireland in response to the AEWA agreement. Under the Northern Ireland Protocol, EU REACH continues to regulate the access of chemicals to the Northern Ireland market. The EU restriction of the use of lead shot in wetlands comes into force on 15th February 2023 and will apply in Northern Ireland[1].

1.1 Scope

[1] UK REACH entered into force on 31st December 2020 at the end of the transition period. It regulates the access of chemicals to the GB market. Under the Northern Ireland Protocol, EU REACH continues to regulate the access of chemicals to the Northern Ireland market.

1.1.1 Concerns to be addressed:

The Defra request relates to considering the risks posed by the use of lead in ammunition, and the potential need for further risk management measures beyond those already in place. Further clarification received from Defra confirmed that lead-containing propellants are not within scope. The focus of this Background Document is on civilian use of ammunition only; police and military use are outside the scope defined by Defra.

In 2010 the Lead Ammunition Group (LAG) was set up by Defra and the Food Standards Agency (FSA) to evaluate the published scientific evidence of the impact (in England only) of lead ammunition on human health, wildlife and the environment generally and on livestock and to propose possible mitigation for the risks identified. The group members included key stakeholders and experts from the gun and ammunition trade, game dealers, landowners, animal welfare and conservation organisations, human health and environmental health and sports shooting organisations. In its 2015 report (LAG, 2015a), the LAG concluded that an eventual phase-out of lead ammunition would be the only effective way to address the risks to wildlife and human health. Prior to the finalisation of its work, members representing the Gun Trade Association, the Game and Wildlife Conservation Trust, The National Game Dealers Association, the Country Land and Business Association and the Countryside Alliance left LAG as they did not support the conclusions reached in the final report (Countryside Alliance, (2016)). LAG (2015a) and the subsequent update (LAG, 2018) identified concerns for both wildlife and human health from the use of lead in ammunition:

a) There is a risk to human health through consumption of game, with the highest levels of lead being in game birds, although the highest risk is to those that consume the highest quantities of game. Potential adverse effects on the health of high-level consumers include reduced intelligence and cognitive function of children, increased risk of spontaneous abortion in pregnant women and cardiovascular effects and chronic kidney disease in adults.

b) There is a present but low risk to human health from consumption of grazing livestock or foraging birds such as ducks and pheasants that have fed on land contaminated with lead ammunition.

c) There is a risk to wildlife either by direct ingestion of the ammunition or by scavenging contaminated carcasses.

d) There are likely subclinical effects on wildlife, with some impacts recorded in wildfowl and some other water birds.

e) There is the potential for exposure of wildlife to lead to impacts on population size.

The risks identified to both humans and wildlife are primarily associated with the ingestion of lead. These risks do not arise as a result of indoor use of lead ammunition (e.g. at fully enclosed indoor shooting ranges). Therefore, the scope of this Background Document addresses both the risks to human health and wildlife from the placing on the market and use of lead ammunition for civilian outdoor activities.

1.1.2 Key information sources

Throughout this dossier the Agency has extensively referenced the work done by LAG but also that of ECHA on their wetlands restriction and proposed total lead ammunition (and fishing weights) restrictions (LAG, 2015a, 2018; ECHA, 2022a, 2022b, 2017a, 2017b). Since the UK was a member of the EU at the time that the wetlands restriction was proposed and the technical documents to support the proposal were drafted, information in the EU dossier includes data from the UK (and therefore GB). Data which have been assessed by ECHA and/or LAG as reliable are considered to be of a sufficient standard for inclusion without duplicative detailed review and analysis by the Agency. Data from GB have been used when available, with data for the UK, Europe or elsewhere used to add supporting information or to fill data gaps.

The Agency held a call for evidence from August to October 2021, the questions of which are in Annex E, to gather additional GB specific information. A public consultation on the initial restriction proposal ran from May to November 2022, the questions of which are in Annex F. Stakeholder meetings were also held with key groups, more information on these can be found in the final opinion. The information supplied has been used throughout this dossier and referenced to the organisation who supplied it. Information was received from a range of stakeholders, including organisations representing the shooting and animal welfare industries, academics and a number of individuals. Where information is referenced directly from the public consultation the organisation or individual is referenced by the number allocated to them during the collation of the consultation comments, which can be found in the published public consultation documents.

1.2 Substance identity and physico-chemical properties

1.2.1 Substance identification

This dossier concerns the use of zero-valent ‘elemental’ metallic lead or lead alloys used as projectiles. Generally metallic lead is used for projectiles, though lead alloys can also be used. The alloys used in gunshot (lead concentration >90 % by weight) typically contain variable proportions of antimony (up to approximately 6 % by weight) and arsenic (up to approximately 1.5 % by weight) to produce specific properties in the lead shot, such as hardness and roundness (ECHA, 2017b).

Table 1.1 Identification of lead

Identifier	
EC Number	231-100-4
EC name	Lead
CAS number	7439-92-1
Molecular formula	Pb
Molecular weight	207.2

1.2.2 Physical chemical properties

The key physicochemical properties of lead that are relevant for this assessment are summarised in Table 1.2 based on information from the ECHA dissemination website (ECHA, 2021a).

Table 1.2 Physicochemical properties of lead

Property	**Result**
Physical state at 20 °C and 1013 hPa	Lead is available on the market as a solid in both powder and massive forms.
Melting point	326 °C at 1013 hPa (study result, EU A.1 method).
Relative density	11.45 (study result, EU A.3 method).
Vapour pressure	Lead metal is stated to have a vapour pressure of 133 Pa at a temperature of 1,000 °C. It has a negligible vapour pressure at 20 °C.
Water solubility	185 mg/L at 20 °C (study result, EU A.6 method). Water solubility varies with pH and solid form.
n-Octanol-water partition coefficient	Not relevant for an inorganic substance.

1.2.3 Justification for grouping

Metallic lead and lead alloys have been considered together in this restriction dossier as they are used in both shot pellets and single projectiles and the hazards and impacts are very similar, as they both result in the emission of lead to the environment and may ultimately result in lead poisoning of environmental receptors (principally birds).

1.2.4 Classification and labelling

Lead powder (particle diameter <1 mm) and lead in massive form (particle diameter ≥ 1 mm) are listed in the GB Mandatory Classification and Labelling (MCL) list. Table 1.3 presents the resulting classifications as they appear..

Table 1.3 Classification and labelling as listed in the GB MCL list

Index No.	International Chemical Identification	EC / CAS No	Hazard class category	Hazard statement code(s)	Spec. Conc. Limits, M-factors, ATEs
082-013-00-1	Lead powder [particle diameter <1 mm]	231-100-4 / 7439-92-1	Repr. 1A Lact. Aquatic Acute 1 Aquatic Chronic 1	H360FD H362 H400 H410	Repr. 1A; H360D: C ≥ 0.03 % M = 1 M = 10
082-014-00-7	Lead massive [particle diameter ≥ 1 mm]	231-100-4 / 7439-92-1	Repr. 1A Lact.	H360FD H362	

1.3 Manufacture, use and regulatory background

1.3.1 Uses of lead in ammunition

Lead is used in the manufacture of shot cartridges and other ammunition used by members of the public, law enforcement and the military.

Under UK REACH there are 9 grandfathered registrations and 3 registrations for metallic lead (as of September 2023). Of the submitted dossiers, 8 include part A of the chemical safety report (CSR), which contains a summary of the risk management measures and declarations that risk management measures are implemented and communicated through the supply chain. These dossiers all state that Part B, which includes the information on hazard, fate, exposure and relevant risk management measures will be submitted by the Lead Registrant. A Lead Registrant has not yet been appointed for metallic lead under UK REACH, so this information has not yet been submitted. In the absence of this information the Agency has drawn from the ECHA restriction reports (2021b, 2021c) as well as the information provided by GB based stakeholders. An overview of the use of lead ammunition is shown in Table 1.4.

Table 1.4 Overview of uses

Sector of use	Use #	Use title
Live quarry shooting	1	Live quarry shooting with shot
	2	Live quarry shooting with bullets
	3	Live quarry shooting with airgun ammunition
Outdoor target shooting	4	Outdoor target shooting with shot
	5	Outdoor target shooting with bullets
	6	Outdoor target shooting with airgun ammunition

In this dossier, each of the uses are assessed to determine whether they pose a risk to human health and/or the environment that is not adequately controlled. As each of the uses may have a different risk profile and differing potential for substitution with an alternative substance, the potential benefits and consequences of a restriction on marketing or use will also vary.

1.3.2 Manufacture of lead projectiles

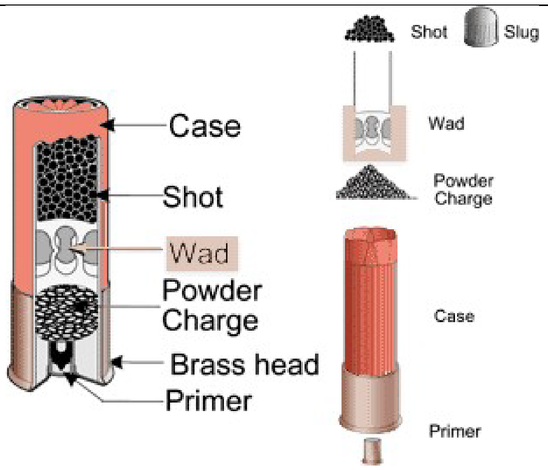
ECHA (2021c) provides an overview of the manufacturing processes which is summarised here. Further information can be found in ECHA (2021c).

There are several different types of projectiles as detailed below:

- Shot cartridges
- Solid lead bullet
- Jacketed bullet with lead core
- Muzzle loading ammunition
- Airgun ammunition
- Shotgun slugs

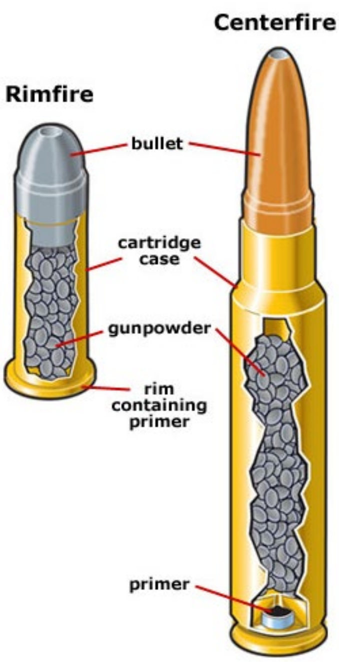
Lead shot is manufactured in two different ways, depending on the size of shot required. The Bliemeister method is used for smaller sized shot (between 2 and 2.4 mm in diameter). This involves dropping molten lead alloy through small holes into a hot liquid. It is then rolled down an incline to produce regular spheres. Larger shot sizes are manufactured using the wire process, where extruded lead wire is fed into dies and then tumbled and polished to produce the round shot. The resulting shot pellets are loaded into a cartridge assembly, which is summarised in Table 1.5:

Table 1.5 Overview of components in a shot cartridge

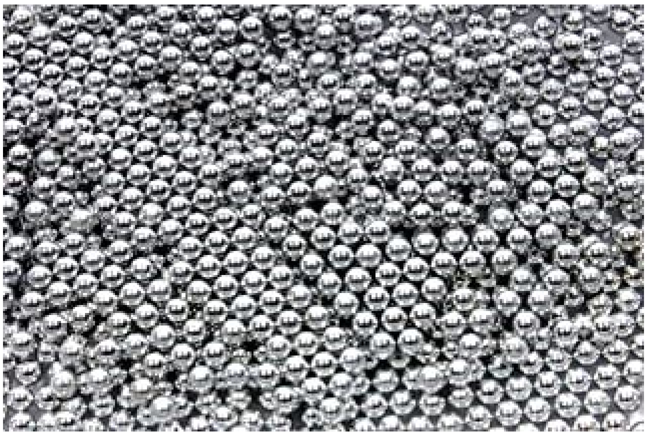
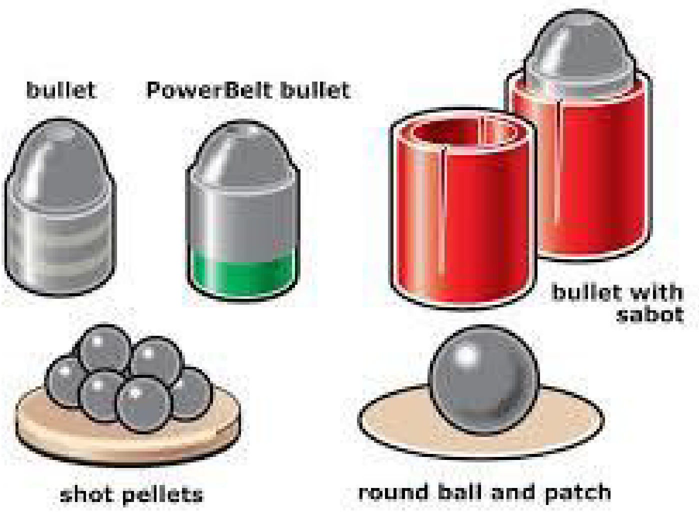
Ammunition	Description of a lead shot cartridge
Lead shot	 Source: http://theshotgunguide.blogspot.com/2013/06/the-anatomy-of-shotgun-ammo.html, accessed 5th January 2022 Typical lead shot sizes used in live quarry shooting in the UK have diameters between 2.2 mm (#8 shot) for Snipe and 4.01 mm (#BB shot) for Geese (BASC, 2023b) with loads of 30 g to 32 g. Shot sizes for clay pigeon sports must not exceed 2.6 mm (#6) for competition and more commonly shot with diameters of 2.54 mm (#7), 2.29 mm (#8) and 2.03 mm (#9) are used depending on the discipline, with maximum 28 g loads.

The manufacture of solid lead bullet components for centrefire cartridges, rimfire bullets, airgun ammunition, muzzle loader projectiles and shotgun slugs is done by the shaping of lead from ingots which is then punched into an appropriately shaped mould. Jacketed lead core bullets comprise an outer metal jacket (usually copper or brass) into which a lead core is inserted and pressed into the desired bullet shape. A description of these types of ammunition is provided in Table 1.6:

Table 1.6 Overview of other types of lead ammunition

Ammunition	Description of other types of lead ammunition
Bullets (centrefire and rimfire)	Centrefire bullets are those that have primers located in the centre of the base of their metallic cartridge casings. On firing the pin will strike the primer causing it to detonate (hence centrefire) and in turn ignite the main propellant charge within the casing. The primers are typically separate components seated into a recessed cavity and are replaceable by reloading. With rimfire ammunition, primer compound is located within a protruding rim at the base of its metallic casing. The gun's firing pin strikes the rim causing the primer compound within the rim to detonate (hence rimfire), and in turn ignite the propellant within the casing (ECHA, 2022c).  Source: https://www.hunter-ed.com/california/studyGuide/Centerfire-and-Rimfire-Ammunition/20100501_66837/ accessed 2nd March 2022

Airgun ammunition	Airguns generally use a slightly undersized projectile that is designed to expand upon shooting so as to seal the bore and engage the rifling. Airgun ammunition typically comprises pellets, slugs or 'BB's'. **Airgun Pellets** Airgun pellets are typically a diabolo shape. Common airgun pellet calibres are .177 (4.5 mm diameter; 0.5 g) and .22 (5.5 mm diameter; 1 g) and are approximately 7 mm to 8 mm in length.  Source: https://www.shootinguk.co.uk/guns/ammunition/picking-perfect-airgun-pellets-80011 accessed 2nd March 2022 **Airgun Slugs** Airgun slugs are cylindro-conoidal shaped. Slugs tend to be used in pre-charged pneumatic airguns. Commom calibres are .177, .22, .25 and .30.  Source: https://www.airgun101shop.co.uk/products/fx-airguns-hybrid-slugs-44-5 g-30cal accessed 05 May 2023

	BB's BB's are spherical metallic projectiles typically 4.5 mm/.177 calibre, made of steel or lead.  Source: https://www.amazon.co.uk/ accessed 05 May 2023
Ammunition for muzzle loaders	Muzzle loading firearms generally use round balls, cylindrical conical projectiles, and shot charges  Source https://www.hunter-ed.com/muzzleloader/studyGuide/Projectiles/222099_88839/ accessed 5th January 2022

Shotgun Slugs	Shotgun Slugs are solid projectiles generally made of lead, copper or steel (or other materials) fired from a shot gun. The projectile is placed in a casing like that used in a shotgun cartridge. The projectile may be of different shape or size, have a rifled design such as the Brenneke type (shown in the image) or 'Foster'-type, be encased in a 'sabot' or wad to engage with the shotgun bore or be stabilsed with a plastic stabiliser. Legal civilian uses in GB with the appropriate firearm/ shotgun certificates include large quarry shooting and practical shotgun.  Source: https://www.brenneke-ammunition.de/en/law-enforcement/atsr-anti-terror-slug/ accessed 2nd March 2022

1.3.3 Use of lead ammunition in live quarry shooting

In GB there are a wide range of hunting pursuits, broken down as follows:

- Wildfowling
- Game including gamebirds, deer stalking and wild boar hunting
- Pest and predator control, including pigeons, crows and rabbits

The choice of gun and ammunition used for each activity is defined by the quarry being shot, the preference of the shooter and relevant legislative requirements including specified muzzle energy, muzzle velocity, calibre and bullet weight (see

Section 1.3.5.3). Muzzle loading shotguns and antique breech loading shotguns may be used for certain live quarry shooting, whereas shooting game with muzzle loading rifles / pistols is prohibited in the UK as they do not conform to the legal muzzle energy requirements (Muzzle Loaders' Association of Great Britain (MLAGB); Organisation #121).

Live quarry shooting in GB takes place using all the identified types of lead ammunition and takes place in various forms, for example organised groups for deer stalking, driven game shoots or farmers shooting pests on their own land. The purpose of the projectile, whether shot, pellet or bullet, is to transfer sufficient energy to a target to result in a rapid kill (where unnecessary suffering is minimised) (ECHA, 2021b).

Home Office (2022) guidance also requires live quarry shooters / shooters managing wildlife, to be able to zero their equipment i.e., to align the firearm's sights so that the point of aim and the point of impact are the same at a chosen distance.

1.3.3.1 *Risk management measures (RMM) and their effectiveness for the environment during live quarry shooting*

Live quarry shooting takes place over a diverse range of habitats, including woodlands and open grouse moors. As such, any ammunition that misses its target is unlikely to be recovered. For live quarry shooting with bullets or airgun ammunition the aim is for each projectile to hit the prey e.g. Aebischer et al., (2014) report that 95% of shots taken by the deer stalkers in their UK survey hit the quarry. When using lead shot, the shot spreads out as it leaves the muzzle, and only a proportion of the shot in the shot pattern will impact the quarry so even if the quarry is hit the majority of shot will not hit the target and will be emitted to the environment. In addition, quarry that are shot but not retrieved (e.g., because the quarry escaped, or was killed but the carcass was not recovered) will have unrecovered lead embedded in their bodies.

The Agency has no information on the proportion of carcasses recovered following hunting and cannot draw any conclusions on the amount of lead in carcasses that are recovered or left in the environment. However, it is assumed that at least some carcasses are not retrieved and so lead is emitted to the environment via this route.

The only potential risk management measure to limit release of lead bullets or pellets from live quarry shooting is for shooters to only fire when the chance of a kill is high, and they can retrieve the carcass. This risk management measure could slightly limit the amount of lead emitted to the environment but would not prevent all releases as its effectiveness will depend on the perception and skill of the hunter as only a small proportion of the shot pellets released would be embedded in the animal and the remainder would be left in the environment.

1.3.4 Use of lead ammunition in outdoor target shooting, including competitive shooting

Outdoor target shooting use covers the shooting of both static targets and moving targets, such as clay pigeon shooting.

Target shooting in GB takes place either at formal permanent ranges or at temporary locations for recreation, training and competition. The sport of target shooting is a test of accuracy (and sometimes reaction speed, depending on the discipline) and involves the use of airguns, pistols, breech loading shotguns, muzzle-loading firearms (including, muskets, rifles, shotguns and pistols), and breech loading rifles (both rimfire and centrefire). Clay target shooting, Practical Shotgun and Practical Rifle are important branches of the target shooting disciplines.

Clay target shooting (clay pigeon shooting) is the sport of shooting with a shotgun at a frangible flying disc made from a mixture of pitch and chalk and designed to withstand being launched from a clay trap at high speeds, but which also breaks easily when hit by just a very few pellets. Many shooters enjoy informal clay target shooting, or shoot at clay targets in practice for hunting, but there are also several tiers of formal competitive shooting in specific disciplines such as trap and skeet, at club, county, national and international level (BSSC, Organisation #100).

The Clay Pigeon Shooting Association (CPSA, Organisation #101) is the national governing body for clay target shooting in England. It has *c*.320 registered grounds at which registered competitions are held. Clay target shooting grounds are in general privately run and some have been operating over decades and have had many millions of cartridges fired over them. Shooting grounds accommodate both ‘sporting’ layouts at which clay targets are thrown, often in or around woodland to simulate the flight of gamebirds; and trap or skeet layouts on more open ground. Trap shooting is where the clays are launched from in front of the shooters position at varying speeds, angles and elevations away from the shooter. Skeet ranges are those with two towers of differing heights, where clays are shot out of either one or both in varying arcs across the shooting position at set trajectories and speeds. Competition clay target shooting is currently undertaken with lead shot, in compliance with international competition regulations. The rules for different disciplines are set by various national (e.g., National Rifle Association (NRA), CPSA) and international shooting organisations including the International Sports Shooting Federation (ISSF) and the Federation International des Armes de Chasse (FITASC). Clay pigeon sites vary in design, from larger fixed sites which are repeatedly fired over that are registered with the CPSA to smaller mobile ones that operate under the 28 day rule for planning permission, known as straw bale shoots (CPSA, 2005).

Rifle and pistol sports target shooting is a diverse collection of sporting disciplines including shooting range, defined area to contain all discharged projectiles, construction and layout, distance from shooter to target, target specification, firearm type, calibre, barrel length, loading action, stock format, ammunition type, ballistic specification, projectile mass and projectile velocity. Rifle and pistol shooting sports generally fire projectiles into backstops.

Full-bore and smallbore refer to the different size calibres used in the respective target shooting disciplines. Competitive target shooting with full-bore (centrefire) rifles emerged in the 19th Century from military target practice, hence the larger calibres involved. Target shooting has a wide range of different classifications based upon the type of equipment used and the ranges at which shooting is carried out. There are also specific disciplines for schools, cadets and people with disabilities (BSSC, Organisation #100).

Airgun target shooting (shooting any non-live target, formal competition, informal “plinking” etc) can take place at a variety of locations, including commercial ranges, shooting clubs, and informal “backyard” ranges (individual #2168). Most people practice their sport lawfully in their own back gardens. Airgun target shooters can achieve high levels of accuracy engaging paper targets at ranges from 10 to 50 metres. Airgun target shooters commonly use pellet traps to catch pellets - this is often necessary for safety reasons given that many shooters are using their gardens and need to ensure that pellets do not stray beyond their boundaries (individual #466). The British Field Target Association (BFTA, Organisation #41) confirms that their events and competitions are held outdoors only, primarily in wooded areas, open farmland, waste ground and in disused quarries. The air rifles used are .177 calibre (4.5 mm) legal limit (<12 ft/lbs). Shooters aim at metal targets with a circular hit zone comprising a metal paddle, which when hit caused the target to fall over. Target distances are unknown but between 10 and 50 m, such that a shooter must adjust their aim for range and wind conditions.

Practical or dynamic Shooting is a competitive target shooting sport in which the object is to shoot as many targets as possible in as short a time as possible. This shooting takes place on some 60 dedicated practical shooting ranges, as well as on ranges which are used for other target shooting disciplines. The national governing body for practical shooting in Great Britain, the United Kingdom Practical Shooting Association (UKPSA), has 1400 members and is affiliated to the sport’s international controlling body, the International Practical Shooting Confederation (IPSC), which governs practical shooting across 109 countries. Disciplines supported by the UKPSA in GB include Shotgun, Long Barrel Pistol/Revolver, Pistol Calibre Carbine, Rifle, Mini Rifle and Action Air. In addition, the National Target Shotgun Association (NTSA, 400 members), the National Rifle Association (NRA, 805 target shotgun members) and the British Western Shooting Society (BWSS) also conduct dynamic or fast action shooting competitions with shotguns.

1.3.4.1 *Risk management measures (RMM) and their effectiveness for the environment at target shooting ranges in GB*

In GB there are a number of different types of target shooting that are carried out on a variety of different shooting grounds and ranges.

1.3.4.1.1 Clay pigeon shooting grounds (Use 4)

There are no requirements for installation of any lead recovery infrastructure or processes at clay target shooting sites in GB in any domestic legislation. The governing body for clay target shooting, the Clay Pigeon Shooting Association (CPSA), which covers the larger sites, does not set any requirements in their membership for capture or recovery of lead. A number of sites perform recovery, in part because the lead has an economic value, and these are discussed in detail below as they are site specific.

The CPSA submitted information in the call for evidence and at the time had 319 registered grounds, of which 17 offered responses to the call for evidence questionnaire circulated and collated by the CPSA. Clay pigeon shooting sites in GB are very varied; some are located on open land, others are within woodlands and some of them are located in or close to agricultural

land. They may be a fixed location or mobile. Trap and skeet grounds are easier to recover lead from, owing to their topography. Sporting grounds, where shots are often fired within or into woodland or other temporary locations, present much greater obstacles for lead recovery. Two of the 17 respondents (11.8 %) recover lead and a further three (17.6 %) are considering recovery (so around 71 % of the respondents had no plans). There is no information about recovery for 312 (97.8%) of the total number of registered grounds covered by the CPSA. One of the individual respondents to the call for evidence said that they did not think that any of the clay pigeon sites would be able to recover a minimum of 90 % of the lead shot as proposed by ECHA (2022a).

The National Clay Shooting Centre at Bisley comprises a large purpose-built clay pigeon target shooting centre with trap and skeet grounds. It has over 90 clay release machines and is the nominated training ground for the British Shooting team. Bisley Shooting Ground (also known as the Long Siberia) is a sporting ground set in mature woodland and the Colony Bog and Bagshot Heath Site of Special Scientific Interest (SSSI) and comprises 22 stands for a variety of different hunting simulations.

The clay pigeon target shooting centre has a shot fallout zone which is covered by rough grass, heather, scrub and trees. Recovery of lead on the part of this area with the highest density of shot is undertaken every 3-5 years by scraping off the top 5 cm of soil and spinning it to separate and remove the lead shot. The last time this was done 340 tonnes of lead were removed for recovery, although it is unknown what proportion of discharged shot this represents. During a site visit by members of the case team the photograph in Figure 1 was taken showing the lead shot sitting on the ground for up to 3 years since the last screening. This is considered to be worst case for potential emissions as this is one of the busiest sites and may therefore not be representative of the other sites in GB.

Figure 1 Fall out area of the clay pigeon shooting ground at the National Shooting Centre, Bisley (photograph taken 14/2/23)

No recovery of lead is possible at the Bisley sports shooting ground, which is based on a wooded slope, not least because groundworks are prohibited under the regulations of the SSSI.

Nuthampstead Shooting Ground is a clay pigeon shooting ground situated on the site of the former wartime RAF Nuthampstead. The site offers trap, skeet and sporting disciplines. It has been developed with a large earth berm covered in plastic to catch falling shot, with an estimated 75% recovery rate (information from CPSA stakeholder meeting).

1.3.4.1.2 Shooting ranges (Uses 5 and 6)

In GB there is no statutory requirement for the design of ranges, although the National Rifle Association has published a series of guidance documents for range managers and range safety officers for both full-bore and smallbore target shooting ranges. All ranges affiliated to the NRA and National Smallbore Rifle Association (NSRA) are required to adhere to the guidance and be inspected by officials of the governing bodies in order to maintain their affiliation. The NRA Range Design and Safety handbook (2022) is based upon published guidance from the Defence Safety Authority for military ranges (originally Joint Service Publication (JSP 403), since replaced by Defence Safety Authority (DSA) Ordnance Munitions and Explosives (OME) DSA 03.OME).

The guidance from the NRA (2022), which is considered best practice, sets out the requirements for the design, build and maintenance of ranges to ensure bullets are captured without causing ricochet or back-splash. Typical construction used for stop butts include vertical walls, natural earth embankments, manufactured bunds and cutting into natural hill features. Where the embankment (or berm) is an earth bank, or any other inert material, it must then be covered with sand to protect the incline. Sand faced stop butts are suitable for all firearms and are commonly used in outdoor ranges, an example of which is shown in Figure 2. The requirement for design includes the following:

- the angle at which the sand should be contoured to ensure it is stable and capable of safely slowing and stopping the bullets,
- the type of sand to allow capture without ricochet while allowing the profile to be retained.

The guidance requires regular checks of stop butts to ensure that there has been no lead build-up (“balling” – i.e., aggregation into a cluster of bullets repeatedly fired into the same location) to prevent potential ricochet, regular de-leading to minimise the risk to the shooters, target markers or third parties (off-site); and regular reprofiling, particularly following heavy rainfall.

Figure 2 Stop butt for a range at the National Shooting Centre, Bisley

(photograph taken 14/2/23)

The use of rubber granule stop butts is generally in smaller ranges and are managed in similar ways to sand stop butts, but as the granules are more robust than sand maintenance is less frequent. The lead drops to the bottom as it is heavier than the rubber so the whole stop butt needs to be emptied to recover the lead. An example of a rubber granule stop butt is shown in Figure 3.

Figure 3 Rubber granule stop butt for a range at the National Shooting Centre, Bisley (photograph taken 14/2/23)

During the GB call for evidence and public consultation a number of shooting organisations submitted extensive information collected from their members and the sites they operate.

In the public consultation the NRA (Organisation #127) undertook a survey of their members, of which 57 ranges out of 279 responded. They found that 2 % of the ranges who responded do not currently have bullet catchers, approximately 5 ranges. Of the ranges that do have bullet catchers 95 % are de-leaded. Of these 24 % of the range operators employ a contractor for de-leading while 71 % use club members. The British Shooting Sports Council (BSSC) (Organisation #100) gives further details on recovery of lead from a number of NRA ranges, including names, some de-leading frequencies, and quantities removed.

The NSRA (Organisation #123) gave an overview of bullet recovery rates for different types of bullet and pellet catchers done during test firings at a range of different locations. Pellet catchers for air rifle had a recovery rate of 96-99 %. Sand traps for .22 long rifle bullets was 101.7% by weight, this is above 100 % due to sand adhering to the surface of the bullet. Steel traps for .22 long rifle bullets had a recovery rate of 97.8 %.

The British Sports Shooting Council estimated the number of sites in GB to be 400 outdoor shooting ranges. They undertook a survey of their members asking for information on the collection and recovery of spent lead projectiles. A summary of the responses is provided below.

The largest shooting complex in GB is at the National Shooting Centre at Bisley in Surrey, owned by the NRA. This site has a number of different rifle ranges, and is adjacent to a military range. The site estimates that approximately 5 million copper jacketed lead bullets are shot each year on their target ranges. These bullets are captured using either sand or rubber composite stop butts, which are screened to recover the bullets on a regular schedule. The range recovers 25 - 30 tonnes of lead per year which, based on the average weight of a bullet being 7 g (ECHA, 2022a), gives a recovery rate of between 71 and 85 %.

Information was supplied by 2 other outdoor rifle ranges, one of which de-leads the range twice a year and recovers 300-800 kg of lead / copper each time. The material is retrieved by hand, heated and separated and sold for scrap. The other organisation has 2 ranges. The 100-yard (91-metre) range is de-leaded every 100,000 rounds. The 500-yard (457-metre) range is de-leaded when 20,000 rounds have been fired into each target bullet catcher. At the last de-leading the contractor removed 940 kg of material for re-processing. For both of these organisations the percentage recovered and the method of bullet capture is unknown.

The UKPSA has reported on lead recovery at five of its clubs. One of these clubs operates 2 airgun ranges, 3 full-bore rifle ranges and 4 shotgun ranges, using lead slugs on the airgun ranges, copper jacketed lead bullets on the rifle ranges and lead shot cartridges on the shotgun ranges. On this range approximately 750,000 rounds are fired per year, amounting to 3,500 kg of lead. Information was not provided to allow a break down on this total value by ammunition type. The full-bore ranges have sand backstops, are situated beneath steel and concrete bullet catcher canopies and are de-leaded by a mechanical process every 200,000 rounds, with a recovery rate of 95%. Rubber curtains on the airgun ranges allow pellets to drop to the ground for reclamation. All backstops are under bullet catcher canopies and remain dry and there is no water runoff from contaminated areas on either the airgun or full-bore ranges. The shotgun bays are not de-leaded, but are bunded, clay lined and self-contained to prevent any water runoff. Of the other UKPSA sites that provided information, one club does not undertake any lead recovery, although all shot is captured within shotgun bays, whilst three clubs recover lead from sand or earth backstops (BSSC, Organisation #100).

The Preparatory Schools Rifle Association (PRSA) is an association of 30 school rifle clubs using air rifles, air pistols and .22 rimfire rifles for national competitions of which only 5 are outdoor ranges. All the clubs collect the bullets using metal deflector bullet traps and over 90% of lead pellets are recovered. Small sand traps are usually situated beneath the deflector plates to assist this process. Recovery is a relatively quick operation, taking only one day in most cases. Owing to range construction there is minimal, if any, water run-off.

De-leading on smaller ranges is generally done by hand, often by members of the club and the recovered lead is then sold for recycling (Bisley stakeholder meeting). Mechanical recovery is also possible where the stop butt is of sufficient size and there is access for the equipment. During a site visit by part of the case team the photograph in Figure 4 was taken showing mechanical recovery of lead from a sand stop butt. The digger has a sieve to collect sand down to a depth of 0.5 m, and the sand is skimmed off by rotation.

Figure 4 Mechanical recovery of lead in a sand stop butt at the National Shooting Centre, Bisley (photograph taken 14/2/23)

As with rifles, formal airgun ranges will generally use some method of pellet capture and recovery, be it metal pellet traps or rubber curtains. Outdoor field target disciplines tend to be set in less formal and wooded/vegetated areas, where shooters might fire at a number of targets from different locations, that may be varied from one competition to the next by moving the targets and/or firing positions. The BFTA (Organisation #41) confirmed that currently the sport does not use pellet catchers or sand back stops from which pellets can be recovered.

1.3.4.1.3 Summary of GB risk management measures

Based on the information submitted during the call for evidence, public consultation and the site visit to Bisley, recovery of lead ammunition on outdoor shooting ranges using airguns (e.g. pellet traps) and bullets (e.g. stop butts) is easier and more frequent than for those using lead shot. Recovery of lead bullets from ranges already takes place at most sites due to the requirement to de-lead for safety reasons in line with NRA and NSRA national guidance. There are varying amounts of active recovery at a small number of sites the Agency received information from. At Bisley, a significant amount of lead recovery is undertaken at the shooting ranges but the proportion of the total used is unknown as the total amount of lead bullets shot on site is not recorded. Recovery rates for ranges who have measured them are between 90 and 100% and as the methods used for bullet capture and recovery are fairly similar across different ranges it is expected that this recovery rate would be feasible for all sites with capture systems, if they are operated and maintained as per the guidance from the NRA. The sale of the recovered lead is also a revenue stream from the ranges and for some ranges and disciplines recovered lead is recycled for recasting.

Recovery of lead shot on clay pigeon and practical shooting grounds is more difficult due to the larger lead ammunition fall out area and differing terrain. There are some options to collect lead shot, some of which are in place at a small number of GB sites, but it is unlikely that this would be appropriate for most of the other lead shot shooting grounds, particularly sporting grounds where woodland/heavily vegetated areas make recovery impractical. We are aware that, in the case of Bisley, the cost of recovery can be partially or fully offset from the sale of the recovered lead.

Several respondents to the call for evidence stated that they were not aware of any sites with remediation plans nor any closed sites that had or will undergo remediation.

1.3.4.2 *Risk management measures worldwide*

In the EU registration for lead a EU Chemical Safety Report (CSR) for the use of lead in shot and ammunition submitted was by the Lead Consortium to ECHA in 2020 as part of their REACH registration obligations. In their report ECHA (2021c) reviewed the CSR and stated that it contains several required RMM for the use of lead ammunition in sports shooting, indicating that a risk that is not adequately controlled is identified by the Registrants without these and therefore management of the risks are recommended (but not binding). Below is an excerpt from the ECHA restriction (ECHA, 2021c).

‘Exposure Scenarios (ES) for these various uses of lead in ammunition are described, including an ES for the professional and consumer (non-military) use of lead ammunition. In this ES, the use of lead ammunition in sports shooting is covered in relation to outdoor pistol/rifle shooting and clay target shooting (incl. sporting clays or simulated game hunting). The RMMs identified in the CSR as “required” to prevent releases during service life at different types of shooting ranges are the following:

- Measures to prevent rivers from crossing the lead deposition area
- Bullet containment in the shooting range: “at least one or a combination of bullet traps, sand traps or steel traps”
- Overhanging roof over the lead impact zone to prevent runoff
- Control of water runoff
- Lead shot deposition must be within the boundaries of the shooting range
- Remediation plan upon closure

Specifically, the identified RMMs are supposed to be applied according to the following Table 1-5. No information is provided in the CSR in relation to the expected specific effectiveness of each of the measures.’

Table 1-5 RMM to prevent releases during service life in a typical outdoor pistol/rifle range and (sporting) clay target range, as indicated in the EU REACH registration CSR

RMM to prevent releases during service life	Outdoor pistol/ rifle range	Clay target range	Sporting clay target range (simulated game hunting)
Measures to prevent rivers from crossing the lead deposition area	required	required	required
Bullet containment in the shooting range: at least one or a combination of bullet traps, sand traps or steel trap	required		
Overhanging roof over the lead impact zone to prevent runoff	required		
Control of water runoff		required	required

Lead shot deposition must be within the boundaries of the shooting range	required	required	required
Remediation plan upon closure	required	required	required

Although these RMM are listed in the EU CSR as required to ensure safe use, the Agency does not know to what extent these have been implemented for all sports shooting ranges in GB (Section 1.3.4.1.2). There are a number of best practice guidance documents for environmental protection on shooting ranges internationally – some of which are statutory in their respective locations. These include US EPA Best Management Practices for Lead at Outdoor Shooting Ranges (2005), Finnish Ministry of Environment Management of the Environmental Impact of Shooting Ranges (2014) and Environmental Protection Authority Victoria, Australia guidance for managing contamination at shooting ranges (2019). In Germany, the implementation of risk management measures are legally binding (German BMI, 2012).

1.3.4.3 *Conclusion on risk management measures for sports shooting*

The Agency considers that based on the information provided during the call for evidence, public consultation, subsequent meetings with the shooting organisations and the information in section 1.3.4.2, it is possible for static ranges to be able to implement pellet and bullet control and recovery measures to limit the amount of lead emitted to the environment. In general they will already have these in place for safety reasons. In order to demonstrate a particular recovery rate, records of the amount of lead ammunition used and recovered on each site would need to be gathered. A best practice document could be developed to ensure that the appropriate environmental protections are implemented and maintained appropriately. This could be done by the Agency working closely with the shooting industry to ensure that the range guidance also covered bullet capture and recovery. This is discussed in more detail in section 2.5.2.2.4

Implementation of risk management measures for uses of lead shot is more difficult, particularly given some of the terrain involved and because some sites are mobile (i.e. not at fixed locations). Therefore shot capture and recovery is very unlikely on most sites.

1.3.5 Regulatory background

1.3.5.1 *Existing legislation relating to lead ammunition*

This section summarises the current legal framework which influences the marketing and use of lead ammunition for firearms and airguns. This is with respect to GB only, as under the terms of the Northern Ireland Protocol NI will continue to apply EU REACH and adopt EU REACH restrictions, including a restriction of lead shot over wetlands which came into effect after 15 February 2023 and the proposed restriction for outdoor shooting and fishing weights which has been submitted to the European Commission.

1.3.5.2 *Firearms and shooting clubs*

In GB the possession by the general public of firearms, shotguns and ammunition is subject to strict control measures under the Firearms Act 1968 (as amended). Individuals must obtain a firearms certificate or a shotgun certificate from their local police force to own and use firearms. There are strict conditions imposed on the certificate holder to store their firearms safely and securely, and local police forces can impose additional conditions over and above the statutory ones. There are some other provisions which fall outside of the Firearms Act relating to the shooting of birds and animals, whereby shooting is allowed or prohibited under certain circumstances. Further information (and details of related legislation) is contained within Chapters 13 and 14 of the Home Office guidance (2022).

Police forces are also required to keep a register of firearms dealers, which are defined in the Firearms Act as a person or a corporate body who, by way of trade or business: manufactures, sells, transfers, repairs, tests or proves firearms or ammunition to which Section 1 of this Act applies, or shotguns; or sells or transfers air weapons. Firearm dealers are provided with a certificate of registration, listing all the premises within which the dealer operates, the categories of firearms and/or ammunition the dealer may trade in and, any conditions placed on the dealer by the local police force.

Additionally, Section 15 of the Firearms (Amendment) Act 1988 permits members of Home Office approved rifle and muzzle loading pistol clubs, school and cadet corps to have in their possession firearms and ammunition when engaged as members of the club, without holding a firearms certificate themselves. Shooting ranges themselves are not specifically covered by the Firearms Act and are no longer regulated by the Ministry of Defence (except at their own ranges). However, they must have the correct liability insurance to enable shooting to take place.

The Firearms Act does not specify what material must be used for ammunition. The Act and associated legislation are accompanied by a detailed guidance document. The guidance explains the relationship between firearms; weight of ammunition or shot; and feet per pounds of power. However, the guidance does not cover all situations where firearms are used and there is still potential for individuals to use firearms, in certain circumstances, without a certificate.

While certificates place specific requirements on the holder regarding the possession and use of the firearms they are permitted to hold, firearms legislation was put in place to control the possession and use of firearms and to protect members of the public. Furthermore, while these certificates cover possession and use of most firearms and shotguns in most circumstances, there are situations and types of firearms which fall out of scope. Therefore, firearms and shotgun certificates would not prevent, nor be able to enforce against, lead ammunition being used and consequentially affecting the environment.

The Gun Barrel Proof Act 1868 (as amended) contains specific reference to the gravity of lead and its relationship to the weight of bullets. This Act does cover the sale and supply of ammunition but mainly focuses on the "proving" of the barrels of the guns themselves and to ensure that they have been notified to proof houses established by this Act. However, as the scope of the proposed restriction also includes exemptions, different types of lead ammunition (not just bullets) and aims to regulate for environmental purposes, these requirements could be out of scope of the Act. Given the age of this legislation, it may require some updating to take account of newer technologies and concerns.

Antique firearms are defined in S126(2D)(b) of the Policing and Crime Act 2017 and The Antique Firearms Regulations 2020. A firearm may be defined as an 'antique firearm' if it was manufactured before 1 September 1939. These include breech loading and muzzle loading firearms, centrefire, rimfire, airguns, pistols and rare historic firearms such as Paradox type rifled and rifled choke shotguns, which are designed for both lead shot and a single specially designed lead bullet. There are many historic, heritage and vintage firearms in the hands of museums, collectors and shooters, designed for use with lead or lead core bullets. Collectors and collecting are recognised by the Home Office 'Guide on firearms licensing law' as a means of preserving Britain's unique firearms heritage. Additionally, there are many more vintage firearms which are licensed in the normal way and kept on a Firearm Certificate for use with currently available lead ammunition, for example vintage service rifles (e.g., .303 Lee Enfield), .22 rimfire rifles, airguns, and fine sporting arms (e.g., those produced by Purdey, Holland & Holland, Rigby, Boss, etc. (Home Office, 2022; Historical Breechloading Smallarms Association (HBSA); Organisation #94).

1.3.5.3 *Hunting regulations*

The Environmental Protection (Restriction on Use of Lead Shot) (England) Regulations 1999 (as amended: The Environmental Protection (Restriction on Use of

Lead Shot) (England) (Amendment) Regulations 2002 and The Environmental Protection (Restriction on Use of Lead Shot) (England) (Amendment) Regulations 2003) specify that lead shot cannot be used in England for shooting any species of bird on or over any area below the high-water mark of ordinary spring tides; any species of bird on or over a list of specified Sites of Special Scientific Interest (some of which are inland); Eurasian Coot, Common Moorhen, Golden Plover, Common Snipe or any species of duck, goose or swan, anywhere. An identical restriction exists in Wales under equivalent legislation, The Environmental Protection (Restriction on Use of Lead Shot) (Wales) Regulations 2002. The scope of the equivalent Scottish legislation is slightly different: lead shot cannot be used for shooting any species of bird over wetlands (including the foreshore, streams, rivers, ponds, marshes, wet fields and moorlands with visible standing water), The Environmental Protection (Restriction on Use of Lead Shot) (Scotland) (No.2) Regulations 2004.

The Guide on Firearms Licensing Law (Home Office, 2022) explains that the Deer Act 1991 (*Deer Act*, 1991) stipulates suitable calibres for shooting deer in England and Wales range from .22 centrefire to .45-70. The Deer Act 1991 does not specify the material of the ammunition to be used for deer hunting. For shooting Muntjac and Chinese Water Deer, a rifle with a calibre of not less than .220 inches and a muzzle energy of not less than 1000 foot-pounds using a soft or hollow nosed bullet of not less than 50 grains can be used. For shooting Roe, Fallow, Sika and Red Deer, a rifle with a calibre of not less than .240 and a muzzle energy of not less than 1700 foot-pounds can be used. However, for the larger species (Fallow, Sika and Red Deer), .270 and larger are generally more suitable (Home Office, 2022). For Scotland, the Deer (Firearms etc.) (Scotland) Order (1985) makes different provisions and does not stipulate calibres. For the shooting of Roe Deer the bullet weight must be not less than 50 grains, the muzzle velocity not less than 2450 feet per second and the muzzle energy not less than 1000 foot-pounds (in practical terms, this means a calibre of .222 or greater). For deer in Scotland other than Roe, bullets of not less than 100 grains, and a muzzle velocity of not less than 2450 feet per second and a muzzle energy of not less than 1750 foot-pounds are all required (Home Office, 2022). The Deer Act 1991 requires that "soft nosed or hollow nosed" (expanding) ammunition, or in the case of Scotland ammunition "*designed to deform in a predictable manner",* must be used for shooting deer (Home Office, 2022).

The Guide on Firearms Licensing Law (Home Office, 2022) provides guidance on the types of calibres appropriate for quarry not covered by legislation. For example, "*It is recommended that a rifle of not less than .270 be used for wild boar. For feral goats, DEFRA advises the use of a minimum calibre of .243 with a bullet weight of 100 grains to be humane."* Additionally, it provides guidance to the Police Firearms Licensing Departments' (FLDs) on the minimum calibres that should be authorised for particular quarry types (e.g., Vermin & Ground Game and other Small Quarry –

rat, hare, rabbit, Grey Squirrel and other similar sized quarry) as a guide to establish initial “good reason” for the possession of a firearm.

The British Association for Shooting and Conservation (basc.org.uk) has issued guidance about permissible methods of killing or taking wildlife under the Wildlife and Countryside Act 1981 (as amended) (Quarry species & shooting seasons). It provides advice about illegal equipment, such as any shotgun where the barrel has an internal diameter at the muzzle of more than 1¾ inches. The use of this (or any other) guidance is not legally enforceable.

The use of lead is referenced within the Hunting Act 2004, which applies to England and Wales. Requirements concerning the weight of bullets may have an indirect relationship to lead.

1.3.5.4 *Control of wildlife*

The primary responsibility for management of wildlife and / or pests for the prevention of damage to agricultural crops, property or livestock resides with local communities and the individual landowner. According to Natural England / Defra (2023) an individual does not require a licence to control pests such as rats and cockroaches.

The Prevention of Damage by Pests Act (1949) made local authorities responsible for keeping their districts free, as far as is practical, of rodents. A farmer or agricultural landowner is not required to notify the local authority if there are rodents on their land. However, the authority can demand the farmer / landowner control rodent infestations or, if they fail to do so, carry out control themselves and charge the farmer / landowner for the work.

The Pests Act 1954 designated England and Wales (except for the City of London, the Isles of Scilly and Skokholm Island) as a Rabbit Clearance Area (*Pests Act*, 1954). In this area, every occupier of land is responsible for the killing or taking of wild rabbits on his land, or take the necessary steps to prevent them causing damage. Defra has the power to serve a Notice under the Agriculture Act 1947, requiring rabbit control to be carried out; if this is not done, they may arrange for the necessary work to be undertaken at the expense of the occupier, who could also be liable to a fine.

Under the Wild Mammals (Protection) Act (1996) it is an offence to intentionally inflict unnecessary suffering, as specified by the Act, on any wild mammal.

The Wildlife and Countryside Act 1981 defines certain species that are afforded protections from being unlawfully killed (Wildlife and Countryside Act 1981 (legislation.gov.uk))

The Department for Environment, Food and Rural Affairs (Defra), Natural England, NatureScot and Natural Resources Wales issue licences for individuals and companies to remove wildlife under specific conditions. This is mainly used for removing protected wildlife from an area or property where there is a risk of serious damage or health (Wildlife licences: when you need to apply - GOV.UK (www.gov.uk). For example GL42: general licence to kill or take certain species of wild birds to prevent serious damage (GL42: general licence to kill or take certain species of wild birds to prevent serious damage - GOV.UK (www.gov.uk)).

1.3.5.5 *Occupational and food regulations*

The Control of Lead Regulations 2002 set out the requirements for controlling human exposure to lead from work activities. Since these regulations are for occupational settings and indoor use is exempt from the scope of this restriction, they are not relevant for the concerns covered by this restriction proposal (environmental exposure and human exposure via food). Nevertheless, a restriction that results in less manufacture and supply of lead-based ammunition will also result in less occupational exposure to lead of those concerned in the manufacture and handling in the supply chain of such ammunition.

Although existing food regulations (European Commission Regulation (EC) No. 1881/2006 [as retained in GB law] “setting the maximum level of certain contaminants on foodstuffs”) prohibit the sale of specific food commodities containing lead above maximum specified levels (*0.10 and 0.50 mg/kg wet weight respectively in the case of Pb for meat (muscle) and offal of cows, sheep, pigs and poultry respectively*), they do not extend to game meat.

1.4 Environmental assessment

1.4.1 Environmental fate

This review of the environmental fate properties of lead is based on detailed reviews by ECHA (2018a, 2018b). Those reviews included data from LDAI (2008), Danish EPA (2014), SAAMI (1996) and the EU REACH registration dossiers.

Lead is an element and so, by definition, cannot be degraded. Therefore, it is not relevant to assess degradation rate as is usually done for organic compounds. As such, this section considers the potential transformation of lead in water, its environmental distribution and bioaccumulation.

1.4.1.1 *Transformation*

Lead in its metallic form (Pb^0) can be transformed to its ionic forms in the environment; Pb (II) (Pb^{2+}) is the dominant form, as it is more stable than Pb (IV) (Pb^{4+}) (ECHA, 2021c). Environmental conditions affect lead speciation (ECHA, 2021c). The extent and rate of transformation has been assessed in standardised transformation/dissolution protocol (T/Dp) tests in accordance with OECD guidance, showing a decrease in transformation to ionic forms occurs with:

- higher pH: T/Dp tests carried out on fine lead powders (<75 µm diameter) at a loading of 100 mg/L for 24 hours resulted in concentrations of 3,211 µg/L at pH 6, 607 µg/L at pH 7 and 188 µg/L at pH 8 (ECHA, 2017b).
- larger particle size: a T/Dp test carried out on fine lead powder (<75 µm) at a loading of 100 mg/L at pH 6 produced a dissolved lead concentration of 3,211 µg/L at 24 hours. Assuming a linear kinetic model for dissolution, a 100-fold decrease in loading rate from 100 mg/L to 1 mg/L would decrease the concentration of the lead in solution 100 times from 3,211 µg/L to 32 µg/L. This is a conservative assumption; the concentration at 1 mg/L loading is expected to be >32 µg/L at 24 hours for fine lead powder (<75 µm). A T/Dp test carried out on larger lead particles (1 mm diameter) at a loading of 1 mg/L at pH 6 produced a dissolved lead concentration of 5.1 µg/L after 7 days (ECHA, 2018b).

Transformation rates of lead under normal environmental processes are slow, demonstrated by the results from the full T/Dp test (1 mg/L loading of 1 mm particles for 28 days at pH 6), where concentrations of lead were 5.1 µg/L at day 7 and 14.2 µg/L at day 28 (ECHA, 2018b).

Transformed lead ions can precipitate as hydroxides, sulphates, sulphides, carbonates and phosphates; these processes are directly controlled by pH, oxidation-reduction conditions and the concentrations of the anions (in turn, driven by, for example, dissolved organic carbon content) (ECHA, 2021c). Such processes vary across sites, meaning it is the site-specific conditions that determine lead solubility.

The removal half-life of lead in soil has been estimated to be between 740 and 5,900 years (Alloway et al., 1997). No half-life data are available for sediments, but as the metallic lead corrodes the lead compounds formed may associate with the sediment. Lead sulphide is expected to form in anaerobic sediment.

1.4.1.2 *Environmental distribution*

Lead is a natural constituent in all environmental compartments, including biota.

Overall, the fate of spent lead ammunition in the environment largely depends on whether it remains exposed or becomes buried in sediments or soils (ECHA, 2021c).

Lead ammunition can accumulate on the soil surface of shooting areas. Projectiles may fragment on impact and/or lead may leach from projectiles due to weathering. The rate of corrosion of metallic lead is often controlled by the build-up of lead salts on the metal surface. Many of these salts have very low solubility in water, particularly lead sulphate and lead carbonate. Several studies have considered the effects of weathering on lead (for example, Anderberg et al., 1990; Linder, 2004; Scheinost, 2004). Based on these studies, the supplementary CSR for the use of lead ammunition developed for the EU REACH registration of lead (ILAE, 2010; cited within ECHA, 2021c) identified corrosion rates of 1 % per year as a worst-case estimate. Corrosion rates of 1 % per year (or less) demonstrate that large amounts of lead ammunition remain in the environment in solid form (approximately 99% or more per year), providing an ongoing exposure route via direct ingestion (see Section 1.4.5).

Small fragments of projectiles, smaller sizes of lead shot and the lead compounds that result from weathering are the most mobile (ECHA, 2021c). Where shooting areas are continuously disturbed and therefore soil is left bare, erosion during rainstorms and the associated surface water runoff can cause the transport of lead to adjacent water bodies (ECHA, 2021c).

The fate of lead within terrestrial and aquatic compartments is regulated by physico-chemical processes, including oxidation/reduction, precipitation/dissolution, adsorption/desorption and complexation/chelation (ECHA, 2021c). In the terrestrial environment, soil conditions (e.g. mineral content, organic matter content, pH, and redox conditions) affect both the speciation of lead and the sorption of lead species to the soil, as reviewed in detail by ECHA (2021c). In general, lead is more soluble in acidic conditions than under neural or alkaline conditions. In the aquatic environment, the partitioning of lead into the dissolved phase in surface waters is driven by pH, natural organic matter levels, the presence of anions (hydroxides, carbonates, sulphates and phosphates), and water velocity (i.e. mechanical disturbance). The parameters that control the fate of lead are highly variable between sites (dependent on the site hydrological and geological conditions) and, therefore, the mobility of lead in both the terrestrial and aquatic environments is site-specific (ECHA, 2021c).

In surface soils, where lead ammunition is commonly found, conditions are usually oxic (unless waterlogged), which leads to high sorption and relatively low mobility of lead (ECHA, 2021c). If the soil surface layer capacity of lead is reached, lead will migrate towards lower soil layers, again driven by site-specific soil properties.

Solid lead slowly dissolves in soft waters, whereas it generally does not dissolve in hard waters. In most surface and ground waters, dissolved lead tends to form complexes with anions, which precipitate out of the water column. Therefore, in general, a significant fraction of the lead present in surface waters can be expected to be present as (ECHA, 2021c):

1. colloidal particles;
2. larger undissolved complexes of lead carbonate, lead oxide or lead hydroxide; or
3. other lead compounds incorporated within/sorbed onto particulate matter.

Partition coefficients (log K_D) for lead between freshwater and suspended particulate matter in the UK are provided in Table 1.7; these demonstrate strong adsorption to suspended particulate matter. In aquatic environments with low water velocities, the suspended matter with lead bound to it will become buried in bottom sediments, moving lead to the anoxic sediment layer where it can become strongly adsorbed onto sediment particles.

Table 1.7 K_D values reported for lead in freshwaters in the UK

Location	Log K_D (L/kg)	Remarks	Reference
Calder River	4.45 – 5.98	minimum–maximum	(Lofts and Tipping, 2000; cited within ECHA, 2021c)
Nidd River	4.69 – 6.25	minimum–maximum	
Swale River	4.58 – 6.20	minimum–maximum	
Trent River	4.61 – 6.06	minimum–maximum	
All rivers	5.41	observed mean	
All rivers	5.71	predicted mean	
Upland-influenced river water	4.6	modelled value	(Tipping et al., 1998; cited within ECHA, 2021c)
Low-salinity water	5.5	modelled value	

1.4.1.3 *Bioaccumulation*

ECHA (2021c) reviewed the bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) for lead from water to aquatic invertebrates and fish as summarised in LDAI (2008) and the EU REACH registration for lead. A focussed review on BAFs was provided because these are preferred over BCFs, due to their higher ecological relevance as they include all possible exposure routes: water, food and soil/sediment.

ECHA (2021) selected a concentration range of 0.18 to 15 µg/L lead to represent background levels. Within the 0.18 to 15 µg/L concentration range, reported BAFs range between (10 to 90th percentile) (ECHA, 2021c):

- 11 and 143 L/kg_{ww} (median: 23 L/kg_{ww}) for fish;
- 18 and 3,850 L/kg_{ww} (median: 675 L/kg_{ww}) for molluscs;
- 968 and 4,740 L/kg_{ww} (median: 1,830 L/kg_{ww}) for insects;
- 1,583 and 11,260 L/kg_{ww} (median: 3,440 L/kg_{ww}) for crustaceans.

For lead exposure of predators (birds and mammals) via the aquatic compartment, ECHA (2021c) calculated a ‘realistic mixed diet’ BAF of 1,553 L/kg (median; 90th percentile of 3,890 L/kg), which assumed that birds and mammals consume equal portions of crustaceans, molluscs, annelids, acarida, insects and fish.

For terrestrial bioaccumulation, a large number of BAF values are available for earthworms. ECHA (2021c) report the summarised data from LDAI (2008). LDAI (2008) report the BAF range for earthworms as 0.14 to 1.2 kg_{dw}/kg_{dw} (10 to 90th percentile; median, 0.39 kg_{dw}/kg_{dw}) for studies reported on a dry weight basis.

1.4.2 Environmental hazard

Lead and lead compounds are hazardous; there are extensive data on the effects of both short- and long-term exposure for aquatic and terrestrial organisms, which have been collated in the EU REACH registration dossier (ECHA, 2021a) and LDAI (2008), among other reports. The toxicity of lead in the environment is generally dependent on its bioavailability; more bioavailable forms, for example dissolved ionic species, usually have relatively greater toxicity (ECHA, 2021c). Metallic lead can transform into soluble (and therefore bioavailable) species in the environment (see Section 1.4.1), the rate being faster for small particle sizes (diameter < 1 mm) than larger ones. In addition, small particles of lead metal or alloy (for example, arising from lead ammunition) can be ingested by animals (primarily birds) and thereby pose a hazard as they pass through the gut.

This section discusses the toxicity of lead in the aquatic and terrestrial compartments, and on the non-compartment specific effects of lead. As this restriction is mainly focussed on risks to birds, only a brief summary of key hazard endpoints is provided for aquatic and soil-dwelling organisms.

1.4.2.1 *Aquatic compartment*

The mandatory environmental hazard classification of lead in powder form (particle diameter < 1 mm) under GB classification, labelling and packaging legislation (GB CLP) is Aquatic Acute 1 (H400), with an acute M-factor of 1, and Aquatic Chronic 1 (H410), with a chronic M-factor of 10. This is based on a 72-hour EC_{50} of 20.5 µg/L for *Pseudokirchneriella subcapitata* and a 30-day EC_{10} of 1.7 µg/L for *Lymnaea stagnalis* (growth). Further details are provided in ECHA (2018a).

A decision about the environmental hazard classification for metallic lead (particle diameter ≥ 1 mm) has not yet been taken. The EU is considering new data and the environmental classification has not been included in Annex VI to Regulation (EC) No. 1272/2008 as of May 2023. Metallic lead does not currently have a mandatory environmental hazard classification under UK law. Nevertheless, companies still have a responsibility to self-classify. The lead EU REACH Registrant considers that this form of lead does not require a classification for the environment (ECHA, 2021a).

Based on the aquatic toxicity data set, a freshwater Predicted No-Effect Concentration (PNEC) of 2.4 µg/L (as dissolved lead) is presented in the CSR (2020). The quality of the data set, its appropriateness for different abiotic conditions (such as hardness and pH) and derivation method have not been evaluated by the Agency for the purposes of this dossier.

Under UK water quality legislation, lead and its compounds have an Annual Average Environmental Quality Standard (AA-EQS) of 1.2 µg/L (as a bioavailable concentration) in inland surface waters (defined as rivers and lakes and related artificial or heavily modified water bodies). A slightly higher AA-EQS of 1.3 µg/L can be used for other surface waters. The EQS expressed as a Maximum Allowable Concentration (MAC-EQS) is 14 µg/L (as a dissolved concentration). These standards apply in England and Wales under the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 and in Scotland under The Scotland River Basin District (Standards) Amendment Directions 2015.

1.4.2.2 *Terrestrial compartment*

A generic PNEC for soil of 212 mg/kg dry soil (as lead) is presented in the CSR

(2020), based on ecotoxicity data for soil-dwelling organisms. The quality of the data set, its appropriateness for different abiotic conditions (such as organic carbon content and pH) and derivation method have not been evaluated by the Agency for the purposes of this dossier.

1.4.2.3 *Non-compartment specific effects*

Acute or chronic toxicity resulting from metallic lead ingestion is generically termed 'lead poisoning'. The principal routes of lead poisoning by lead ammunition are (ECHA, 2021b):

- Primary ingestion (primary poisoning): that is, the direct ingestion of lead metal through normal feeding or foraging from the environment (for example, mistaking lead particles for grit, which is used to aid break up of food or for minerals); and
- Secondary ingestion (secondary poisoning): that is, the indirect ingestion of lead through feeding on food contaminated with lead (for example, lead particles in prey/carrion, lead contaminated tissues or plants).

There has been extensive research on the effects of lead poisoning in birds (Section 1.4.2.3.1). There are limited studies on the effects of lead poisoning in mammals; predators and scavengers, like foxes, may be exposed through primary or secondary ingestion, but the information is insufficient to detail here. Mammalian toxicity data relevant to humans are reviewed in Section 1.5. There are some data available on ruminants, which are summarised in Section 1.4.2.3.2.

1.4.2.3.1 Birds

The hazard to birds posed by ingestion of lead metal depends on the ecology and physiology of the species (ECHA, 2021b). In particular, species with muscular gizzards are subject to primary poisoning because ingested lead is ground down in the gizzard, enhancing its dissolution and then uptake within the intestine (ECHA, 2021b). Secondary poisoning is particularly important for species that consume prey or carrion left in the environment that have lead within them. Literature describing lead ammunition as a source of lead poisoning has emerged since the 1930s, with recent reviews, as cited within ECHA (2021b), including: Rattner *et al.* (2008), Franson and Pain (2011), Delahay and Spray (2015), LAG (2015a), Golden *et al.* (2016), Plaza and Lambertucci (2019) and Grade *et al.* (2019).

Absorption

The main factors that affect the initial absorption of lead metal following ingestion are stomach characteristics, retention time in the gastrointestinal tract, diet and sex (ECHA, 2021b).

The stomach of birds comprises:

1. The proventriculus: here, gastric juices create an acidic environment. The pH varies but it can be strongly acidic; for example, ducks have a stomach pH of 2.0 to 2.5, and eagles have a stomach pH of 1.0 (ECHA, 2021b). In chickens (n = 20), pigeons (n = 15), pheasants (n = 11), turkeys (n = 4) and ducks (n = 10), the pH of the proventriculus was reported to be 4.4, 4.8, 5.7, 4.7, and 3.4, respectively (Farner, 1942).

2. The muscular gizzard: this grinds food into smaller pieces, often with the aid of grit. The pressures created vary, with gizzards of species that feed on coarse objects (grain/plant material) being larger and more muscular than those that predominantly feed on meat. For example, geese, ducks and chickens can create pressures up to 37, 24 and 17 kPa, respectively (ECHA, 2021b). The environment remains strongly acidic in the muscular gizzard; Farner (1942) reported pH levels of 2.6, 2.0, 2.1, 2.2 and 2.3 in the gizzard of chickens, pigeons, pheasants, turkeys and ducks, respectively.

These stomach characteristics (creation of smaller lead particles and a low pH) promote the dissolution and erosion of lead ammunition when ingested (see Section 1.4.1.1), leading to greater potential for its absorption in the gastrointestinal tract.

Once ingested, lead metal can be regurgitated or passed through the gastrointestinal tract. If not ejected from the body within the first 24 hours, most of the lead will be retained within the gastrointestinal tract for an extended period of time. Here, it is subject to erosion and dissolution in the stomach and will generally be completely eroded within 20 days ECHA (2021b). However, this might not always be the case. For example, a recent study, in which Pekin Ducks (*Anas platyrhynchos* forma *domestica*) were administered with six lead shot pellets by oral intubation, showed 45.3% mass loss of the pellets after 4 weeks (Krone et al., 2019); the Agency assumes that these pellets were retained within the gizzard and thereby provided an ongoing source of lead to the birds.

Bird species that have whole or part-grain diets are more likely to be subject to primary poisoning than those that do not because:

1. they are more likely to mistake lead shot and grit for grain and consume it; and

2. their gizzard is especially muscular, to enhance grinding capabilities.

Where birds have diets high in protein and calcium, these can reduce acidity within the stomach and therefore moderate the initial dissolution of lead within the gastrointestinal tract (ECHA, 2021c).

Sex affects the initial absorption of lead because of the role calcium plays in eggshell formation. Calcium used to form egg shells is sourced from both the diet and the medullary bones (which are effectively an internal calcium reservoir) (Kerschnitzki et al., 2014). Therefore, actively laying birds increase their intestinal absorption of calcium to both directly form egg shells and also replace the calcium that has been sourced from the medullary bones. Lead and calcium have similar chemical properties due to the stable 2+ oxidation state. They also have similar atomic radii and can act as substitutes for each other in some structures (e.g. bone). This means that greater absorption of calcium concurrently results in greater absorption of lead.

Distribution

Once absorbed, lead is transported around the body in the bloodstream (ECHA, 2021b). From the bloodstream, lead is rapidly deposited into soft tissues, with the highest concentrations generally found in the bone, then kidney and liver (ECHA, 2021b). In Pekin Ducks, Krone *et al.* (2019) demonstrated high levels of lead in the liver, kidney and pancreas, compared with the breast muscle and brain, 4 weeks following oral intubation with six lead shot pellets. Over the lifetime of a bird, lead accumulates in the bone in particular, although it can be mobilised (for example during egg laying, as described above). Muscle tissues generally have comparatively low levels of absorbed lead concentrations (ECHA, 2021b). However, after acute exposure bone levels may be low and soft tissue levels elevated.

Metabolism

In birds, calcium plays two important physiological roles, namely, providing structural strength to the skeleton and being integral to several biochemical reactions within the body. Due to the similarity of the biological behaviour of lead and calcium, lead competes with calcium ions and affects those biochemical processes that normally involve calcium (ECHA, 2021b). Lead also becomes deposited in the bone instead of calcium.

Elimination

Lead can be eliminated from birds in their faecal sacs. However, with continuous or repeated exposure, lead will be retained and concentrations within their bones will increase if this exceeds the elimination rate (ECHA, 2021b).

Lethal and sub-lethal effects

Toxicological studies have been conducted with captive birds, including wildfowl species (primarily), predators and scavengers (ECHA, 2021b). In general, birds have been dosed with lead ammunition (typically lead shot) and then blood lead concentrations, physiological parameters and other clinical signs have been monitored (ECHA, 2021b). Some studies investigating sub-lethal effects have dosed using other forms of lead or related effects to measured concentrations of lead in wild birds.

Lethal effects

Acute (short-term) and chronic (long-term) exposure to lead metal (i.e. lead ammunition) can both cause mortality in birds. Acute poisoning generally occurs after a bird has ingested a large quantity of lead shot over a short period of time, although it can occur after ingestion of a single shot if absorption is rapid. It can result in mortality within 1 to 3 days, without the bird exhibiting obvious symptoms of lead poisoning (ECHA, 2017b). Chronic lethal poisoning occurs when a bird ingests lead and smaller amounts are absorbed over a longer period of time, resulting in a progressive illness that results in death (ECHA, 2017b). In this case, birds initially exhibit almost fluorescent, green faecal diarrhoea, followed by increasing muscular weakness, which initially causes abnormal wing positioning, then progressive loss of the ability to walk or fly (ECHA, 2021c). Finally the emaciated birds seek refuge and become comatose before death (or are eaten by a predator) (ECHA, 2021c). Internally, birds subject to chronic lethal poisoning often have myocardial damage, liver atrophy, an enlarged gall bladder (due to build-up of thick, dark-green bile) and impaction of the oesophagus and stomach (ECHA, 2021c). The factors influencing lead absorption, including retention time of the lead object(s), its size and surface area, its dissolution and absorption through the intestine wall, along with the physiological condition of the bird, result in the relationship between exposure and effects varying. However, on average, the higher the exposure (in terms of number of lead shot and surface area) the greater the risk of severe impacts.

Lethal effects have been demonstrated in experimental studies with different bird species, including:

- Mourning Doves (*Zenaida macroura*): of 157 birds that were administered 2 to 24 lead pellets, 104 died (all 22 in the control group survived) within 21 days (Schulz et al., 2006; cited within ECHA, 2021c). In a separate study, mortality in doves (25 per treatment) exposed to 0, 1, 2 or 4 #8 lead shot was 0%, 24%, 60% and 52%, respectively (Buerger et al., 1986).

- Brown-headed Cowbirds (*Molothrus ater*): of 10 birds dosed with a single 7.5 mm lead shot and given a relatively natural diet, three died within one day. Of the survivors, all but one excreted the lead shot they had ingested within 24 hours. All of the dead birds retained their shot. The greatest erosion of lead was observed in birds that died (2.2 to 9.7%) (Vyas et al., 2001).

- Willow Ptarmigan (*Lagopus lagopus*): four groups of 9 birds were each administered 0, 1, 3 and 6 individual 2.5 mm lead shot, respectively. In both the 3-shot and 6-shot groups, 22% mortality was observed within 8 to 15 days. The amount of eroded lead among the birds that died was significantly different from the survivors, with a tendency towards increased lead residues in the liver with increased eroded lead (Gjerstad and Hanssen, 1984).

- Bald Eagles (*Haliaeetus leucocephalus*): four out of 5 birds dosed with lead shot (10 shot at a time, additional doses administered if previous shot regurgitated) died, after 10, 12, 20 and 125 days. The fifth bird became blind and was sacrificed after 133 days. Each bird had lost body weight at death (23, 17, 16, 23 and 20%, respectively). Individual responses were variable, but cardiovascular lesions (myocardial necrosis, fibrinoid necrosis) and renal lesions (nephrosis) were observed (Pattee et al., 1981).
- Mallard (*Anas platyrhynchos*): administration of a single shot comprising 0.073 g lead caused 35% mortality in 10 ducks, with higher doses (0.21 to 1.0 g) causing 80 to 100% mortality (Finley and Dieter, 1978). In another study, 0.2 g lead shot caused 90% mortality (n = 10) (Brewer et al., 2003).

In experimental studies, the time to death after ingestion of lead ammunition varies between species and dosage; waterfowl generally die within 2 to 4 weeks, while some raptors can survive more than 15 weeks.

Lethal effects have also been reported from field observations (see Sections 1.4.4 and 1.4.5).

Sub-lethal effects

Sub-lethal effects associated with lead poisoning at levels that may not cause immediate mortality have been demonstrated following both short-term and long-term exposure. These have been summarised into the following categories:

- **Haematology**: Lead causes severe anaemia (potentially leading to death), as a result of the accumulation of non-haeme iron and abnormal blood pigments in malformed erythrocytes (ECHA, 2017b). The abnormal surface membranes of the erythrocytes means they are unable to effectively transport oxygen, are short-lived and break down much more rapidly than normal erythrocytes; this leads to accumulation of haemosiderin in tissues, particularly the liver, causing hemosiderosis (ECHA, 2021c, 2017b)

  Lead causes inhibition of two enzymes involved in haemoglobin synthesis: delta-aminovulinic acid dehydratase (δ-ALAD) and haeme synthetase (ferrochelatose; responsible for combining ferrous iron and protoporphyrin IX, PPIX). In Domestic Pigeons (*Columba livia*), oral exposure to a single lead pellet caused an 80% decrease in plasma δ-ALAD activity compared to the controls (J. P. Holladay et al., 2012). Northern Bobwhite Quail (*Colinus virginianus*) dosed with single, spent, 50 mg shot exhibited δ-ALAD inhibition, which was particularly severe for females (92% δ-ALAD inhibition 8 weeks after dosing) (S. D. Holladay et al., 2012). In Griffon Vultures (*Gyps fulvus*) and Eagle Owl (*Bubo bubo*) a 94% and 79% decrease in δ-ALAD activity was observed at blood lead concentrations of >30 µg/dL and >20 µg/dL, respectively (Espín et al., 2015). Inhibition of ferrochelatase causes the accumulation of PPIX in erythrocytes. Bald Eagles exposed to lead shot exhibited reduced haematocrit, haemoglobin and δ-ALAD activity as well as changes in serum biochemistry (ECHA, 2017b).

- **Cardiovascular system**: Anaemia as described above can cause damage to the walls of blood vessels. This can result in atrophy of muscles in the heart and myocardial infarction (dead portions of heart muscle) (ECHA, 2021c, 2017b).

- **Kidney histopathology**: Histologic sections of kidney tissue from lead poisoned mallards (*Anas platyrhynchos*) contained ‘acid-fast intranuclear inclusion bodies’ or ‘renal inclusions’ located in the nuclei of cells within the proximal convoluted tubule of the kidney. These cells are responsible for resorption of water, simple sugars and other essential nutrients. The functioning of these cells is compromised by the presence of renal inclusions, causing lead-poisoned animals to lose excessive water, amino acids, salts and simple sugars (Locke and Thomas, 1996; cited within ECHA, 2017b). Renal inclusions have been reported in several bird species when exposed to lead, including Mute Swans (*Cygnus olor*), Whooper Swans (*Cygnus cygnus*), and White-tailed Eagle (*Haliaeetus albicilla*) (Golden et al., 2016; cited within ECHA, 2017b).

- **Ocular effects**: Eid *et al.* (2016) described ocular lesions in a male Bald Eagle (*Haliaeetus leucocephalus*) in association with blood lead concentrations of 6.1 ppm (610 µg/dL). Pattee et al. (1981) dosed 5 Bald Eagles with 10 lead shot at a time (additional doses administered if previous shot regurgitated) and one bird became blind before being sacrificed after 133 days (the other 4 birds died before this point; see section above).

- **Growth and body condition**: Winter body condition in Whooper Swans (*Cygnus cygnus*) was significantly negatively correlated with blood lead concentrations when they were >44 µg/dL (these levels were found in 27/260 swans tested) (Newth et al., 2016).

- **Behaviour and learning**: Ecke et al. (2017) found that increased blood lead concentrations in wild Golden Eagles (*Aquila chrysaetos*) were associated with reduced flight height and movement rate even at sub-lethal levels

(0.025 µg/g ww).

Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*) exposed to lead (via injection of lead acetate at doses sufficient to produce lead concentrations in feathers equivalent to those found in wild birds) exhibited changes in locomotion, begging behaviour, individual recognition, balance, depth perception, and thermoregulation; further experiments in the wild showed the behavioural deficits were sufficient to affect growth and survival in the Herring Gulls (Burger and Gochfeld, 2000).

Exposure to 1,000 µg lead/L in drinking water during development (0 to 100 days post-hatch) caused disruption in song learning ability, reduction in the volume of song nuclei and bills with less redness in male Zebra Finches (*Taenoiopygia guttata*), resulting in less attention from females (Goodchild et al., 2021).

- **Immune function**: A detailed review of the immunotoxic effects of lead on birds by Vallverdú-Coll *et al.* (2019) showed lead at blood levels >50 µg/dL in adults and >10 µg/dL in developing birds can cause immunosuppression and ultimately reduce resistance to infection. Lead affects B-lymphocytes and the humoral immune response; T-lymphocytes and the cell-mediated immune response; macrophage function; granulocyte cells and total leukocyte counts; and oxygen-independent forms of pathogen killing (e.g. lysozyme activity) (Vallverdú-Coll et al., 2019).

  A study into the seasonal variability of the effects of lead in Red-legged Partridges (*Alectoris rufa*) also portrayed a complex picture (Vallverdú-Coll et al., 2015b). It showed lead exposure reduced natural antibody levels in spring, while in autumn it reduced lysozyme levels but increased phagocytic activity. Exposure to lead increased the T-cell response to phytohemagglutinin (PHA) (indicative of cell-mediated immune responsiveness) in both seasons, but caused a decrease in the humoral immune response (T-independent) in autumn (Vallverdú-Coll et al., 2015b). In Mallard (*Anas platyrhynchos*) ducklings, positive correlations were found between blood lead concentrations and the humoral immune response, endogenous antioxidants and oxidative stress biomarkers, while negative correlations were observed between blood lead concentrations and the cellular immune response (Vallverdú-Coll et al., 2015a).

- **Reproduction and development**: lead can disrupt the blood-brain barrier in immature birds, reduce juvenile survival and affect reproductive success (including hatchability, growth and survivability) (ECHA, 2021c). For example:

- Mallard (*Anas platyrhynchos*) eggs collected from nests in close proximity to rice fields (where lead shot was still allowed and Mallards feed) produced ducklings with mean blood lead concentrations of 3.57 ± 1.34 µg/dL (n = 30), which demonstrates maternal transfer. Those ducklings with blood lead concentrations >18 µg/dL had reduced body mass and survival (they all died within one week of hatching) (Vallverdú-Coll et al., 2015a).

- Exposure of 15 female Red-legged Partridge (*Alectoris rufa*) to 3 shot pellets (330 mg lead) significantly decreased hatching rate (from 80 % in the control group to 62 %). In males (n = 15) 3 shot pellets reduced acrosome integrity (from 65.7 to 56.3 %). However, maternal exposure to 1 pellet (110 mg lead) resulted in significantly heavier chicks (12.28 to 12.51 g) (Vallverdú-Coll et al., 2016), demonstrating a complexity of effects.
- Mourning Doves (*Zenaida macroura*) (n = 25) also exhibited a significant decrease in egg hatchability following exposure to single #8 lead shot, despite there being no differences in egg length, width or weight, productivity, fertility or squab weight (Buerger et al., 1986).
- Lead concentrations in feathers of Bonelli's Eagles (*Aquila fasciata*) from Spain were found to be statistically significantly higher in birds whose breeding attempts resulted in 0-1 fledglings compared to birds whose attempts resulted in 2 fledglings (Gil-Sánchez et al., 2018).

- **Susceptibility to lethal events**: the sub-lethal effects described above may directly affect the health of a bird, and may also increase the potential for it to be subject to predation, hunting or death via collision (ECHA, 2021c). For example, Ecke *et al*. (2017) found that increased liver lead concentrations at sub-lethal levels in Golden Eagles (*Aquila chrysaetos*) were associated with increased likelihood of mortality from other causes.

1.4.2.3.2 Ruminants

Effects due to ingestion of lead ammunition have not been extensively studied in mammalian species. However, some data are available for ruminants.

Absorption

When ingested, lead ammunition can often remain in the reticulum (forestomach), which is an alkaline environment; in this case, the metallic lead would remain inert and would not be absorbed. However, if the lead ammunition moves to the abomasum (gastric stomach), it can become more bioavailable (due to the acidity of the abomasum), leading to absorption (ECHA, 2021b). In line with this, lead absorption after oral ingestion has been shown to vary from 1% to 80%, depending on animal species, dose, form of lead, feed composition, nutritional status and age (ECHA, 2021b).

A further route of exposure to lead shot for ruminants is via contaminated feed

(ECHA, 2021b). Lead ammunition can become lodged in broad-leafed vegetation destined for silage and incorporated into the feed during processing (ECHA, 2021b). This processing includes a fermentation process that results in acidic conditions and the production of lead salts. The lead metal incorporated into the feed and the lead salts are more easily passed through the gastrointestinal tract and more readily absorbed (ECHA, 2021b).

Distribution

Once absorbed, lead is transported around the body in the blood stream. In cattle and sheep, doses of 100 mg/kg body weight may cause lead blood concentrations of 200 to 400 µg/dL within 12 hours, then reduce to 0.1 µg/dL within 72 hours and then remain above controls for two months (ECHA, 2021b). Lead concentrates in the liver, kidney and, following long-term exposure, bone. It can also enter the brain. Lead can be excreted into milk (ECHA, 2021b).

Metabolism

Lead blood concentrations depend on absorption from the gastro-intestinal tract and mobilisation from bone. Lead is not metabolised (ECHA, 2021c).

Elimination

Overall, elimination rates are very slow; the elimination half-life of lead in lactating ewes is approximately 250 days and it is 95 to 760 days in cattle (ECHA, 2021b). The main route of lead elimination is unabsorbed via faeces. In ruminants, <2% of the ingested dose is excreted via the urine (ECHA, 2021b).

Lethal and sub-lethal effects

Scheuhammer and Norris identified three independent studies that demonstrated no effects or no increase in lead concentrations in cattle after exposure to lead ammunition:

- Allcroft (1951) did not observe evidence of lead poisoning in calves fed metallic lead. No details of this study are available to provide further information.
- Bjørn *et al.* (1982) found no elevation of blood lead concentrations in heifers that grazed in pastures where bird hunting was common. No details of this study are available to provide further information, but the level of exposure is unclear.
- Clausen *et al.* (1981) examined 415 cattle and found 230 of these had between 1 and 55 lead pellets (average 0.47 g lead) present in their reticulum. No correlation was found between the number of pellets in the reticulum and

the lead content in the liver or the kidneys.

Scheuhammer and Norris also found three studies that did demonstrate lead poisoning, including that of Rice *et al.* (1987; cited within ECHA, 2021c), who studied steers that were fed silage from a field used for clay target shooting (n = 14); one died, one exhibited clinical signs of lead poisoning and all showed sub-clinical poisoning in the form of inhibited δ-ALAD activity. ECHA (2021c) state the other two studies, Frape and Pringle (1984) and Howard and Braum (1980), also indicate dairy cattle fed grass or corn silage contaminated by lead shot can suffer from lead poisoning, but the Agency does not have access to these studies to provide further details.

Three further studies have demonstrated the lethal and/or sub-lethal effects of lead exposure to cattle:

- Cattle exposed to lead-contaminated feed in the Netherlands displayed blindness, muscle twitching and hyperirritability; two animals died from the lead poisoning and 40% of the affected cows had to be slaughtered (Wijbenga et al., 1992; cited within ECHA, 2021c). Only an abstract of this study is available, and it does not mention whether the feed was intentionally contaminated.
- An incident occurred near Calcutta, India in which 5 out of 25 cattle (20%) died over a few days at a dairy farm situated near a shooting range. The investigation found that prior to death, the cattle exhibited abdominal pain, low temperature, salivation, bloody discharge from nostrils, convulsions, and coma. Samples of the soil, subsoil and grass taken from the sides of the shoot range had lead concentrations of 0.22 to 0.88 µg/g, 0.011 to 0.42 µg/g and 0.53 to 2.24 µg/g, respectively. Autopsies showed subcutaneous haemorrhage, blood and metal particles in the congested stomach and intestinal mucosa, easily detachable mucous membrane in the rumen, and blood fluid in the peritoneal cavity, among others. Concentrations of lead were measured in the liver, kidney, spleen, stomach walls and intestines, at 5.0, 11.7, 3.5, 7.1, and 4.5 µg/g respectively (Ganguli and Chowhuri, 1953).
- In a study where calves (n = 5; 7 to 9 months old) were allowed to graze in an area that had been used as a shooting range over several years, one calf (20 %) died from acute poisoning after 5 days. The other calves became ill 1 to 3 days later, and all but one of these (which was euthanized) died within hours of first exhibiting symptoms. Neurological disturbances, including maniacal movements, opisthotonos, drooling, rolling of the eyes, convulsions, licking, jaw champing, bruxism, bellowing and breaking through fences, were observed. Grass and soil lead concentrations were 29,550 and 3,900 mg/kg, respectively in a single sample of each (Braun et al., 1997).

- Payne et al. (2013) report two cases of lead poisoning in cattle due to the ingestion of lead shot that resulted in death in the UK. In the first case, cattle were exposed to lead via maize silage harvested from a field adjacent to a clay pigeon shoot. In the second, lead poisoning resulted from cattle grazing directly from a field near a shoot.

A review of lead poisoning in cattle and sheep (Payne and Livesey, 2010) reported the following observed effects:

- In animals that died of acute poisoning: congestion of the liver and pale kidneys, gastrointestinal haemorrhage, and visible oedema of the central nervous system;
- In animals with sub-acute poisoning: laminar cortical necrosis within the cerebrum and nephrosis; and
- In animals subject to chronic poisoning: loss of body condition, emaciation, muscle wastage and developmental abnormalities in foetuses.

1.4.2.4 *Hazard conclusions*

Numerous studies have demonstrated that exposure to lead shot can cause a range of toxic effects in wildlife, particularly birds.

Ingestion of a single lead shot pellet is enough in some circumstances to kill an individual bird. A variety of sub-lethal effects can also occur, such as reduced body condition, altered immune responses, effects on blood parameters and the cardiovascular system, altered kidney histopathology and ocular lesions which may lead to blindness. Effects that are directly relevant at a population level include those on adult survival, behaviour and learning, and reproduction, growth and development (such as reduced egg hatchability and juvenile survival). Intoxicated birds may also be more susceptible to lethal events such as predation or collision.

The data for toxicological effects in ruminants are not generally from experiments testing different levels of exposure. Instead, they are accidental or unintentional exposures that have resulted in effects. However, they indicate that ingestion of lead ammunition can result in adverse effects, including death.

Typically, in environmental risk assessments the calculation of a $PNEC_{oral}$ can be used to assess the risk of direct toxicity for predators (i.e. birds) due to exposure of the predator via its prey (e.g. characterising the soil–worm–bird food chain). The PNEC is calculated based on toxicity data derived from standard test guideline studies, which expose test organisms via the diet and explore endpoints that are considered population relevant (ECHA, 2008). However, the available data summarised in this section do not adhere to standard test guidelines, due to the nature of lead shot. Its toxicity is dependent on pellet size and the toxicokinetics of the various bird species. Therefore, it is not possible to derive a $PNEC_{oral}$ for birds for use in this assessment where the key exposure route is the direct ingestion of lead or the secondary ingestion of lead particles in prey items.

ECHA (2021b) identified indicative thresholds that represent levels where adverse effects in birds are likely to occur based on previously published thresholds, as summarised in Table 1.8. However, it should be noted that sub-lethal effects have been found at lower lead concentrations than these. For example, Espin *et al*. (2014) demonstrated that blood lead concentrations of 15 µg/dL can cause oxidative stress in Griffon Vultures (*Gyps fulvus*), while the threshold for sub-clinical poisoning defined in Table 1.8 is 20 to <50 µg/dL ww. Ecke *et al*. (2017) linked blood concentrations of 0.025 µg/g ww with changes in behaviour (reduced flight height and movement rate), which is below the threshold for background levels of exposure in Table 1.10.

ECHA (2021b) noted that these discrepancies may indicate a need for a review of the thresholds. Regulatory restrictions placed on a range of anthropogenic uses of lead have resulted in a lowering of exposure levels in general and this has enabled effects to be determined at ever lower lead concentrations. In addition, technological advances have enabled the detection of lead concentrations in biological samples at lower levels and the ability to better study behaviour and other effects. Helander et al. (2021) (reviewed in Section 1.4.6.1.2) report that background concentrations without the influence of lead from ammunition may be an order of magnitude lower than previously thought for the species they studied. The Agency notes that as more experimental studies examining additional sub-lethal endpoints become available these may indicate that a revision of the thresholds is required. However, the thresholds in Table 1.8 can still be used to provide an indicative interpretation of the effects of lead concentrations measured in birds and other animals. In addition, as more conservative novel data would only lower the thresholds the current values can be used to estimate the minimum scale of potential effects.

The thresholds should not be considered equivalent to PNECs, although they can be used to interpret tissue concentrations in the management of wildlife on contaminated areas and compare lead concentrations in unexposed wild birds with those where clinical effects and mortality may occur (ECHA, 2021c). In live birds, the sequential analysis of blood lead concentrations within an individual can give a clear picture of exposure over time; that is, the concentrations of lead in the blood provide an indicator of recent (days to weeks) ingestion. The concentration of lead in the bone is generally considered indicative of lifetime (not recent) exposure (ECHA, 2021c).

Table 1.8 Indicative thresholds of lead exposure that represent levels where adverse effects in birds are likely to occur, noting that recent evidence suggests these thresholds may need to be reviewed and revised downwards *(adapted from ECHA, 2021b)*

Lead poisoning endpoint	**Blood lead concentration**	**Liver lead concentration**	**Bone lead concentration**
Background (i.e. no history of lead exposure)	<20 μg/dL ww *or* <0.2 μg/g ww	<2 μg/g ww *or* <6 μg/g dw	<10 μg/g dw
Sub-clinical poisoning	20 to <50 μg/dL ww *or* 0.2 to <0.5 μg/g ww	2 to <6 μg/g ww *or* 6 to <20 μg/g dw	10 to 20 μg/g dw
Clinical poisoning	50 to 100 μg/dL ww *or* 0.5 to 1 μg/g ww	6 to 15 μg/g ww *or* 20 to <50 μg/g dw	>20 μg/g dw
Severe clinical poisoning	>100 μg/dL ww *or* >1 μg/g ww	>15 μg/g ww *or* >50 μg/g dw	-

1.4.3 Environmental exposure – quantities

Information on the amounts of lead ammunition used annually in GB has been reviewed in this section. When possible, amounts are split by ammunition type and use. As this information is not typically publicly available, the majority was provided to the Agency by relevant stakeholders. The Agency requested additional information on the volumes of projectiles used for both target and live quarry shooting for each type of ammunition in the public consultation. We received comprehensive information from a number of the trade associations and some ranges and individuals. The Agency have assessed the methodology for each of the estimates and have updated our original estimates from the Annex 15 dossier (HSE, 2022) with the most appropriate values. The final estimates in this section have been rounded to the nearest appropriate significant figure.

1.4.3.1 *Quantities of lead shot used in GB (uses 1 and 4)*

The Agency received information in the public consultation from five stakeholder organisations on the quantities of lead shot used annually in GB. Each of these organisations used differing methodology to estimate the quantities. Each submission is described in more detail below.

Gun Trade Association (GTA) (uses 1 and 4)

The GTA (Organisation #132) represents manufacturers and retailers of guns and ammunition as well as repair of weapons and provision of shooting opportunities. They commissioned a report on the current market in lead shot and the transition to lead free manufacture for the public consultation which was submitted during the consultation period (Blake International, 2022 Organisation #132). The report is based on interviews with the UK based cartridge manufacturers and gives estimates of the volume of cartridges manufactured, imported, and exported by these companies.

The survey reports that the UK manufacturers manufactured 235 million shotgun cartridges, imported 30 million and exported 21.8 million, giving 243 million cartridges in the domestic market.

The estimates of number of cartridges and volume of lead is shown in Table 1.9 and Table 1.10.

Table 1.9 Current UK Shotgun Cartridge Market by Volume 2021/22 (Excluding Reloader/Artisan Sector)

Cartridge Type	Manufactured (Cartridges)	Imported (Cartridges)	Exported (Cartridges)	Domestic Consumption (Cartridges)
Lead	234,547,770	30,000,000	21,783,000	242,764,770
Steel	44,401,630	120,000	36,826,000	7,695,630
Other metals	1,293,750	0	137,000	1,156,750
Total	280,243,150	30,120,000	58,746,000	251,617,150

Table 1.10 Current UK Shotgun Cartridge Market by Tonnage Shot 2021/22 (Excluding Reloader/Artisan Sector)

Cartridge Type	Manufactured (Tonne)	Imported (Tonne)	Exported (Tonne)	Domestic Consumption (Tonne)
Lead	6,531	896	610	6,817
Steel	1,144	4	1,031	117
Other metals	23	0	4	19
Total	7,698	900	1,645	6,953

The cartridge size used to calculate the volume of lead has not been given, but the Agency calculates that the average is 28 g. The total tonnage from these manufacturers and importers is 6,817 tonnes per year. (Blake International, 2022 Organisation #132) estimated that 77% is used for clay pigeon shooting, there is no justification for the proportions given. Therefore the potential annual release of lead into the environment from live quarry shooting would equate to 1,568 tonnes per year, with the remaining 5,249 tonnes being used for clay pigeon shooting.

The survey covered the 4 large manufacturers and importers; namely: Gamebore, Hull Cartridge Company, Eley Hawk Ltd and Lyalvale Express/Fiocchi and in the agency's view covers the appropriate companies for the GB supply. In addition to these manufacturers, there exists home loaders, minor micro-entities, reloading or making artisanal shot shell products which Blake International, 2022 (Organisation #132) estimates comprises 5% of the total value and volume of the UK market. This gives a volume of 359 tonnes of lead for this use (based on a calculation of ((6,817/95 x 100 = 7,176) (7,176– 6,817=359)). This would equate to an annual UK consumption of lead shot of 7,176 tonnes. On the assumption that the split of live quarry and target shooting is the same for the artisanal and small producers the total volume of lead released from live quarry shooting would equate to 1,649 tonnes per year, with the remaining 5,525 tonnes being used for clay pigeon shooting. Once adjusted for GB (~0.97) the volumes are **1,601** tonnes for live quarry shooting and **5,359** tonnes for target shooting, with a total of **6,960** tonnes per year.

British Association of Shooting and Conservation (BASC) (uses 1 and 4)

BASC (Organisation #83 and #115) is an association whose purpose is the protection and promotion of country shooting and its associated activities. They also provide advice to shooters, specialist publications and shooters insurance.

BASC submitted the estimated volumes of lead released from shot cartridges in a year as below, this was based on information submitted by the British Sports Shooting Council (BSSC) in the call for evidence in 2021, these are shown in *Table 1.11*.

Table 1.11 BASC estimated number of cartridges and volume of lead per year

	'Sports shooting' cartridges			'Hunting' cartridges			
Bore size	**Number of lead cartridges used / year (millions)**	**Average load of lead per cartridge in grams**	**Weight of lead in tonnes**	**Number of lead cartridges used / year (millions)**	**Average load of lead per cartridge in grams**	**Weight of lead in tonnes**	**Number of non-lead cartridges used per year (millions)**
10	n/a	n/a	n/a	0.1	50	<1	<0.1
12	161	28	4,508	61.8	30	1,854	5.2
16	0.9	24	21.6	1.7	28	47.6	
20	10.1	21	212.1	11.7	28	327.6	1.3
28 **				2.5	25	62.5	
36 (.410)	1	11	11	2.5	18	45	
Total	**173**		**4,752.7**	**80.2**		**2,336.7**	**6.5**

* Review of shot weight of lead loads on sale at a leading retailer www.justcartridges.co.uk
** GTA data suggests that 28 bore use in clay shooting is negligible.

The total volume of lead (tonnes) is 7,090. Of this, 2,337 tonnes is used for live quarry shooting and 4,753 tonnes for target shooting. Once adjusted for GB the volumes are **2,270** tonnes for live quarry shooting and **4,610** tonnes for target shooting, with a total of **6,880** tonnes per year.

Wildfowl and Wetlands Trust (WWT) (use 1)

The WWT (Organisation #134) is a leading wetland and conservation charity. They put together an estimate of lead shot used for live quarry shooting based on Aebischer (2019). The total number of birds shot annually is estimated to be 23,971,339 by WWT. The volume of lead used is based on 30 g of lead per cartridge and a shot to kill ratio of 4:1 and 5:1, giving a range of 2,877 – 3,596 tonnes per year of lead shot used for live quarry shooting. Once adjusted for GB the volumes are **2,790 - 3,490** tonnes per year.

Clay Pigeon Shooting Association (CPSA) (uses 1 and 4)

The CPSA (Organisation #101) is the national governing body for clay pigeon shooting. They submitted the same estimate of cartridges in the public consultation as that in the call for evidence. The estimate is 260,000,000 cartridges per year with a split of 30 % used for hunting and 70 % used in clay pigeon shooting. This is based on a previous GTA survey, giving an average of volumes over a period of 5 years (2016-2019). The CPSA do not give an estimate of the total quantity of lead released.

Cartridges used for hunting are generally larger than the typical 24 g used for clay pigeon shooting (CPSA), 30-32 g is commonly used for pigeon and game shooting (LAG, 2015a). Therefore the quantities can be estimated as 30% of 260,000,000 cartridges at 32 g each would be 2,496 tonnes per year for live quarry shooting (0.3 x 260,000,000 x 32)/1,000,000 and 4,368 tonnes per year for clay target shooting (0.7 x 260,000,000 x 24)/1,000,000. This gives a total of 6,864 tonnes of lead per year. Once adjusted for GB the volumes are **2,420** tonnes for live quarry shooting and **4,240** tonnes for target shooting, with a total of **6,660** tonnes per year.

Muzzle Loaders Association of Great Britain (MLAGB) (uses 1 and 4)

Muzzle Loaders Association of Great Britain (MLAGB) (Organisation 121) is the governing body for muzzle loading within the UK. They submitted information gathered from UK government data and a survey they undertook of their members.

The MLAGB used the number of firearms certificates to estimate the number of weapons and a survey of their members to estimate the total volume of lead shot used for target shooting and gave the following figures. The number of shotguns was derived from a survey undertaken by MLAGB of their members in 2022. The survey achieved 40% response rate for the number of weapons held and the quantity of lead shot in a year. These numbers were then extended to cover the whole of the UK (Table 1.12).

Table 1.12 summary of MLAGB shotgun estimates, GB

Weapon	Number of weapons	Total number of projectiles / cartridges	Total lead released tonnes per year	Average weight per projectile / cartridge g
Shotguns	8,020	529,000	15.8	29.9

A small number of muzzle loading arms are used for live quarry shooting in the UK. The MLAGB estimates this number to be less than 100, all of which are shotguns.

The number of shot gun cartridges used for live quarry shooting in the UK is estimated at 2,600, equivalent to 79.4 kg of lead annually in the UK.

Individuals from RISEP (use 1)

Two individuals from RISEP gave feedback that the estimated volumes derived by Blake International, 2022 (Organisation #132) seemed unrealistically low for the volume for live quarry shooting. The comments received from these panel members were that the volume should be based on hunting bag estimates based on Aebischer (2019) and Green and Pain (2015a). These estimates are 2,668 tonnes from Aebischer (2019) and 3,487 tonnes per year from Green and Pain (2015a) and as neither hunting bag contained all the quarry species these were expected to be underestimates. Once adjusted for GB the volumes are **2,587** tonnes and **3,382** tonnes respectively for these studies. These estimates have been considered by the Agency in our revision of this section.

1.4.3.1.1 Quantities used for this dossier

A summary of the different estimates received during the public consultation is shown in *Table 1.13*.

Table 1.13 Summary of volumes of lead released from shot cartridges submitted during the public consultation

Tonnage	GTA – Blake International	BASC (GB,	WWT (GB,	CPSA (GB,	MLAGB (GB,	RISEP feedback

	report (GB, tonnes)	**tonnes)**	**tonnes)**	**tonnes)**	**tonnes)**	
Live quarry shooting	1,601	2,270	2,790 - 3,490	2,420	0.1	2,587 – 3,382
Target shooting	5,359	4,610	No data	4,240	15.8	
Total	**6,930**	**6,880**		**6, 660**	**15.9**	

Estimates of the total tonnage of lead shot used in GB were provided by several key stakeholders as part of the public consultation. The GTA submission is selected as the key data source, as this information has been provided by the manufacturers and importers and is based on a very recent survey of the four GB manufacturers.

The estimate supplied by WWT, using a shooting bag paper from 2019 (Aebischer, 2019), was the highest and is based on two different shot:kill ratios. The estimate provided by BASC used the results of a survey originally supplied by BSSC covering the years 2015-19. The total number of cartridges estimated by the CPSA is also very close to the BASC estimate, but was based on data from the Aebischer (2019) study. The estimates from individuals on RISEP were also similar to those of the WWT, which is to be expected as they are based on the same source.

The Agency acknowledges that the estimated releases of lead shot from live quarry shooting provided by Blake International (2022) are lower than the other estimates outlined above. The estimated releases used by the Agency should not be seen as definitive, rather those considered most appropriate and sufficient for this assessment. In this regard, the Agency considers recent survey data from the manufacturers to be the most reliable source of information. Although well established in the literature, estimates based on game bag data are reliant on several assumptions, not limited to survey estimates of the number of gamebirds shot with lead and the average shot to kill ratio in game shooting. Additionally, Blake International (2022) provides an estimate of the total quantity of lead shot used across both live quarry shooting and target shooting. As such, a greater estimated quantity of lead shot attributed to live quarry shooting necessitates a reduced quantity attributed to target shooting, otherwise the total quantity of lead shot used per year is overstated. The estimated total across the two uses reported in Blake International (2022) is similar to that provided by BASC (2022) and CPSA (2022). In the Agency's cost-benefit analysis of the shot restrictions (see Section 2), cost and benefits are a function of the volumes of lead released to the environment. Increasing the estimated quantity of lead shot used in live quarry shooting increases both the costs and benefits of a restriction on this use proportionately, making no significant difference to the case for restriction on this use, or on target shooting. Were the Agency to use a higher estimated tonnage release based on game bag methodology, this would not change the Agency's conclusions on proportionality.

We have assumed that the quantity of shotgun cartridges used by muzzle loaders are covered by the 5% of artisanal / reloaders included within the GTA estimate. As the GTA estimate was derived from survey of the large manufacturers and importers and takes into account a contribution from the artisanal and reloaders, their value of **6,930** tonnes per year has been taken forward in this analysis.

1.4.3.2 *Quantities of bullets used in GB in live quarry shooting (use 2)*

During the public consultation the Agency requested data on the quantities of bullets used based on small and large calibre using a cut-off of 5.6 mm and this is reflected in the quantities discussion below. However, based on information received during the public consultation a discussion of the appropriate value to select to distinguish between small and large calibre bullets is included in Section 2.2.

1.4.3.2.1 Small calibre bullets (use 2)

BASC (Organisation #83 and #115) submitted an estimate of bullets used for live quarry shooting into the public consultation and use the game bag census data from Aebisher (2019). This estimates 152,560 deer and 89,000 foxes to be taken every year, and a further 507,600 small mammals. They then commissioned a survey in *Guntrade*, a UK online gun trading platform, and conclude that 51% of all rifles fall within the Agency's small calibre definition (<5.6 mm). This breaks down into 37% rimfire, 14% centrefire. They take the shot:kill ratio on rabbits from a study by Hampton et al (2020) which suggests an average shot:kill ratio on rabbits of 1.27:1 with lead rimfire ammunition and assume that all small mammals are shot with rimfire rifles, and therefore 644,650 bullets are used here (507,600 x 1.27). This assumes the rabbit shot:kill ratio is suitable for all 'small mammals'.

BASC state rimfires are 'generally not used' for shooting of foxes and cannot legally be used for shooting deer in UK. As such they just use small game in their rimfire estimate. They state that internal desktop research (2019) suggests 22% of centrefire rifles on sale in the UK met the Agency small calibre definition. They state that these can legally be used for some species of deer, but the use is limited, so they focus on fox shooting, estimating that 22% of the 89,000 foxes are taken with small calibre centrefire rifles 0.22 x 89,000 = 19,580 bullets. They use a shot to kill ratio of 1.076:1 taken from Aebischer (2014) and therefore estimate 21,068 bullets were required to kill these foxes.

These two totals sum to their estimate of 665,718 bullets (644,659 rimfire, 21,068 centrefire). We adjust this by the GB population as a proportion of UK (~0.97), which gives an estimate of 647,239 bullets.

BASC then state that online retailers show centrefire bullet weights ranging from 35 to 85 grains, with 55 grains ‘being a popular bullet weight’. As such, they assume the centrefire bullets to be 55 grains which they state to weigh 3.56 grams. 21,068 x 3.56 g = 0.075 tonnes lead.

To estimate the weight of lead emissions from rimfire bullets, they multiply 644,659 by a bullet weight of 2.4 g = 1.55 tonnes lead.

The total estimated annual UK emission from live quarry shooting with small calibre bullets is 1.62 tonnes lead (0.075 + 1.55).

1.4.3.2.2 Large calibre bullets (use 2)

BASC submitted an estimate of bullets used for live quarry shooting into the public consultation and use the game bag census data from Aebisher (2019). This estimates 152,560 deer and 89,000 foxes to be taken every year. They assume all deer are shot with large calibre rifles (for the majority of deer this is the case, though some species can be legally shot with .22 centrefire) and that 78% of the foxes are shot with large calibre. They use wounding rates in deer from Aebischer (2014) and assume this is the suitable estimate for foxes too. This study finds a shot:kill ratio of 1.076:1. The Agency dossier assumes an average large calibre bullet weighs 7 g (ECHA), and this gives total estimated emissions of:

(152,560 + (89,000 x 0.78)) x 1.076 x 7 g = 1.67 tonnes lead (238,850 bullets).

BASC note that not all foxes are shot, some may be caught by traps. In addition, a minority of smaller deer can be shot with .22 centrefire and so this estimate includes some numbers that would be shot with small calibre bullets. This provides some upward bias in the estimate. However, other mammals (for example boar) would be shot with large calibre bullets that are omitted from this estimate.

1.4.3.2.3 Quantities used for this dossier

The values from BASC have been used in our evaluation in the absence of other estimates. To account for the updated cut-off of 6.5 mm the estimates for small and large calibre have been updated. As discussed above, the total estimate of large calibre bullets is 1.67 tonnes in the UK, defined as being ≥5.6 mm. According to BASC (Organisation #83 and #115) 13.9% of the bullets fired are between 5.6 and 6.5 mm, this gives a total of approximately 0.23 tonnes of lead which we have removed from the large calibre quantity and included in the small calibre quantity. This gives an updated estimate of 1.85 tonnes of small calibre bullets (<6.5 mm) and 1.44 tonnes of large calibre bullets (≥6.5 mm). Further discussion on this change to the threshold for large and small calibre can be found in section 2.2.4.5.

Adjusting this for GB as a proportion of UK results and rounding to the nearest tonne results in **2** tonnes for small calibre and **1** tonne for large calibre.

1.4.3.3 *Quantities of bullets and muzzle loader projectiles used in GB in target shooting (use 5)*

During the public consultation the Agency requested data on the quantities of bullets used based on small and large calibre using a cut-off of 5.6 mm and this is reflected in the quantities discussion below. However, based on information received during the public consultation a discussion of the appropriate value to select to distinguish between small and large calibre bullets is included in Section 2.2, this cut-off was revised to 6.5 mm. The volumes below have been adjusted to take into account the updated cut-off figure.

1.4.3.3.1 Small calibre bullets (use 5)

The National Rifle Association (NRA) (Organisation #127) submitted a report into the public consultation giving the results of a survey they did with a number of their members, who had indicated that they operated ranges. The records for these 279 members do not distinguish between indoor and outdoor ranges. The 279 range operators were sent an NRA survey to estimate lead bullet use, 92 responded. The NRA state that 57 of these have provided sufficient data for them to estimate emissions. The NRA estimate there to be 300 outdoor ranges in the UK, so they apply the average emission per range based on the 57 adequate responses multiplied by 300 to get total emissions in UK ranges.

The average survey response was 38,144 small calibre rounds per range per year. Multiplied by 300 this equals 11.44 million rounds at a UK level. They state this emission of bullets to weigh 30.6 tonnes of lead, which implies an average bullet weight of 2.67 g. This seems reasonable - BASC estimate the (modal) average rimfire bullet used in target shooting to weigh 2.4 g and centrefire 3.56 g.

The NRA also note that the National Shooting Centre (NCS) Bisley sell 305,000 small calibre bullets per year, with an estimated additional 50% from other sources also being shot at Bisley. This results in an estimated 458,000 small calibre bullets being shot at Bisley. The NRA add this to their previous estimate of 11.44m, as Bisley was not included in the 300 outdoor ranges used to derive that figure. This gives a UK total of 11.86m small calibre bullets per year with NRA estimating a weight of 32 tonnes of lead in the UK.

There is some uncertainty regarding the use of the average estimate from each range, it is possible that only the more resourced ranges had capacity or ability to reply to survey. They likely emit more lead, meaning applying their average to all sites could overestimate emissions. There is some uncertainty as there was no differentiation in the data gathering between indoor and outdoor ranges. The estimate also did not include the number of rounds used by civilians on military ranges and therefore is likely to be an underestimate.

British Association of Shooting and Conservation (BASC)

BASC (Organisation #83 and #115) estimated volumes of small calibre bullets of 10.13 tonnes of lead. They used PACEC (2014) estimate of expenditure on rifle bullets divided by 2019 prices of bullets to estimate use. Adjusting for GB this would be **10** tonnes of lead. The data on expenditure and typical bullet price is collected from different years which, even when adjusted for inflation, adds uncertainty as the market may have changed significantly.

1.4.3.3.2 Large calibre bullets (use 5)

National Rifle Association (NRA)

The National Rifle Association (NRA) (Organisation #127) submitted a report into the public consultation giving the results of a survey they did with a number of their members, who had indicated that they operated ranges. The records for these 279 members do not distinguish between indoor and outdoor ranges. The 279 range operators were sent an NRA survey to estimate lead bullet use, 92 responded. The NRA states that 57 of these have provided sufficient data for them to estimate emissions. The NRA estimate there to be 300 outdoor ranges in the UK, so they apply the average emission based on the 57 adequate responses multiplied by 300 to get total emissions. In the survey the NRA requested that each range estimate the total quantity of bullets fired on their rounds in a year and then list the three most popular calibres. The proportion of the total number of rounds fired for each of the three calibres is based upon ammunition sales for these calibres at the National Shooting Centre ("NSC") at Bisley and the bullet weights (in grains) were converted to grams to calculate the weight of the rounds fired by calibre. NRA estimate an average of 16,375 large calibre rounds per range per year. Multiplied by 300, this gives 4.91 million rounds, weighing an estimated 54.3 tonnes. The NRA also note that the National Shooting Centre (NCS) Bisley sell 904,000 large calibre bullets per year, with an estimated additional 50% from other sources also being shot at Bisley. This results in an estimated 1,356,000 large calibre bullets being shot at Bisley with a total weight of 14.6 tonnes of bullets.

As with small calibre, they also add Bisley contributions to this, which results in a total of 6.27 million bullets weighing 68.9 tonnes. They note that the majority of large calibre bullets are constructed with a copper jacket over a lead core. They estimate for this to account for 20% of the weight. As such, 68.9 tonnes bullets equates to 55.1 tonnes of lead, assuming that all the bullets were 80% lead.

The uncertainties are similar to those of the small calibre estimates as discussed in section 1.4.3.3.1, that the figure could be an overestimate. This figure does not include muzzle loading projectiles which have been discussed in section 1.4.3.3.3 below.

British Association of Shooting and Conservation (BASC)

BASC (Organisation #83 and #115) estimated volumes of large calibre bullets of **34** tonnes of lead. They use the LAG (2015b) estimate of annual total rimfire bullet use, and take this away from PACEC (2014) estimates of expenditure on bullets multiplied by the price of bullets (2019) to estimate annual centrefire bullet use. They then estimate what proportion of rifles are large calibre rifles (78%) and multiply this by their estimated number of centrefire bullets used annually to estimate total emissions. They weight this result based on PACEC (2014) assumptions of the ratio of outdoor to indoor ranges. There are lots of steps for uncertainty to amplify in that approach.

Muzzle Loaders Association of Great Britain (MLAGB)

Muzzle Loaders Association of Great Britain (MLAGB) (Organisation 121) is the governing body for muzzle loading within the UK. They submitted information gathered from UK government data and a survey they undertook of their members.

The MLAGB used the number of firearms certificates to estimate the number of weapons and a survey of their members to estimate the total volume of lead released and gave the following figures. The number of pistols is derived for England and Wales only from Firearms Certificate information held by the UK Government. The number of rifles and muskets were derived from a survey undertaken by MLAGB of their members in 2022. We have taken forward the quantities derived for rifles and muskets as part of the large calibre quantities. The survey achieved 40% response rate for the number of weapons held and the quantity of lead ammunition used in a year. These numbers were then extended to cover the whole of the UK (*Table 1.14*).

Table 1.14 summary of MLAGB estimates, UK

Weapon	Number of weapons	Total number of projectiles / cartridges	Total lead released tonnes per year	Average weight per projectile g
Rifles	6,167	518,000	11	20.6
Pistols, including miniature cannon	10,150	1,920,000	17	9.1
Total	**24,337**	**2,967,000**	**28**	

The MLAGB estimates that the total quantity of lead used for muzzle loading shooting in the UK is **28** tonnes made up of **11** tonnes (muzzle loading rifles) and **17** tonnes (muzzle loading pistols). Adjusting for GB as a proportion of UK population gives **27** tonnes of lead.

National Rifle Association (NRA)

The NRA undertook a survey of their members who use muzzle loaders asking a series of questions. 275 people out of 1,043 who had indicated that they shoot muzzle loaders responded. The results are shown below and are taken directly from the response:

i. "What is your best estimate of the number of projectiles fired in a year?

1.

Answer choices	*Average*	*Number responses*	*Aggregate total*
Less than 100	*50*	*76*	*3,800*
100 to 500	*300*	*147*	*44,100*
More than 500	*750*	*44*	*33,000*
Totals		*267*	*80,900*

ii. Therefore the average number of lead projectiles (excluding shotgun) fired by each muzzle loader sports shooter each year = (80,900 / 267) = 303.

iii. Out of a total membership of 10,200 the NRA has 1,043 (10.2%) members who self-define as muzzle loading target shooters. The NRA and affiliated clubs have a combined total of 47,000 members; we estimate this includes 4,800 (i.e. 10.2%) muzzle loader target shooters.

iv. We estimate the number of lead projectiles used in muzzle loaders for sports shooting as (4,800 x 303) = 1.45 million each year.

v. To the question "What is the best estimate of the weight of the projectiles fired in a year?"

2.

Answer choices	*Average*	*Number responses*	*Aggregate total*
Less than 2.5kg	*1.25kg*	*135*	*168.75kg*
2.5kg to 10kg	*6.25kg*	*107*	*668.75kg*
More than 10kg	*15.00kg*	*27*	*405.00kg*
Totals		*269*	*1,242.50kg*

vi. Therefore the average weight of lead projectiles fired by muzzle loader sports shooters each year = (1,242.50 / 269) = 4.62kg

vii. 4.62 kg divided by 303 (average no of projectiles fired) is 235 grains, which is a reasonable estimate for the median weight of a muzzle loaded projectile (range 70 - 450 grains)

viii. We estimate the weight of lead projectiles used in muzzle loaders for sports shooting as (4,800 x 4.62kg) = 22.2 tonnes each year

Adjusted for GB the volume of lead is **22** tonnes per year.

1.4.3.3.3 Quantities of bullets and muzzle loader projectiles used for this dossier

Estimates of quantities were supplied by the different stakeholders are shown in **Table 1.15**.

Table 1.15 Summary of volumes of lead released from bullets for target shooting submitted during the public consultation

Tonnage	NRA GB (tonnes)	BASC (GB, tonnes)	MLAGB (GB, tonnes)
Small calibre	31	10	No data
Large calibre	54	34	No data
Muzzle loaders (assumed to be large calibre)	22	No data	27
Total	**107**	**44**	**27**

The Agency considers the estimate received from the NRA for small and large calibre bullets to be most reliable as it is derived from survey data for their members. However there is some uncertainty over these figures as the survey could have been completed only by those larger ranges who are better resourced and able to respond and therefore these figures could be an overestimate.

To account for the updated cut-off of 6.5 mm the estimate for small and large calibre has been updated. As discussed above, the total estimate of large calibre bullets is 55 tonnes in the UK, defined as being ≥5.6 mm. According to BASC (Organisation #83 and #115) 13.9% of the bullets fired are between 5.6 and 6.5 mm, this gives a total of approximately 8 tonnes of lead which we have removed from the large calibre quantity and included in the small calibre quantity. This gives an updated estimate of 40 tonnes of small calibre bullets (≤6.5 mm) and 47 tonnes of large calibre bullets (≥6.5 mm). Adjusting this for GB as a proportion of UK results **38** tonnes of lead for small calibre and **46** tonnes for large calibre.

For muzzle loaders, the estimate from the MLAGB is considered the most reliable as it is based on the number of firearm certificates held and a survey of their members, which was then extrapolated to cover all the certificate holders. The NRA survey was limited to just NRA members and affiliated sites, so has a narrower reach than that done by the MLAGB, so is likely to be an underestimate. The NRA estimate does not give a split of the different types of weapon, which makes it more difficult to compare with the MLAGB data. However, the average weight of each projectile is 14 g from the NRA and 14.8 g from the MLAGB, so this shows good correlation between the 2 estimates.

The estimate of muzzle loader projectiles have been included in the large calibre estimate as the average weight of projectiles for rifles is 20.6 g and for pistols (including miniature cannon) is 9.1 g. This gives a total estimate of large calibre bullets of 46+27 = **73** tonnes.

1.4.3.4 *Quantities of airgun ammunition used in GB (uses 3 and 6)*

We do not consider that there are any reliable estimates of the number of airguns or the amount of lead used by these shooters. There is no requirement to register airguns in England and Wales and the weapons and pellets are readily available to purchase online and in store. In Scotland, owners of airguns must register them if a firearms certificate is not required. Data from Police Scotland (2021) shows that there were a total of 30,374 airgun certificates on issue as at 31st March 2021.

In the public consultation we received a large number of estimates for quantities of airgun ammunition used in GB. Estimates from shooting organisations and some individuals are reviewed below. Additional information submitted in the consultation which has not been used in the evaluation can be found in the response to comments document.

Shooting Organisations

BSSC (Organisation #100) gave an estimate of 9 million air rifles in the UK firing approximately 30 million pellets per year for both live quarry shooting and target shooting combined, which, based on the weight of air pellets being between 0.5 g and 1 g would result in total emissions of lead of 15 – 30 tonnes of lead per year. Once adjusted for GB the volumes are **15 - 29** tonnes of lead.

The British Field Target Association (Organisation #41) supplied an estimate of 1.2 tonnes per year used for both UK and international competitions in field target shooting. Once adjusted for GB the volume is **1.1** tonne of lead.

The Vintage Arms Association (Organisation #139) estimate the number of pellets to be 25 - 30 million based on the figure of 9 million weapons which, based on the weight of air pellets being between 0.5 g and 1 g would result in total emissions of lead of 12.5 – 30 tonnes of lead per year. Once adjusted for GB the volumes are **12 – 29** tonnes of lead.

BASC (Organisation #83 and #115) estimated that 31.8 million pellets are used per year. This is based on the annual income from shooting sports providers of £0.62m, which gives a total of 13.4 tonnes per year from a survey conducted in 2012/13 (PACEC (2014). In the report BASC estimate that a tin of 500 airgun pellets costs £10.30. They divide £0.62m/£10.30 to estimate that 60,194 tins are purchased per year. This has been amended by inflating the PACEC data to 2019 prices to match the BASC data via HM Treasury's GDP deflator (HMRC, 2023). This results in an updated estimate of 65,313 tins purchased annually, and a total of approximately 32.7m pellets. Adjusting this for GB population gives 31.8m pellets.

From desk research BASC estimate that 45 % of airguns are .177 and 55 % are .22. .177 pellets 'typically' weigh 0.5 g. .22 pellets are 'typically around 1 gram. This provides a weighted breakdown of 45 % of 32.7million x 0.5 g = 7.3 tonnes and 55 % of 32.7 million x 1 g = 17.96 tonnes, giving a total tonnage of 25.26 tonnes per year. BASC estimate that 53% of the total usage is outdoors, so this gives a final lead release to the environment of 13.4 tonnes per year. Once adjusted for GB the volume is 13 tonnes of lead.

Retailers

A number of retailers submitted information on their sales. May of London (Organisation #22) sells in excess of 1 million pellets per year, Surrey Armoury (Organisation #108) sell approximately 50,000 pellets, and Individual #230, a slug retailer, sells between 160,000 and 240,000 pellets per year.

Ranges

A number of ranges estimated the total annual use on their sites. The Welsh Airgun Field Target Association (Organisation #42) estimated that their 135 members shot an average of 5,000 pellets each over their 7 ranges. This gives a total of 675,000 pellets and 365 kg of lead, based on 0.55 g per pellet. West Hull Rifle and Pistol Club (Organisation #45) estimates a total of 35,000 pellets per year and 19.25 kg of lead, based on 0.55 g per pellet. PGL Travel Ltd (Organisation #47), a travel organisation for children, gave information on their 10 outdoor centres and estimated a total of 4 million pellets across all the sites. This gives a total of 2.2 tonnes of lead per year.

Individuals

We received 51 responses regarding individuals' personal usage. There was also a report submitted by individual #2168 who submitted the results of an online survey they had conducted. They surveyed users of an online airgun forum to elicit estimates of their annual use. They then used airgun certificate data from Scotland, calculating the number of certificates per capita and extrapolating this to England and Wales in lieu of certificate data for these two countries. Using this and their survey data, they estimate the annual emissions from airguns to be 935 tonnes per year from target shooting and 108 tonnes per year from live quarry shooting. The individual's methodology is well justified, but it is likely that the sample used in their analysis is biased; the estimates assume that the average airgun user shoots as many pellets as members of an online airgun forum willing to spend time completing a survey. As a result, we do not consider these estimates to be robust and have not used them in our evaluation.

1.4.3.4.1 Quantities used for this dossier

The values derived by the various stakeholders are summarised in *Table 1.16*.

Table 1.16 Summary of airgun ammunition estimates from UK organisations, GB, tonnes per year

	BSSC	BFTO only for their organisation	Vintage Arms Association	BASC
Quantity GB tonnes	15 - 29	1	12 - 29	13

The values from BSSC (Organisation #100) and the Vintage Arms Association (Organisation #139) gave numerical values with no background information on how they were derived. The British Field Target Association (Organisation #41) gave the numbers relevant for their members only.

While the estimate from individual #2168 uses the most sophisticated analysis and takes into account the breakdown of users, types of shooting and frequency of shooting the sample is highly skewed and therefore is considered to be a gross overestimate.

In the estimate from BASC, based on PACEC (2014), it is not clear what the estimated income to 'shooting sports providers' means. Airgun pellets can be purchased easily, such as on eBay and other internet sites, so it is expected that this figure does not capture all of the market. It is likely that this number represents a lower bound. The Agency's estimate is based on 2014 market analysis inflated to 2019 via a GDP deflator. This assumes that prices in this market have risen in line with the GDP deflator which may not be the case.

In the absence of more comprehensive data the estimate from BASC (Organisation #83 and 115) of **13 tonnes of lead** released per year has been used for the evaluation. This approach does not allow for a breakdown by use. The Agency considers this to be a lower bound estimate of the true annual use. Individual #2168 derived a split between live quarry shooting (106 tonnes) and target shooting (935 tonnes), giving 10.2% of the total used in live quarry shooting and 89.8% used in target shooting. Although there is uncertainty regarding these percentages as discussed above the Agency have used them in the absence of better data. Using these proportions a value of **1** tonne for live quarry shooting and **12** tonnes for target shooting is calculated.

1.4.3.5 *Summary of overall quantities used*

The Agency has assessed all the public consultation response comments and derived the total estimated annual volumes of lead released from lead ammunition to be approximately 7,089 tonnes per year. The breakdown for these volumes is shown in *Table 1.17* .

Table 1.17 Estimated annual releases of lead from each use

Use	**Annual release (tonnes per year)**	**Source of data**
1. Live quarry shooting with shot	**1,601**	GTA – Blake International report
2. Live quarry shooting with bullets	2 small calibre 1 large calibre **3** total	BASC
3. Live quarry shooting with airgun ammunition	**1**	BASC and individual #2168
4. Outdoor target shooting with shot	**5,359**	GTA – Blake International report
5. Outdoor target shooting with bullets (small 5a, large 5b)	38 small calibre 73 large calibre **111** total	NRA and MLAGB
6. Outdoor target shooting with airgun ammunition	**12**	BASC and individual #2168
Total	**7,089**	

Notes: all figures rounded to the nearest tonne. Totals are calculated based on unrounded estimates and rounded to the nearest tonne, rather than summing individual rounded estimates.

1.4.4 Lead ammunition densities in the environment

The density of lead ammunition in the environment differs depending on the source. A number of studies have focused on the density of lead found in the environment around areas of high shooting activity such as shooting ranges, clay pigeon sites, and intensively reared gamebird shooting estates or regularly used blinds (ECHA, 2021c). Clay pigeon and target shooting ranges typically have the densest concentration of spent ammunition as they are generally in fixed places and hold multiple shoots per year, unlike pheasant shots who can be in fixed places but are limited to 4 months per year. The higher the density the higher the risk to the environment and wildlife.

According to PACEC (2014), which predominantly looked at live quarry shooting, the area of land shot over in the UK is generally considered to be 75% of the rural land, which is 16 million hectares. The area of land which is actively managed specifically for shooting is 1.8 million hectares.

1.4.4.1 *Live quarry shooting*

The density of lead ammunition on shooting estates, open fields or moorlands has not been studied in detail in GB, but there are a few studies from European shooting estates. For example, LAG (2015a) discusses a Spanish estate where Red-legged Partridges (*Alectoris rufa*) had been shot occasionally since the 1950s: the shooting density was 7.4 shot/m^2 in the top 1 cm of soil, in front of the shooting lines, which equated to 8.1 kg lead/hectare of number 7 shot. ECHA (2021c) describes the distribution of lead ammunition on shooting estates across the world and concludes that the distribution in European estates is likely to be similar to those in US fields managed for dove hunting:

> 'On five public hunting areas managed for dove hunting in Missouri during 2005–2011, the average amount of lead ammunition deposited per year ranged between 2.5 and 8.9 kg ha−1 among areas. The estimated average number of no. 8 lead pellets (2.26 mm in diameter) ranged between 35 624 and 128 632 hectare (ha) per year among areas (Schulz et al. 2012). Shultz et al. (2006) reported that on 14 managed public hunting areas in Indiana, the mean density of lead shot post season was 27 515 pellets/ha; a 645 % increase from pre-season soil sampling estimates (Castrale, 1989). Using similar soil sampling protocols, posthunt shot densities in Missouri were 6 342 pellets/ha; a 1697 % increase from pre-season estimates (Schulz et al. 2002).'

Over wetlands a study described in the proceedings of the Oxford Lead Symposium (2015) showed that most experimentally seeded shot remained within the top 4 cm of the sediment 3 years after deposition. In the Camargue marshes in France the half-life of shot within the top 6 cm, where the shot is available to feeding waterfowl, was estimated to be 46 years, and complete settlement beyond this depth would take over 66 years.

1.4.4.2 *Target shooting sites*

On clay pigeon shooting grounds the shot is generally widely distributed and has a higher surface area to mass ratio than bullets which may make them more susceptible to weathering (wca, 2021a).

The use of shotguns for trap, skeet and sporting clays will discharge lead shot over a diffuse area and large numbers of cartridges are used, hence creating high lead shot densities in the impact area. The nature of trap and skeet shooting causes spent shot to land in a wide but predictable impact area. Sporting clay shooting typically takes place over 40-100 ha of land, and the continually changing layout of the course means that loadings of shot occur over a much wider and more unpredictable area than for trap and skeet. A typical round of sporting clays (100 shots) will release 3.2 kg of lead per shooter to the impact area (Darling and Thomas, 2003). There are legal requirements concerning property boundaries and fall of shot: depositing shot on a neighbouring property could constitute a constructive trespass. Furthermore, there are strict safety rules regarding shot fallout areas, so the fall of spent shot is controlled and spent shot is contained and sequestered within the shooting ground for all 320 CPSA registered shooting grounds (BSSC, Organisation #100; CPSA, Organisation #101). It is expected that the density of lead shot would be higher for trap and skeet than sporting clays as the shooting direction is in a much tighter arc.

There is no up to date information on ammunition density in the UK, but LAG (2015b) summarises the limited historic data. At a clay pigeon shoot in Lancashire, a maximum of 257 shot/m^3 was found in the top 15 cm of soil, with decreasing density farther away from the shooting positions. The site had been operating for approximately 20 years. A study of shot density close to a clay pigeon shooting range at Lough Neagh, County Antrim showed the soil contained 2,400 shot/m^3 in the upper 5 cm of the shoreline in front of the range. Shot was also retrieved from the lakebed up to 60 m from the shore. The Agency is not aware of the size of either of these shooting ranges or the amount of round shot over the land. Additional studies have taken place in the EU (LAG, 2015a, 2015b). For example, a study at two Dutch clay pigeon sites found shot densities of 400 and 2,195 shot/m^2 and an additional study reports four Danish shooting ranges located near shallow water which had shot densities ranging from 44 to 2,045 shot/m^2. Another study found that lead shot made up to 30-40% of the top layer of soil at a clay pigeon shooting ground in Austria (wca, 2021a).

The density of shot increases over time if shot continues to be used and no recovery takes place. A number of studies have looked at the movement of the spent shot pellets in the soil. The shot will generally sink over time and new soil will accumulate above it, as discussed in the Oxford Lead Symposium (2015).

Hartikainen and Kerko (2009) report a study undertaken in Finland on the mobility of lead shot on an old and a new clay pigeon shooting ground. They showed that the pellets weathered slowly, losing 10% of the metallic lead over 16-37 years. They also estimated an average migration rate of approximately 2-3 mm per year on a stony soil.

There are no GB data available for target shooting ranges using other forms of ammunition. ECHA (2021c) presents some information on ranges in the EU. The quantity was reported as 15 tonnes per range per year in Finland, and up to 44 tonnes per range per year in Cyprus (based on a stakeholder survey which reported that 220 tonnes had been used over 5 ranges each year). Rifle and pistol shooting sports generally fire projectiles at targets that have backstops. Hence, these sports have lead accumulations in a more restricted area. Where projectiles are fired into earthen backstops lead may be readily removed from the backstops and recycled (Darling and Thomas, 2003). It is expected that most of the lead bullets released in these ranges will be recovered from the stop butts due to range safety rules.

Summary

In conclusion, the available evidence indicates that shooting occurs over 75% of GB's rural land and more intensive shooting takes place over 1.8 million hectares. Therefore there is widespread deposition of lead ammunition. This can result in a high density of spent lead ammunition in a range of different environments, including rivers / lakes, agricultural fields and moorland. It is also clear that the highest density of shot and bullets occurs in areas with fixed shooting positions such as clay pigeon or target ranges. Over time, the lead ammunition deposited on the soil surface will migrate deeper into the soil. However, this process is slow, and the lead projectiles can remain on or close to the soil surface for many years.

1.4.5 Environmental exposure - Exposure pathways

A fully quantitative exposure assessment for the various uses of lead in ammunition has not been attempted for the purposes of this dossier, due to the wide range of locations and environments where shooting can occur. Instead, the Agency has considered the evidence about the key exposure pathways for each use in GB. The use of source – pathway – receptor models is a standard approach in risk assessment to determine whether there is potential for exposure, and therefore impacts, to occur. The available information on the releases of lead ammunition to the environment, evidence of lead exposure in birds and other animals that can be linked to use of lead in ammunition, and information on concentrations of lead in water, soil and vegetation that can be linked to the use of lead in ammunition is reviewed.

LAG (2015a) identified five potential exposure pathways for lead from ammunition. These were:

a. Direct ingestion of spent lead ammunition (mainly shotgun pellets) from the environment (primary exposure).

b. Indirect ingestion by predators/scavengers of spent lead ammunition in the bodies of their prey (secondary exposure).

c. Movement of lead via plants into their consumers.

d. Movement of lead by ingestion of soil or soil organisms/invertebrates into their consumers.

e. Movement of lead from embedded shot/bullets into body tissues/organs.

LAG (2015a) concluded that there was evidence of both pathway 'a' (for many species of wildfowl, and some other waterbirds and gamebirds) and for pathway 'b' (raptors) from the UK and other parts of the world. Other wildlife may also be exposed via pathway 'a', although there is little published evidence of this in the UK. There was some evidence to support pathways 'c' and 'd', although this was generally not from the UK. Although there is evidence that lead ammunition can become embedded in shot animals that are not killed, there is uncertainty about whether this results in increased tissue concentrations that would support exposure pathway 'e'.

The following sections of this dossier summarise the evidence reviewed by LAG (2015a) and supplementary evidence reported in Pain et al. (2019b), ECHA (2021b, 2021c), Chiverton, Cromie and Kock (2022) and a list of publications relevant to the risk assessment of lead from ammunition maintained by the LAG (http://www.leadammunitiongroup.org.uk/resources/). Although two separate environmental risk assessments were reported by LAG (2015a, 2015b) using different methodologies, the same exposure datasets were reviewed in both and a consensus conclusion on exposure pathways was reached. In all sections, GB studies are discussed first, followed by a brief summary of evidence from other countries.

1.4.5.1 *Direct ingestion of spent lead ammunition (mainly shotgun pellets) from the environment (primary exposure)*

The primary ingestion exposure pathway is particularly relevant for bird species that may mistake the lead shot deposited in the environment for food items or grit. Some bird species seek out and ingest grit sized particles that remain in their muscular gizzards to aid digestion. As well as breaking down food by grinding, the avian gizzard is generally highly acidic (e.g. Farner, 1942). Any lead shot that is ingested may be ground down in the gizzard, increasing its surface area which together with the acidic pH will enhance its dissolution and then uptake within the intestine. The presence of lead shot in the gizzard indicates that the bird has ingested lead shot. Lead shot may be fired from a shot gun or by a muzzle loader.

Bullets and airgun ammunition are generally considered too large to be ingested by birds.

1.4.5.1.1 Terrestrial birds

Butler (2005) examined 637 post-mortem records for Red-legged Partridge (*Alectoris rufa*) recorded by the Game Conservancy Trust's pathology unit from sites across the UK between 1955 and 1992. Of these, 1 (0.2 %) reported the presence of lead shot in the gizzard. LAG (2015b) note that this study relied on a sample of birds that had been found dead and historical reports conducted by different pathologists, who were not specifically investigating the presence of lead shot in the gizzard.

Butler (2005) also reports on the presence of lead shot in the gizzard of 144 shot Red-legged Partridge collected from 10 UK shooting estates in the 2001/02 shooting season. Of the birds examined 2 (1.4 %) had ingested lead shot.

Butler (2005) reported on the number of Common Pheasants (*Phasianus colchicus*) with lead shot found in their gizzards. The birds were collected from 1996 to 2002 from 32 game farms across 11 counties in the UK. A total of 437 birds were examined, with half shot during the shooting season and half shot on licence outside the shooting season. On average, 3 % had ingested pellets. Of these, 77 % had ingested a single pellet, 15 % two pellets and 8 % three pellets.

Potts (2005) examined post-mortem records for wild Grey Partridge (*Perdix perdix*) found dead in south-east England between 1963 and 1992. Of the 446 adult birds examined 20 (4.5 %) had lead shot in their gizzard. A further 29 chicks collected from the South Downs between 1968 and 1978 were examined, and of these 2 (6.9 %) had lead shot in their gizzard. LAG (2015b) notes similar weaknesses in this study as for Butler (2005). Potts (2005) also references a doctoral study that examined 77 Grey Partridge killed by raptors at 20 sites in England in which no birds were found to have lead shot in the gizzard.

Thomas, Scheuhammer and Bond (2009) investigated the lead content of shot Red Grouse (*Lagopus lagopus*) from two estates in Scotland (Glendye and Invermark) and one in Yorkshire, and identified the source of the lead exposure using isotope ratio analysis. The authors considered an elevated bone lead level to be >20 µg/g dw. Although 38 Red Grouse from the Yorkshire estate were considered to have elevated bone lead levels, the isotope ratio of these indicated exposure to galena (a naturally occurring mineral) was responsible for the majority of this. The Red Grouse collected from the two Scottish estates had elevated bone lead in 3 of 85 (3.5 %) and 6 of 111 (5.4 %) cases and the authors considered the isotope ratios found to be consistent with the ingestion of lead shot.

In the Public Consultation, the Wildfowl and Wetlands Trust (Organisation #134) provided additional data from a study of 49 live-caught pheasants from England that were radiographed to determine the presence of lead shot. Eight to 12 % of the birds contained ingested shot, whilst 14 % contained embedded shot.

LAG (2015b) cite that the Animal Health Veterinary Laboratory Agency of Defra report on thirteen incidents of lead poisoning in birds in the UK between October 2007 and December 2012. Of these, six (46%) are related to the ingestion of lead shot or airgun pellets by chickens, ducks and geese. In one incident, Payne *et al*.

(2013) report that a flock of 2,000 free-range poultry was exposed to lead shot from nearby clay pigeon shooting. Post-mortems on a representative sample of the chickens found lead pellets in the gizzards. In a second incident, the source of lead poisoning of 400 ducks was found to have come from adjacent land that had been used for clay pigeon shooting for the previous 10 years (LAG, 2015b). In a third incident, between 3 to 5 % of 400 ducks reared for shooting 150 metres from a clay pigeon shoot suffered clinical disease and numerous lead pellets were found in the gizzards of the ducks (LAG, 2015b). In the Public Consultation, the Wildfowl and Wetlands Trust (Organisation response #134) informed us that they periodically receive calls from members of the public to report lead poisoning of poultry due to lead shot falling onto their land after shoots. Consumption of lead shot by egg laying hens thought to be exposed due to a nearby clay pigeon shoot has also resulted in a recall of eggs by a supermarket (BBC, 2008).

The UK evidence for ingestion of lead shot in terrestrial bird species or ducks exposed via the terrestrial environment is summarised in Table 1.18. Several studies have been identified that provide information on this potential exposure pathway, with five relating to gamebirds, two to domestic chickens and two to ducks. Although the studies are small in number, and use relatively small sample sizes, they demonstrate that some terrestrial birds do ingest lead shot and therefore are exposed via this route. In addition, AHVLA (2008) reports ingestion of lead airgun pellets by ducks.

Table 1.18 Evidence of ingestion of lead shot in UK birds via the terrestrial environment

Species	Number of birds	% overall ingestion (average)	% with elevated bone lead concentration (>20 µg/g dw) attributed to lead shot by isotope analysis	Reference
Common Pheasant (*Phasianus colchicus*)	437 (collected between 1996 and 2002)	3	NR	(Butler et al., 2005)
	49	8-12	NR	WWT, public consultation (Organisation

Species	Number of birds	% overall ingestion (average)	% with elevated bone lead concentration (>20 µg/g dw) attributed to lead shot by isotope analysis	Reference
				#134)
Red-legged Partridge (*Alectoris rufa*)	637 (collected between 1955 and 1992)	0.2	NR	(Butler, 2005)
	144 (2001/02 hunting season)	1.4	NR	(Butler, 2005)
Grey Partridge (Per*dix perdix*)	446 (collected between 1963 and 1992)	4.5	NR	(Potts, 2005)
	29 (collected between 1968 and 1978)	6.9	NR	(Potts, 2005)
	77	0	NR	(Watson, 2004) cited in (Potts, 2005)
Red Grouse (*Lagopus scoticus*)	111 (Glendye, 2003)	NR	5.4	(Thomas et al., 2009)
	85 (Invermark, 2003)	NR	3.5	(Thomas et al., 2009)
Chickens (*Gallus*	2000	Lead pellets in gizzards.	NR	(Payne et al., 2013) cited in

Species	Number of birds	% overall ingestion (average)	% with elevated bone lead concentration (>20 µg/g dw) attributed to lead shot by isotope analysis	Reference
domesticus)		% not stated.		(LAG, 2015)
Ducks (species not stated)	400	Lead pellets in gizzards. % not stated.	NR	(LAG, 2015b)

NR: not reported.

Three studies were identified that have reported ingestion of lead shot by terrestrial bird species found in the UK, but for which UK data are not available. Romero *et al*. (2020) found evidence of lead shot ingestion in Rock Dove (*Columba livia*), Stock Dove (*Columba oenas*) and Common Woodpigeon (*Columba palumbus*) from Spain. Stamberov *et al*. (2018) found evidence in Quail (*Coturnix coturnix*) from Bulgaria. Tavernier *et al*. (2004) report ingestion of lead shot by racing pigeons (*Columbia livia*) in Belgium.

LAG (2015b) and ECHA (2021b, 2021c) also review the evidence from outside the UK. Both documents conclude that there is evidence of lead shot ingestion from numerous different terrestrial bird families, with the prevalence of ingestion varying as a function of diet and grit preference and lead availability. The ingestion of lead shot has not been investigated in many species specifically. However, it is likely that the same exposure pathway can be assumed for species that have similar feeding habits. ECHA (2021b) report a list of the terrestrial species at most risk of lead poisoning based on evidence of ingestion of lead shot by these species, extrapolation from species in the same taxonomic group based on similarity of feeding ecology and an assessment by the United Nations Environment Programme Convention on Migratory Species (UNEP/CMS) ad hoc Expert Group (see Section 1.4.6.1.1).

In addition, most seed-eating birds, and some birds that eat invertebrates, will eat grit (Best and Gionfriddo, 1994; Gionfriddo and Best, 1999). The size of the grit ingested will vary between species but, in general, smaller birds eat smaller grit although there is often a wide range in grit size. For example, several song bird species were found to have grit <0.2 – 3.4 mm (Vyas et al., 2000) and House

Sparrows (*Passer domesticus*) to have grit 0.1 – 2.4 mm in size (Gionfriddo and Best, 1995). Larger birds, for example gamebirds, would be expected to be able to ingest larger size grit. The typical shot sizes used in GB range from #9 (2.03 mm) to #BB (4.01 mm) (Section 1.3.2), so are in this same size range.

LAG (2015b) also reviewed studies from outside the UK that identified the source of elevated lead concentrations in wild birds due to primary ingestion either by using stable isotope analysis or calculating the association between spatial or temporal changes in exposure and measured tissue concentrations. Many of the studies focus on wetland birds, so are not reviewed here. Scheuhammer *et al*. (2003) analysed the lead content and isotope ratios of soil, earthworms and wing bones from the American Woodcock (*Scolopax minor*) in Canada. Total lead and lead isotope concentrations were positively correlated between soil and earthworms. However, despite earthworms being a major food source for this species, the Woodcock samples had different isotopic ratios, which were consistent with the ingestion of lead shot. Franson, Hansen and Schulz (2009) sampled 4,229 Mourning Doves (*Zenaida macroura*) from areas where lead shot was permitted for use and 655 from areas where it was banned in the United States of America (USA). Similar proportions of birds had evidence of ingested ammunition in both areas. Bone lead concentrations were found to be higher in those areas where lead could be used, but no difference was found in liver concentrations. The field studies reviewed (both terrestrial and wetland) are considered by LAG (2015b) to provide strong evidence that ingestion of lead shot by birds is the main cause of elevated tissue concentrations in areas where shooting occurs.

1.4.5.1.2 Wetland birds

GB has previously concluded that there is evidence of ingestion of lead shot by wetland birds, particularly those that ingest grit as part of their feeding ecology, and that this exposure leads to an unacceptable risk. Legislation was introduced to mitigate this risk in England in 1999, with similar legislation in Wales and Scotland following shortly after (see section 1.3.5.1). The evidence for this exposure pathway has therefore not been re-examined here.

The wetland restrictions across GB vary between the administrations and do not uniformly apply to all wetland habitats or protect wetland birds that feed in terrestrial habitats (such as grazing swans, geese and ducks) from ingestion (as evidenced by the two studies on domesticated duck summarised in the previous section).

There is also evidence that compliance with the current restrictions on the use of lead over wetlands is low. Cromie *et al*. (2010) were commissioned by Defra to assess the compliance with the legislation in England by identifying the shot types used to kill ducks purchased from game suppliers in 2008/09 and 2009/10. Their study found that non-compliance with the Regulations was widespread, with 344 of 492 (70 %) of the ducks analysed having been killed with lead shot. Updated studies indicate that breaches of the Regulations are still high, with the proportion of ducks killed illegally with lead shot increasing from 68 to 77 % over surveys carried out from 2001 to 2013 and 87 % in the 2018/19 shooting season, (Cromie et al., 2022)). Based on the Cromie et al. (2015) dataset, (Stroud et al., 2021) estimate that 12.9 million ducks were killed illegally with lead shot between 1999 and 2020. The results of these investigations suggest that shooting of wetland birds with lead shot is still widespread, even though it is illegal.

Therefore, this exposure pathway is still considered relevant for GB.

1.4.5.1.3 Other animals

The ingestion of lead shot by non-avian species has not been well investigated. However, three GB studies were identified that report on this exposure pathway.

Payne and Livesey (2010) reviewed 454 incidents of lead poisoning of cattle or sheep in the UK between 1998 and 2008. The ingestion of metallic lead (including lead shot from clay pigeon shooting, lead flashings and pipes, and unspecified sources) was found to be the source of the lead in 31 (6.8%) cases. No further information is given on the numbers of each source within the group ‘metallic lead’.

Frape and Pringle (1984) reported that dairy cows ingested lead pellets and clay fragments in haylage that had been harvested from a field where clay pigeon shooting had occurred before harvest. Payne *et al*. (2013) report that cattle were exposed to lead via maize silage harvested from a field adjacent to a clay pigeon shoot. Payne *et al*. (2013) also report lead poisoning from cattle grazing directly from a field near a shoot.

There are a few further studies from outside GB. Braun *et al*. (1997) and Muntwyler (2010) report on the direct ingestion of lead shot and the effects (acute poisoning and mortality) on cows that were grazing on or adjacent to shooting ranges in Switzerland. In contrast, sheep grazing on shooting ranges are not thought to absorb as much lead as cows once ingested and no mortality has been reported (ECHA, 2021b). In a study on the potential for lead poisoning of sheep on Norwegian Armed Forces’ shooting ranges, analysis of liver samples of grazing lambs showed no difference in lead concentrations with those of lambs grazing elsewhere (Johnsen et al., 2019).

Howard and Braum (1980), Rice *et al*. (1987), Bischoff *et al.* (2012) and Bischoff *et al*. (2014) report exposure of cattle to lead shot within silage harvested from areas contaminated with shot in the USA, and Vermun, Hill and Quinn (2002) report on a case in New Zealand. Rice *et al*. (1987) state that even when lead pellets were removed, samples of silage still contained a concentration of lead sufficient to cause toxicity, independent of ingestion of any lead gunshot pellets. This suggests that the process of producing the silage or the uptake of lead by plants growing in soils contaminated with metallic lead may be an exposure route, in addition to the direct ingestion of lead shot pellets. Silage is very acidic (pH< 4.8), which may increase the rate of lead solubilisation (see Section 1.4.1).

There is also the potential for wild animals, such as deer, to consume shot whilst grazing. Lewis et al (2001) report detection of lead fragments in the stomach of White-tailed Deer (*Odocoileus virginianus*) that grazed on a shooting range in North America. Although reports of this pathway are lacking from GB it can be anticipated to be a relevant pathway for any grazing animal that consumes soil particles along with plant material.

1.4.5.1.4 Conclusion

There is strong evidence from both GB and international studies that direct ingestion of lead shot by terrestrial and wetland birds is a key exposure pathway for this assessment. One study also reported ingestion of lead airgun pellets by birds.

There is some evidence that other animals ingest lead shot whilst grazing. This is considered a relevant exposure pathway for livestock and poultry (and likely wild animals) that feed in areas with high lead shot use (e.g. on a shooting range). There is also a potential exposure pathway via silage harvested from areas contaminated with lead shot.

No evidence was found that animals directly ingest lead bullets or bullet fragments. Due to their size and shape, direct ingestion by birds and other animals is considered less likely than for shot or airgun pellets and this is not considered further in this assessment.

1.4.5.2 *Indirect ingestion by predators/scavengers of lead from lead ammunition in the bodies of their prey (secondary exposure)*

There are three pathways by which indirect ingestion may occur. Firstly, the previous section demonstrated that lead shot and airgun pellets can be directly ingested by birds. If these birds are preyed upon then the lead can move up the food chain. Secondly, lead ammunition may be present in quarry animals that are shot but not killed. Quarry animals that are weakened, but not killed, are also thought to be at greater risk of predation. Thirdly, animals that are shot and killed but that are left unrecovered in the environment, or that are butchered in the field and have the viscera discarded, could also be eaten by predators/scavengers.

Researchers have investigated the presence of lead ammunition and fragments of lead ammunition in shot animals or after test firing.

Lead shot

- Pain *et al*. (2010) analysed for the presence of lead shot and tissue lead levels in six wild-shot species of gamebirds. Birds were bought from supermarkets, butchers or directly from shoots across England, Scotland and Wales. A sample size of 16 to 26 birds was available for Pheasant (*Phasianus colchicus*), Red-legged Partridge (*Alectoris rufa*), Woodpigeon (*Columba palumbus*), Red Grouse (*Lagopus lagopus*), Eurasian Woodcock (*Scolopax rusticola*) and Mallard (*Anas platyrhynchos*). Across all samples, 65 % contained lead shot or fragments of lead shot, with this ranging from 50 to 85 % between species. On average, each bird that contained shot had 2.2 embedded pellets, ranging from 1 to 18 for each individual bird. Radiographs identified that 76 % of birds contained radio-dense particles, ranging from 65 to 85 % by species. These were presumed to be metallic fragments of the shot, and were sometimes associated with the pellet wound channels. When both analyses were considered together, 87 % of birds contained visible whole shot or (presumed) fragments of shot. Of the birds not visibly containing shot, 60 % contained small radio-dense particles that were presumed to be fragments of lead shot.

- Stankeviciute et al. (2013) report that 23 % of the 22 European Hares (*Lepus europaeus*) they studied from two districts in Lithuania had multiple lead shot fragments throughout their bodies from previous non-fatal shootings.

- Green et al. (2022b) used a 3D computerised tomography (CT) scanner to locate and size metal fragments in eight Pheasants (*Phasianus colchicus*) killed by hunters using shotguns and purchased from a butcher in Cambridge in 2016. Seven of the eight birds had detectable whole shotgun pellets visible on the scans, with a mean of 3.5 pellets per carcass (range 0 – 7). The mean proportion of the larger fragments identified as lead by ICP-AES was 99.9 %. All eight birds had fragments <2 mm diameter visible on the scans, with a mean of 39 fragments per carcass (range 3 – 68). The majority of metal fragments (312/340; 92 %) had diameters of <1 mm, with most of these being at the lower end of this range. As the limit of detection was 0.07 mm the authors conclude that it is likely that many more smaller fragments were present, that could not be detected using this method. The mean distance between metal fragments and the nearest whole pellet was 24 mm (range of carcass means 10 – 38 mm) and the most distant fragment averaged 52 mm from the nearest whole pellet (range across carcasses 17 – 68 mm).

- In the Public Consultation, the Wildfowl and Wetlands Trust (Organisation response #134) provided data from a study of 49 live-caught pheasants from England that were radiographed to determine the presence of lead shot. Fourteen percent contained embedded shot.

Lead bullets

- Pain *et al*. (2007) conducted radiographs of rabbits that had been shot with 0.22 calibre rifles. The analysis demonstrated many bullet fragments along the path of the bullet in 3 of the 4 rabbits, with between 1 and 10 objects per rabbit. The bullet fragments were distributed in the thorax and abdomen of two of the rabbits and one object was found in the forelimb of the third rabbit, indicating that the fragments can be widely spread.

- Knott *et al*. (2010) conducted radiographs of ten Red Deer (*Cervus elaphus*) and two Roe Deer (*Capreolus capreolus*) that were shot by a single lead rifle bullet to the thorax. The ammunition used was 0.270 ammunition (Norma 130 gr copper-jacket lead-core bullet). The deer were eviscerated before a radiograph was taken from each side of the carcass, and a third radiograph was taken of the viscera. The average number of fragments was 412 in the carcass and 180 in the viscera, equating to 1.48 g and 0.21 g of metal respectively. Fragments in the viscera were typically smaller than those in the carcass.

- Hampton et al. (2020) conducted radiographic analysis of 28 European Rabbits (*Oryctolagus cuniculus*) shot with lead-based .22LR bullets as part of a wider study investigating alternative non-lead ammunition. Bullet fragments were present in 82 % of carcasses.

Airgun pellets

- In the Public Consultation, BASC (Organisation response #115) provided results from a study they conducted on the potential fragmentation and weight loss of lead airgun pellets. A group of five pellets were weighed before being shot into water and then re-weighed to act as a control. A further group of five pellets were weighed before being shot into ballistic soap, which represents the soft tissue of quarry, and then re-weighed. The pellets were also examined visually to determine if there was any fragmentation. When fired into water or ballistic soap there was no weight loss and no fragmentation was observed. The Agency notes that the weighing scales had an accuracy of 6 mg, so would not have the same level of precision in detecting small fragments of lead that radiographic techniques would and that this study does not indicate what would happen if the pellet was to strike bone.

LAG (2015b) summarises a large number of non-UK studies that report on the prevalence of embedded shot in bird (mainly wildfowl) species, as well as data on the concentration of lead in the flesh of game animals shot with lead ammunition (see also Section 1.5.2). Quarry species can survive carrying lead shot, and in some wildfowl species this can be as high as 20 to 30% of the population (Pain et al., 2014). The human health assessment in LAG (2015b) concluded that the available data indicated that mean lead concentrations in meat from animals shot with lead ammunition were often elevated compared to background levels, and that this was particularly the case for small game and meat from tissues where the ammunition had struck.

Pain *et al*. (2019b) reported that additional studies post the LAG review have found the presence of lead fragments or elevated tissue concentrations in prey species. This adds to the evidence of lead contamination in these populations.

It is unknown how many of the animals shot are recovered from the environment and how many are discarded, either because they cannot be recovered or because they are not required. PACEC (2014) report that 97 % of edible quarry goes into the human food chain in the UK, suggesting limited potential for exposure via unrecovered game. However, it is reported that more gamebirds are shot than enter the human food chain, with reports of some carcasses being dumped or used as bait for foxes (Harris, 2021). In addition, pest mammal and bird species would not be included in this estimate. In their response to the public consultation, BASC (Organisation response #115) note that best practice for pest mammal and bird species would be to dispose of the carcasses via a certified waste carrier, to incinerate or to leave in a discreet location away from public view. Although the first two methods would remove any lead ammunition from the environment, the latter would leave the lead ammunition available for scavenging wildlife to consume.

BASC (Organisation response #115) also note that best practice for disposal of viscera is to bury it away from water courses and at least 1 metre deep, deposit it with a certified waste carrier or to place it in a discreet location away from public view. Again, this latter option would leave any lead ammunition in the viscera available for scavenging wildlife to consume. Removing the gralloch (entrails) of deer and leaving them in the field is promoted as a potential food source for wildlife in the UK (e.g. Wallace, (2021)).

Nadjafzadeh, Hofer and Krone (2015) conducted feeding experiments by providing ungulate carcasses containing different size particles of iron to wild Common Ravens (*Corvus corax*), Common Buzzards (*Buteo buteo*) and White-tailed Eagles (*Haliaeetus albicilla*) and six captive White-tailed Eagles. As the diameter of the iron particles increased, so did the avoidance of the particles; nearly all particles with a diameter of 8.8 mm or more were not ingested. However, the particle sizes smaller than 8.8 mm, which were more similar to those of lead shot, pellets or bullet fragments, were more frequently ingested.

The available data on animals killed using lead shot and bullets clearly shows that lead fragments are dispersed in the carcass. In addition, lead ammunition may also be embedded in quarry that are shot, but not killed. Together with primary ingestion resulting in the presence of lead shot in potential prey items, there is a clear potential for predators or scavenging wildlife to be exposed to lead in their diet.

Information provided in the public consultation (e.g. BASC Organisation response #115 and individual respondents) states that lead airgun pellets do not fragment when they hit their target and that as a single shot to the head or heart results in death, this limits the amount of lead in potential prey items. Despite these mitigating factors, lead airgun pellets could still be ingested by scavenging birds or mammals that eat carcasses that are not collected and so this is a potential exposure pathway.

1.4.5.2.1 Birds

Obligate scavengers that eat carrion only, such as vultures, do not live in the UK. Red Kite (*Milvus milvus*), Golden Eagle (*Aquila chrysaetos*), White-tailed Eagle (*Haliaeetus albicilla*), Common Buzzard (*Buteo buteo*), Marsh Harrier (*Circus aeruginosus*), Common Raven (*Corvus corax*), Carrion Crow (*Corvus corone*), Hooded Crow (*Corvus cornix*) and Eurasian Magpie (*Pica pica*) among others are facultative scavengers, and so they are the bird species whose diet is most likely to include carrion (including animals shot but not recovered) and discarded viscera from hunting. Scavenging in many species is opportunistic and most raptors and many species from other taxa such as owls (Allen et al., (2020)) will scavenge, particularly in times of food scarcity. These same species and other predatory species such as Peregrine Falcon (*Falco peregrinus*) and Goshawk (*Accipiter gentilis*) that feed upon live prey may also be exposed to contain lead ammunition. Prey animals that are debilitated by injury or lead intoxication may form a larger proportion of the diet than those that are not debilitated (ECHA, 2021c).

Pain, Sears and Newton (1995) reported on the liver lead concentrations of 424 raptors from 16 species that had been found dead and collected between 1981 and 1992 in the UK. The number of individual birds per species varied from 1 to 150. A concentration of 6 µg/g dw was used to identify samples that were above typical ‘background’ levels of exposure based on thresholds suggested by other authors. Median liver concentrations ranged from below the limits of detection to 2.17 µg/g dw, with a maximum of 909.1 µg/g dw in one Buzzard. The mean percentage of individuals exceeding the ‘background’ level was 4.7 %. However, although the authors considered that lead ammunition from food sources was likely to be the cause of the elevated lead concentrations, this study did not attempt to demonstrate this analytically.

Pain *et al*. (2007) analysed regurgitated food pellets from a Red Kite roost site in the Midlands to determine whether they contained lead shot. Radiographs showed that 29 of 264 pellets (11 %) contained radio-dense material. Seven pellets contained spherical objects and the other 29 contained objects of ill-defined shape. Of the 7 pellets that contained spherical radio-dense objects, 6 were found to contain between 1 and 3 spheres after dissection. Eleven of the total 13 spheres were determined to be composed of 61 – 99 % lead (median 78 %) and so were concluded to be lead shot. The authors estimated that a minimum of 2 % of the total regurgitated food pellets contained lead shot. Pain *et al*. (2007) conducted post-mortem analyses and liver and bone lead analysis on Red Kites that had been found dead across England. One of the 87 birds investigated (1.1 %) had a cause of death attributable to lead poisoning. However, 7 of 44 birds analysed (16 %) had liver lead concentrations above the 'background' (6 µg/g dw) and 18 of 86 (21 %) had bone lead concentrations above 'background' (20 µg/g dw). Lead isotope analysis indicated that the lead shot found in the regurgitated food pellets was the source of the elevated liver and bone concentrations, as it did not match with that of other sources of lead (i.e. mining, petrol, coal).

Walker *et al*. (2012) carried out lead isotope analysis on liver samples from Red Kite carcasses submitted by members of the public in England and from Sparrowhawks (*Accipiter nisus*) from England, Wales and Scotland. For both species, the liver lead isotope analysis substantially overlapped with that of lead shot but was distinct from leaded petrol. For Red Kites, the lead isotope analysis also overlapped with that of coal.

Molenaar *et al*. (2017) analysed the concentration of lead in Red Kites from England that were submitted for post-mortem analysis between 1989 and 2007. Six of the 44 birds (14 %) were determined to have liver lead levels greater than 15 µg/g dw. In an additional 11 birds (13 %), reported mean bone lead values of 30.3 to 187.5 µg/g dw were reported. One of these birds was found to have lead shot in the oral cavity.

The UK Predatory Bird Monitoring Scheme (PBMS) sampled 220 dead or dying Common Buzzards found in the wild between 2007 and 2018 (Taggart et al., 2020). These carcasses were obtained opportunistically following requests to members of the public, bird watchers and wildlife managers and the cause of death was not clear in many cases, so they may not fully represent the population at large. Samples were taken from both the liver and the femur and analysed for lead:

- The results of the liver analysis showed that the mean concentration of lead in 187 birds was 2.573 µg/g dw (standard deviation: 7.516 µg/g dw). Liver lead concentration was not related to the age of the bird, but varied markedly between years and increased substantially during the UK hunting season. The authors assumed that a liver lead concentration in excess of 6 µg/g dw (around 2 µg/g ww), derived by Pain *et al*. (1995) as having biological significance, was indicative of an abnormally high exposure to lead. Fifteen of the samples (8 %) exceeded this value.

- The results of the analysis of the femur from 125 birds showed that the mean concentration was 5.460 µg/g dw (standard deviation: 10.669 µg/g dw). Femur lead concentrations did not show a consistent pattern over time, but older birds had around double the levels of younger individuals. The authors used a bone lead concentration in excess of 10 µg/g dw, derived by Mateo *et al*. (2003) as having biological significance to indicate an abnormally high exposure to lead. Twelve of the samples (9.6 %) exceeded this value.

In order to identify whether the lead found in the buzzard samples was due to lead shot, samples of cartridges sold by the 5 largest manufacturers that represent 90 % of UK sales were obtained and the lead isotope ratios determined for each brand (Taggart et al., 2020). These ratios were then compared to the ratios found in the liver samples, and a significant positive correlation found. The authors concluded that buzzard liver samples with higher lead concentrations more closely resembled the isotope ratios of lead shotgun pellets widely used in the UK than samples with lower lead concentrations. The stable isotope analysis indicated that 57 % of the lead detected in the sampled livers was derived from shotgun pellets, increasing to 89 % for the birds with lead concentration indicative of acute exposure.

The Environment Agency (2021) summarises data on the concentrations of lead detected in the liver of Eurasian Sparrowhawks (*Accipiter nisus*) found dead in England between 2007 and 2014. These data were also generated as part of the UK PBMS. The concentrations of lead were not found to be significantly different over time and the range of lead concentrations in the 172 birds analysed was 0.035 to 16.8 µg/g dw. No indication is provided of the possible source of the lead.

The levels of lead found in wild raptors and scavengers in the UK and the sources of this as suggested by the report authors are detailed in *Table 1.19*.

Table 1.19 Lead concentrations in wild UK birds of prey

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Lead source**	**Reference**
Common Buzzard (*Buteo buteo*)	1981-1992	Liver: 1.34* (NA-909.1) n=56	Suggested ingestion of ammunition	(Pain et al., 1995)
	2007-2018	Liver: 2.573 (<0.011-85.4) n=187 Bone: 5.46 (0.146-110) n=125	Ingestion of shot based on isotope analysis	(Taggart et al., 2020)
Eurasian Sparrowhawk (*Accipiter nisus*)	1981-1992	Liver: 0.55* (NA-12.33) n=150	NA	(Pain et al., 1995)
	NS	Liver: NA	Ingestion of shot based on isotope analysis	(Walker et al., 2012)
	2007-2014	Liver: 0.69 (0.035-16.8) n=172	NA	(Environment Agency, 2021)

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Lead source	Reference
Goshawk (*Accipiter gentilis*)	1981-1992	Liver: 1.21* (NA- 4.63) n=6	NA	(Pain et al., 1995)
Golden Eagle (*Aquila chrysaetus*)	1981-1992	Liver: 0.34* (NA- 2.96) n=5	NA	(Pain et al., 1995)
Hen Harrier (*Circus cyaneus*)	1981-1992	Liver: 2.17* (NA- 5.71) n=7	NA	(Pain et al., 1995)
Hobby (*Falco subbuteo*)	1981-1992	Liver: <0.1* (NA- 12.33) n=7	NA	(Pain et al., 1995)
Kestrel (*Falco tinnunculus*)	1981-1992	Liver: 0.69* (NA- 10.32) n=32	NA	(Pain et al., 1995)
Little Owl (*Anthene noctua*)	1981-1992	Liver: 0.82* (NA- 14.15) n=27	NA	(Pain et al., 1995)
Long Eared Owl (*Asio otus*)	1981-1992	Liver: <0.1* (NA- 2.67) n=22	NA	(Pain et al., 1995)

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Lead source	Reference
Marsh Harrier (*Circus aeruginosus*)	1981-1992	Liver: <0.1* n=1	NA	(Pain et al., 1995)
Merlin (*Falco columbarius*)	1981-1992	Liver: <0.1* (NA- 14.93) n=63	NA	(Pain et al., 1995)
Montagu's Harrier (*Circus pygargus*)	1981-1992	Liver: 2.12* (NA- 2.9) n=2	NA	(Pain et al., 1995)
Peregrine Falcon (*Falco peregrinus*)	1981-1992	Liver: 0.48* (NA-22.03) n=26	Suggested ingestion of ammunition	(Pain et al., 1995)
Red Kite (*Milvus milvus*)	1981-1992	Liver: 1.52* (NA- 3.06) n=6	NA	(Pain et al., 1995)
	1995-2003	Blood: 24.07 (0.8-333.78) n=125; Bone: 18.28 (5-187.5) n=86; Liver: 6.26 (0.5-46.7) n=44	Ingestion of shot based on isotope analysis	(Pain et al., 2007)

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Lead source	Reference
	NS	Liver: NA	Ingestion of shot based on isotope analysis	(Walker et al., 2012)
	1989-2007	Bone: NA (30.3-187.5) n=11; Liver: >15 n=6	1 bird with lead shot in the oral cavity	(Molenaar et al., 2017)
Sea Eagle (*Haliaetus albicilla*)	1981-1992	Liver: <0.1* n=1	NA	(Pain et al., 1995)
Short Eared Owl (*Asio flammeus*)	1981-1992	Liver: 1.61* (NA-7.25) n=15	NA	(Pain et al., 1995)

Monclus *et al*. (2020) report a systematic review and meta-analysis of all published data on lead in raptors (covering the period 1983 to 2019). The authors reviewed 114 studies, covering 39 raptor species across Europe. They found that the Common Buzzard, the Golden Eagle and the White-tailed Eagle had the highest lead concentrations in their tissues and that the highest levels were found during the hunting season. These are their final conclusions:

- '*scavengers, both obligate and facultative species, are more prone to lead contamination than non-scavengers including birds of prey and owls,*
- *lead contamination in raptors is still widely detected across Europe despite partial bans on the use of lead in ammunition and shot,*
- *there is a seasonal peak in blood lead concentrations related to hunting season in southern European countries,*
- *the levels of exposure in several species are generally relatively high and exceedance of subclinical threshold levels is widespread.*'

1.4.5.2.2 Other animals

Other scavenging animals that could be exposed to lead via this pathway in GB are Badgers (*Meles meles*), Red Fox (*Vulpes vulpes*), Pine Martens (*Martes martes*) and other mustelids. No GB data on secondary poisoning of these species or any other predatory or scavenging non-avian species have been identified. However, it is likely that they may be exposed to lead through the predation and consumption of contaminated prey and through contaminated gut piles, discarded meat or unrecovered game left in the environment by the hunters (Pain et al., 2019b).

There are some studies from outside GB. ECHA (2021b) refers to one case of lead poisoning in Cougar (*Puma concolor*) that was attributed to lead shot and bullet ingestion (Burco et al., 2012), and one additional study where ammunition was the suspected source of lead poisoning in European Brown Bears (*Ursus arctos*) (Lazarus et al., 2020). Kelly et al. (2021) report that the availability of deer viscera influences the exposure of wild wolves (*Canis lupus*) to lead.

In addition to wild animals it is likely that companion animals may be fed meat contaminated with lead from ammunition, particularly dogs belonging to hunters that may be fed offcuts of hunted game or surplus game (D. Pain et al., 2022). PACEC (2014) report that 97 % of edible quarry goes into the human food chain in the UK, with some of the remaining 3 % being used to feed companion animals. Raw food diets for companion animals are becoming increasingly popular (e.g. Dodd et al. (2020)) and dog and cat food containing wild-shot game is available in the UK. Pain et al. (2023) report that lead concentrations in samples of three types of raw pheasant-based dogfood purchased in the UK exceeded the EU Maximum Residue Level (MRL) for lead in animal feed/complete feed in 74.1 % of samples. X-rays identified spherical and irregularly shaped radio-dense objects in the samples of raw food. Although these objects were not subject to chemical analysis, the authors consider that they are shot or pieces of shot, most likely to be lead.

Fernandez et al. (2021) studied the exposure of dogs fed game meat and offal killed with lead ammunition in Argentina, and compared this to their owner's lead exposure. Concentrations of lead in samples of dog blood and hair indicated exposure to lead, and this was correlated with the exposure of their owner. Rosendahl et al. (2022) report that blood lead concentrations were significantly higher in dogs fed wild game monthly, weekly or daily than those that did not eat wild game in Finland.

Captive animals that have been fed on lead-shot meat have also been reported to be exposed via this pathway. For example, North et al. (2015) report on a case of two captive Cheetahs (*Acinonyx jubatus jubatus*) dying as a result of lead poisoning via their diet of shot game. Hivert et al. (2018) report on a survey of captive and wild Tasmanian Devils (*Sarcophilus harrisii*) that found significantly higher blood lead concentrations in captive animals fed on possum and wallaby shot using lead ammunition. Blood lead concentrations decreased when measures were introduced to reduce lead exposure by removing flesh with wound tracks from the diet.

1.4.5.2.3 Conclusion

There is strong evidence from both GB and international studies that secondary exposure of predatory/scavenging birds is a key exposure pathway for this assessment. There have been no GB studies investigating exposure of other wild animals via this route. However, as prey items are known to contain lead arising from all forms of ammunition within the scope of this dossier, this is considered a likely exposure pathway. Secondary exposure will be considered for all use scenarios where primary ingestion has been identified as a key exposure pathway and for all use scenarios which involve live quarry.

Game trimmings and surplus game are known to contain lead arising from ammunition and this is known to be fed to companion animals in GB. In addition, a recent study on lead concentrations in raw petfood identified potential shot and shot fragments and lead concentrations above the EU MRL, although this specific risk has been brought to the attention of the regulator for pet food, so it is not necessary to considered further here. Exposure of companion animals to lead ammunition in game trimmings and surplus game is therefore considered a likely exposure pathway in this assessment.

1.4.5.3 *Movement of spent lead ammunition via ingestion of soil, accumulation in soil organisms or vegetation*

Lead in ammunition is emitted to the environment during use, unless it is collected (e.g. in animal carcasses retrieved during hunting and pest control, or in bullet traps for sports shooting). It may enter the environment as intact bullets or shot or be present as fragments or lead 'dust'. In areas which are repeatedly used for shooting (e.g. shooting ranges), both the number of lead particles and the soil lead concentrations would be expected to increase over time. Soil may be ingested by some animals, or the lead present could accumulate in soil-dwelling organisms that could then be eaten. Although metallic lead is expected to be relatively stable in the environment, it can transform to more soluble forms which may be mobile especially in acidic soils (such as those in heath/moorlands which may be used for gamebirds) (Section 1.4.1) and have the potential for uptake by plants.

Natural lead concentrations in uncontaminated European topsoil tend to range from 10 to 30 mg/kg soil [not stated whether dw or ww] (EFSA, 2010a). The British Geological Survey (BGS) has identified a Normal Background Concentration (NBC) of soil lead over 94 % of the area of England as 180 mg/kg dw (Ander et al., 2013). The NBC is defined as a typical level of lead that could be expected as a combination of both natural background and diffuse pollution inputs. Urban areas and areas with high lead content in the underlying rock have higher NBC values. Widespread diffuse inputs of lead in GB have declined due to the move away from coal for heating and the banning of leaded petrol

A number of GB studies have reported on the concentration of lead in soil from sites at which lead ammunition is used.

Mellor & McCartney (1994) measured soil lead concentrations at a clay pigeon shooting range in Bolton, which had been in use for 20 years. Samples were taken from near to the shooting stands and from a control site 300 m away. Samples were sieved with a 1.8 mm sieve, extracted with nitric acid and acetic acid extraction (to provide both total and plant available concentrations) and analysed by atomic absorption spectrophotometry. In samples taken from 80 to 140 m from the shooting stands the total soil lead concentrations ranged from 5,000 to 10,600 mg/kg and the plant available lead concentrations ranged from 1,000 to 4,100 mg/kg. The authors also counted the number of lead pellets in these samples and up to 257 pellets per sample were reported in a 10 cm core from the top 15 cm of soil.

Clements (1997) measured soil lead concentrations on a dairy farm in southern Worcestershire. Samples were collected from areas with a 10-year history of clay pigeon shooting and from control fields. Samples were not sieved and were extracted with nitric acid followed by flame atomic absorption analysis. In samples taken 100 to 175 m from the shooting stands the mean soil lead concentration was 3,038 mg/kg (maximum 8,172 mg/kg dw), compared to 72 mg/kg dw in the control samples.

Reid and Watson (2005) measured soil lead concentrations at a clay pigeon site in Norfolk that had been used since the 1960s. Samples were collected from the shooting area and control areas that were not used for shooting. Samples were not sieved and were extracted with nitric acid and acetic acid (to provide available and total lead concentrations) before analysis by inductively coupled plasma optical emission spectrometry. Mean total soil concentrations were 6,410 ± 2,250 mg/kg dw in samples from the shooting area and 296 ± 98 mg/kg dw in control samples. The available lead concentrations were reported to be 1,050 ± 240 mg/kg dw from the shooting area and 12 ± 9 mg/kg dw in the control area.

Sneddon *et al*. (2009) measured soil lead concentrations in samples from a Cheshire shooting ground that had been used for 200 years for game shooting and 20 years for intensive pheasant shooting. Samples were collected from a woodland copse used for shooting, a meadow used for shooting and a woodland and a grassland control site. Samples were sieved with a 2 mm sieve, before they were extracted with nitric acid and analysed by plasma-mass spectrometry. Mean total lead concentrations were 160 mg/kg dw in the woodland, compared to 60.2 mg/kg dw in the control site, and 68.3 mg/kg dw in the meadow compared to 43.9 mg/kg dw in the control site.

A small number of UK studies have investigated the potential for lead in soil that is attributed to the use of lead in ammunition to be accumulated by plants or soil-dwelling organisms.

LAG (2015b) cites an unpublished study by RPS Environmental Sciences Ltd (1989) which investigated lead concentrations in grass, cereals, potatoes, beans and heather at samples taken from long established UK clay shooting grounds. Lead concentrations in samples of potatoes and beans were not elevated compared to controls. Concentrations of lead in heather ranged from 8 to 35 mg/kg dw, compared to 8 to 18 mg/kg dw from control samples. Concentrations of lead in grass samples ranged from 18 to 95 mg/kg dw, compared to 4 to 9 mg/kg dw in control samples. Although highly variable, cereals had the highest recorded lead concentrations ranging from 9 to 160 mg/kg dw, compared to 5 to 10 mg/kg dw in control samples.

LAG (2015b) also cites a second unpublished study (RPS Clouston, 1991) that investigated lead concentrations in grasses (permanent and ley pasture) and heather from areas of intensive and informal game shooting. The intensive areas had been in operation from 15 to over 100 years and held 10 to 20 drives per stand per year. The informal game shooting areas had been in operation for 12 to 15 years, and held shoots on between 24 and 30 days per year. Lead concentrations ranged from 31 to

360 mg/kg in the grass samples and from 18 to 19 mg/kg in the heather samples. No results from control samples are reported in LAG (2015b).

Several of the studies that reported soil lead concentrations summarised above also reported on lead concentrations in vegetation collected from the same sites.

Mellor and McCartney (1994) measured lead concentration in oilseed rape collected from within the fall-out area of the clay pigeon shooting range. The results are reported as both parts per million (ppm) and mg/kg, with different values given for both (a factor of 20 different) without further explanation. Despite this, the results demonstrate that samples taken from the shooting range had elevated lead levels compared to the control in the roots (up to 470 ppm dw compared with 10 ppm dw), stem (62 ppm dw compared with 4 ppm dw) and seeds (148 ppm dw compared with below the limit of detection).

Clements (1997) analysed 50 unwashed rye grass samples from the fall-out area of a clay pigeon range on a dairy farm. Forty-nine of the samples had lead concentrations below the limit of detection, but a single sample had a lead concentration of 121.75 mg/kg dw.

Sneddon *et al*. (2009) reported concentrations up to 38.4 mg/kg dw in washed rye grass from the shooting field in their study, compared with 0.89 mg/kg dw in the control grassland.

Two GB studies were identified that investigated the uptake of lead from ammunition in terrestrial organisms.

Reid and Watson (2005) collected earthworms from the same sites as they collected soil samples. The worms collected from the clay pigeon shooting sites had concentrations of lead nearly 1,000 times higher than worms collected from a control site (mean 6,100 mg/kg dw, compared to 7.1 mg/kg dw). The Agency notes that the mean concentration in worms from the shooting sites is similar to the reported mean soil concentration from the same sites (6,410 mg/kg dw).

As well as reporting on lead concentrations in soil and vegetation samples, Sneddon *et al*. (2009) also analysed earthworms and their gut contents together with hair samples taken from Wood Mice (*Apodemus sylvaticus*) and Field Voles (*Microtus arvensis*) for lead content. The worm body lead content was not statistically significantly different to the control in the shooting field samples, but for the woodland samples the shooting area had significantly higher concentration than the control (111.79 mg/kg dw compared to 5.49 mg/kg dw, $p < 0.01$). The Agency notes that the mean lead concentrations in worms did not exceed that for the soil samples taken from the same sites. The highest reported mean lead concentration in worms was from the samples from the woodland shooting area, which had comparable mean soil concentrations (111.79 mg/kg dw in worms compared to 160 mg/kg dw in soil). For worm gut content, a statistically significantly higher lead concentration was found in the shooting field samples than the control (35.61 mg/kg dw compared to 16.41 mg/kg dw, $p < 0.01$). Although worm gut lead levels were highest from the woodland samples (298.86 mg/kg dw), no control data were reported to compare this to. The lead concentrations measured in rodent hair were variable and did not follow a consistent pattern, but the highest concentration was reported in a sample from the control area.

ECHA (2021c) also summarise reported soil lead concentrations from areas of lead ammunition use and uptake of lead by plants outside the UK. Dinake, Kelebemang and Sehube (2019) reviewed over 100 studies on the concentrations of lead in soils from shooting ranges published between 1983 and 2018. The highest reported concentration was 300,000 mg/kg dw in a berm from a shooting range in the Netherlands (Van Bon and Boersema, 1988). ECHA (2021c) notes that soil lead concentrations are expected to be highly variable within a shooting range due to the irregular distribution of the lead ammunition. The highest concentrations at a target shooting range would be expected to be over a relatively limited area, closest to the target (i.e. within the berm or in front of the berm). Soil concentrations have been shown to be equivalent to background concentrations below the berm, even when the berm is heavily contaminated (e.g. (Astrup et al., 1999)) The highest concentrations at a clay pigeon shooting site or at a site repeatedly used for live quarry shooting would be expected to be in the drop zone where spent lead shot falls. Sites where lead shot is used therefore have the potential for increased soil lead concentrations over a wider area.

Several studies have investigated the uptake of lead by plants grown on shooting ranges and shown concentrations above control samples in Pine trees (Turpeinen et al., 2000), Spring Barley (Chrastný et al., 2010), vegetation comprised of ~85% *Poaceae* grasses (Bennett et al., 2007) and in unspecified plants collected from berms (Dallinger, 2007).

Migliorini et al (2004) measured concentrations of lead in soil and two species of arthropod collected from a clay pigeon shooting range in Italy. Samples were split into control, low, medium and high exposure groups with lead concentrations of 80.5 – 82.5 mg/kg dw, 212 – 268 mg/kg dw, 624-915 mg/kg dw and 1576-1898 mg/kg dw respectively. Three Pillbug (*Armadillidium sordidum*) and five Devil's Coach Horse Beetle (*Ocypus olens*) were analysed for lead content from each group. Mean concentrations increased from control through to the high exposure group for both species. Mean concentrations ranged from 1.55 mg/kg dw in the control group to 494.76 mg/kg dw in the high exposure group for Pillbug and 1.18 mg/kg dw to 40.9 mg/kg in the high exposure group for the Devil's Coach Horse Beetle. The authors conclude that although lead is dispersed along the food chain it does not biomagnify.

Ma (1989) investigated the concentration of lead in small mammals collected from an area contaminated with lead shotgun pellets. Measured concentrations of lead in kidney, bone and liver samples from Wood Mice (*Apodemus sylvaticus*), Bank Voles (*Clethrionomys glareolus*) and Common Shrews (*Sorex araneus*) were elevated when compared to samples collected from control sites.

1.4.5.3.1 Conclusion

GB data and evidence from other parts of the world clearly shows that soil lead concentrations in areas of intensive or repeated lead ammunition deposition will be above background levels. In GB, measured concentrations up to three orders of magnitude higher than natural background have been reported, whilst concentrations up to four orders of magnitude higher than natural background have been observed in other parts of the world.

The lead in soil has the potential to be ingested and accumulated by soil organisms or to be taken up and accumulated by plants, both of which may then be eaten resulting in lead moving along the food chain. Several species of grasses and crops have been reported to accumulate lead when grown on shooting ranges. Bioaccumulation Factors (BAF) in the range 0.14 – 1.2 kg_{dw}/kg_{dw} (median 0.39 kg_{dw}/kg_{dw}) have been reported for earthworms (Section 1.4.1.4) indicating that lead would not typically be concentrated in earthworms above soil concentrations, but that it may accumulate to similar levels to those observed in the soil. Earthworms collected from sites with high input of lead ammunition have been reported to have increased lead concentrations compared to worms from control sites, which are in a similar range to concentrations observed in soil samples taken from the same sites. Two species of arthropod have also been found to have increased lead concentrations compared to individuals sampled from control sites. Soil may also be ingested directly by grazing animals. Increased soil, vegetation and soil-dwelling organism lead concentrations will occur both during and after the service life of the site, unless a remediation plan is implemented.

This exposure pathway is therefore relevant for those uses which result in high inputs of ammunition to the same sites (e.g. shooting ranges or rural areas with regular shoots). Target shooting ranges would be expected to have increased soil lead concentrations in a relatively limited area, closest to the target (i.e. within the berm or in front of the berm). Release of lead shot from target shooting or from shooting of live quarry regularly over the same site would be expected to result in increased soil lead concentrations over a wider area.

1.4.5.4 *Movement of lead from spent lead ammunition to surface or ground waters*

Lead compounds and lead powder can be relatively mobile in soil solution or runoff water. Therefore, where sites are contaminated by lead ammunition and are in close proximity to surface or ground water, there is a risk for the transport of lead into the aquatic environment (see Section 1.4.1). Leaching has been demonstrated under aerobic conditions in *in vitro* leaching tests, but not under anaerobic conditions (ECHA, 2021c). Increased lead concentrations in surface waters would result in direct exposure of aquatic organisms, and the potential for bioaccumulation and transfer along the food chain based on the reported bioaccumulation factors (Section 1.4.1.3). There would also be potential exposure of wildlife and humans via untreated drinking water (Chiverton et al., 2022).

Information was submitted to the Agency during the call for evidence by a local council that had investigated two instances of drinking water contamination with lead that were suspected to be caused by the release of lead from spent ammunition. In the first case, bullets fired during soldier training on an acidic moorland were considered to be the cause of lead contamination of a private water supply serving thirteen dwellings. Lead concentrations up to 27.4 µg/L were reported. In the second case, lead shot from a clay pigeon shooting range on an acidic moorland site was considered to be the cause of lead contamination of a private water supply serving a commercial premises. Lead concentrations up to 27.7 µg/L were reported. In both cases, naturally occurring lead deposits and lead sources from water distribution systems (i.e. pipework/storage tanks) were ruled out as the potential source. No information was provided on the duration that the sites were used or on the number of bullets/shot present, but spent bullets and cartridge shells were observed at both sites.

Neither LAG (2015b) nor ECHA (2021c) identified any published studies on the concentration of lead in surface waters or groundwaters in GB from sites at which lead ammunition is used, although some non-GB studies were reviewed. Concentrations of waterborne lead up to 2,900 µg/L have been observed in surface waters located near to land contaminated by lead ammunition (cited within ECHA, 2021c; US EPA, 1994). Lead concentrations in water leaching from a clay pigeon site that had been closed for 20 years were higher than those from an adjacent site that was in use for the previous 20 years in Finland (Selonen et al., 2012). Also in Finland, concentrations of lead in groundwater at one of three shooting ranges studied was above the drinking water standard (Sorvari, 2007).

Several authors have investigated the movement of lead from spent ammunition either down through the soil column or into surface water run-off. In general, lead has been found to have limited vertical movement in the soil column (e.g. (Ash et al., 2013; Astrup et al., 1999; Cao et al., 2003; Clausen and Korte, 2009; Jørgensen and Willems, 1987; Knechtenhofer et al., 2003; Mariussen et al., 2017b; Murray et al., 1997; Sanderson et al., 2012)). The fate of lead is summarised in Section 1.4.1.2. Once deposited on the ground, lead ammunition will weather and a layer of lead oxides or lead salts form that may reduce the dissolution of soluble forms of lead.

Soluble lead would be expected to form complexes with anions and precipitate or sorb to particulate matter. This explains why the lead primarily remains in the soil layers closest to the surface.

wca (2021a) conducted an assessment of the potential for lead contamination of groundwater from use of ammunition at shooting ranges. The authors concluded that the potential for lead contamination of groundwaters depended on a combination of the soil chemistry and groundwater vulnerability. The sites with highest risk of contamination would be those with acidic soils with high organic matter content but low concentrations of iron, manganese and phosphate, sites with coarse soils (e.g. sandy soils), sites with preferential flow pathways (e.g. fissures or cracks in soil, plant root channels or animal burrows) and those with a shallow depth to the groundwater. wca (2021a) also conclude that clay pigeon shooting sites are expected to pose a higher risk to groundwater than rifle or pistol ranges due to the higher surface area:mass of lead shot compared to bullets, the wider spread of contamination from the use of lead shot and the use of bullet traps and recovery mechanisms for bullets that limit the amount of lead entering the environment.

Concentrations of lead in surface water run-off from shooting ranges have been found to be raised above background levels (e.g. (Craig et al., 1999; Labare et al., 2004; Mariussen et al., 2017a, 2012; Strømseng et al., 2009)), with higher concentrations observed during periods of precipitation or snow melt. This is considered to be due to the larger volume of water moving through the soil surface layers with highest lead concentrations, resulting in greater transfer of soluble lead and lead bound to colloids as well as transfer of lead bound to particulates.

1.4.5.4.1 Conclusion

There have been no GB studies investigating the concentration of lead in surface waters or groundwaters from sites where lead ammunition is used. However, monitoring data from elsewhere and knowledge of the fate of lead from laboratory studies demonstrates that there is the potential for contamination of surface waters and groundwaters in areas of intensive ammunition use (e.g. shooting ranges or rural areas with regular shoots). The scale of this exposure pathway will depend on the amounts of lead emitted to the environment, site conditions, proximity of surface water courses or groundwaters and time. Increased water lead concentrations may occur both during and after the service life of the site, unless a remediation plan is implemented. Aquatic organisms in surface waters may be exposed to the lead and may bioaccumulate lead, resulting in lead moving along the food chain. Wildlife and humans may be exposed via drinking water. This exposure pathway is therefore relevant for those uses which result in high inputs of lead in ammunition to the same sites (e.g. outdoor shooting ranges or rural areas with regular shoots).

1.4.5.5 *Movement of lead from embedded shot/bullets into body tissues/organs*

No GB data to support this potential exposure pathway have been located.

LAG (2015b) and Pain, Mateo and Green (2019b) review the evidence for this potential pathway using data for both birds and other animals from other countries. Studies on 22 species of live wildfowl have shown that 20 to 30 % of individuals have lead shot embedded in their bodies (Pain et al., 2014).

There is some evidence that embedded lead can be mobilised and result in higher blood lead concentrations in birds. For example, blood samples taken from birds of prey with embedded lead had significantly higher lead concentrations than samples from birds without embedded lead (22.4 µg/dL compared to 14.3 µg/dL) (Berny et al., 2017). Concentrations above 20 µg/dL are indicative of sub-clinical poisoning (Table 1.10), indicating that continued exposure to embedded lead may result in adverse effects. Finkelstein et al (2014) studied three wild California Condors (*Gymnogyps californianus*) that had embedded lead shot. The isotopic ratios of blood samples and the removed embedded lead shot were indistinguishable for two of the birds. Based on lead concentrations in feather and blood samples, the authors suggest that one bird was most likely acutely exposed by ingestion of lead shot with the same isotopic signature as the embedded shot, e.g. by feeding on a carcass shot with the same ammunition or by ingestion of lead shot when preening their wound. The other bird had lower blood concentrations which the authors suggest indicates exposure via mobilisation of the embedded lead. This bird was recaptured a year later suffering from lead poisoning as a result of ingestion of buck shot (a larger form of lead shot). The isotopic ratios of blood samples and the buck shot were indistinguishable on this occasion but were distinct from the remaining embedded lead shot.

LaDouceur et al (2015) studied 14 carcasses of wild animals (12 bird and 2 mammal) that had embedded lead projectiles which were not considered to be related to the cause of death. In the five cases where the embedded lead was in bone all had callus formation around the projectile. In three of the twelve cases where the embedded lead was in soft tissue a fibrous capsule had formed. Although lead poisoning from the embedded lead could not be definitively excluded in all cases, embedded lead was considered by the authors to present a low risk of toxicity.

Although some authors have linked embedded lead to reduced survival or condition, it is often difficult to identify toxicity arising from the embedded lead as the cause of these impacts, rather than the shooting injury, lead ingestion or a combination of factors.

1.4.5.5.1 Conclusion

The number of studies on this topic is small. They suggest that any effects on the organism from embedded lead are likely to be less important than those that are due to ingestion of lead from ammunition. Therefore, although this is an exposure pathway which could lead to sub-lethal effects, this is not considered further in this assessment.

1.4.5.6 *Overall conclusions*

The evidence base for the potential exposure pathways for lead in ammunition were comprehensively reviewed by LAG (2015b). Further information has been summarised in Pain, Mateo and Green (2019b) and ECHA (2021c, 2021b).

For the purposes of this assessment, the following exposure pathways will be taken forward for consideration in the environmental risk assessment and are shown in *Table 1.20*:

Table 1.20 Overview of key exposure pathways for the environment

Use	Use name	Exposure pathways
1	Live quarry shooting with lead shot	Primary and secondary poisoning of birds Secondary poisoning of non-avian wildlife and companion animals Soil contamination Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Poisoning of livestock (ruminants) via silage grown on shooting ranges/areas used as agricultural land Surface or groundwater contamination

2	Live quarry shooting with bullets	Secondary poisoning of birds Secondary poisoning of non-avian wildlife and companion animals
3	Live quarry shooting with airgun ammunition	Primary and secondary poisoning of birds Secondary poisoning of non-avian wildlife and companion animals
4	Outdoor target shooting with lead shot	Primary and secondary poisoning of birds Soil contamination Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Poisoning of livestock (ruminants) via silage grown on shooting ranges/areas used as agricultural land Surface or groundwater contamination
5	Outdoor target shooting with bullets	Soil contamination Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Surface or groundwater contamination
6	Outdoor target shooting with airgun ammunition	Primary and secondary poisoning of birds Soil contamination Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Surface or groundwater contamination

1.4.6 Environmental risk assessment

A fully quantitative risk assessment for the various uses of lead in ammunition has not been attempted for the purposes of this dossier. Instead, the Agency has considered the reported impacts on individual organisms and populations along with the evidence on hazard (Section 1.4.2) and exposure pathways (Section 1.4.5) to produce a description of the risk. As the source of the lead does not alter the impact, the various uses are considered together in a single environmental risk assessment. When possible, a semi-quantitative estimate of risk has been made, but where this was not appropriate risks are assessed qualitatively. In addition, the Agency has considered whether the relative scale of the risk between different uses can be determined for each receptor.

The risk assessment endpoints considered are adverse effects on:

- individual animals, including lethal and sub-lethal effects; and
- the population.

Thresholds are available for soil-dwelling organisms, forage material and water which can be compared to measured concentrations to assess risk in a quantitative manner. Thresholds represent a concentration below which adverse effects are not expected to occur. Measured concentrations in excess of the thresholds indicate that safe use has not been demonstrated, and that the risk is therefore not adequately controlled. The comparison of modelled or measured concentrations to a threshold to determine whether risks can be considered adequately controlled or not is standard practice in environmental risk assessment of chemicals. It is not a requirement to have measured evidence of adverse impacts in the field due to a specific chemical exposure in order to demonstrate risk.

1.4.6.1 *Impacts on individual birds (mortality/sub-lethal) – primary and secondary exposure*

Primary and secondary exposure of birds have been identified as a key exposure pathways (Section 1.4.). In order to conclude on the potential risk it is necessary to determine the level of exposure that may result in adverse effects.

The range of possible adverse effects of lead exposure have been investigated in experimental laboratory studies (Section 1.4.2). Evidence of the effects of lead on wildlife is also available from pathology reports and observational studies (e.g. (AHVLA, 2008; Pain et al., 2007; Potts, 2005). As well as causing mortality, lead exposure can result in sub-lethal effects on behaviour, development and reproduction. In addition to the lethal and sub-lethal effects that can be measured, there will also be welfare impacts that are less easy to measure (LAG, 2015a, 2015b).

Mortality has been observed in experimental studies after ingestion of a single lead shot pellet (e.g. (Buerger et al., 1986; Finley and Dieter, 1978; Vyas et al., 2001). These studies used adult birds and it is expected that higher levels of mortality would have been observed if chicks or juveniles had been used (the dose being proportionally higher due to their lower body weight and higher levels of lead absorption during periods of active growth). Sub-lethal and welfare effects will occur at exposure concentrations lower than those at which mortality occurs. Impacts will depend on the amount of lead ingested (either directly or via secondary poisoning) in relation to the body size of the bird, with different species also having differing sensitivities. Sub-lethal and welfare effects have also been shown to increase the risk of predation, susceptibility to disease and death from other causes (e.g. collisions) (Pain et al., 2014). Welfare impacts will occur preceding death and also when exposure is not fatal, and can result in severe and prolonged discomfort, distress and pain. Sainsbury et al. (1995) considered the effects of lead shot ingestion to be one of the most significant human-induced welfare impacts to wildlife across Europe. LAG (2015b) state that exposure to lead can result in:

"a range of pathological changes and clinical conditions which impact welfare. These include: anaemia; lethargy; anorexia, paralysis of the upper alimentary canal leading to food impaction and vomiting, weight loss, muscular atrophy and emaciation; degeneration of liver and kidney; oedema; a range of central nervous signs including reduced muscular coordination, demyelinating lesions in the central nervous system, paralysis of the legs and/or wings (birds losing their ability to walk may drag themselves about causing abrasions on their wings, WWT, unpublished); convulsions; and diarrhoea (Friend and Franson, 1999; Sainsbury et al., 1995)."

In addition to physical effects, lead exposure leads to negative mental state in affected animals. The Five Domains Model for animal welfare assessment (e.g. (Mellor et al., 2020)) describes how effects on nutrition, physical environment, health and behavioural interactions can result in both positive or negative effects on mental state. Lead poisoning is known to alter nutrition, health and behavioural interactions negatively. For example, birds with chronic lead poisoning will suffer from pain and hunger from reduced feeding success as a consequence of being unable to perform their full behavioural repertoire, and as a result, their mental state, and thus their welfare, will be poor as well. The impacts of such effects on population sustainability are unknown

1.4.6.1.1 Primary exposure of birds

Ingestion of one or more lead shot results in high levels of lead exposure over a short time period in some species. For this exposure pathway, background levels of lead from other natural or anthropogenic sources are not relevant as the exposure dose from ingestion is so much higher. There are no other comparable pieces of metallic lead (or lead alloy) in the terrestrial environment that can be ingested in the same way as a piece of lead shot.

Several UK studies have reported on the proportion of terrestrial gamebird samples that contained lead shot in their gizzards (Section 1.4.5.1). The proportions were 3 to 12 % in Common Pheasant (Butler et al., 2005; WWT, Organisation response #134), 0.2 to 1.4 % in Red-legged Partridge (Butler, 2005) and 0 to 4.5 % in Grey Partridge (Potts, 2005; Watson, 2004). A study of Grey Partridge chicks reported a higher proportion of 6.9 % (Potts, 2005).

These reported values are a spot estimate in time, from either a limited sample of shot birds or birds found dead. It is therefore important to consider their potential biases. Once ingested, lead shot may be egested, or retained in the gizzard. The lead particles in the gizzard will be eroded over time until they become too small to be observed, or leave the gizzard completely. Lead pellets are estimated to remain in the gizzard for up to 20 days , although some studies suggest a longer duration (Section 1.4.2), and therefore the reported values would underestimate the numbers of birds exposed annually. Modelling conducted by the CMS and submitted to the ECHA public consultation shows that if a half life of 20 days is assumed, a spot sample of 1 % prevalence would equate to an annual risk of exposure of 10.9 %, and a spot sample of 5% would equate to an annual risk of exposure of 45.6 %. Studies using birds found dead may underestimate the number of birds with ingested lead, as lead poisoning debilitates birds and may make individuals more prone to predation or hiding when sick or dying (LAG, 2015b) or overestimate if lead ingestion is the cause of mortality. Shot bird samples are likely to over-represent young birds, as these are more usually shot. Individuals that have ingested shot may have already been removed from the population if they have died due to lead poisoning and so be underestimated. However, Bellrose (1959) reports that Mallards experimentally dosed with 1, 2 or 4 lead shot pellets were 1.5, 1.9 and 2.1 times more vulnerable to hunting, respectively, than control ducks, indicating that birds with ingested lead may be over-represented in samples of shot birds. There is therefore the possibility that the reported values may both underestimate or overestimate the proportion of birds with ingested lead shot, depending on the species involved and sample type. Studies that have collected fully representative samples of birds are not available, either from the UK or other countries.

A single study is available on the levels of mortality attributable to the ingestion of lead shot by a terrestrial gamebird in the UK. Potts (2005) examined post-mortem records for wild Grey Partridge found dead in south-east England between 1947 and 1992. During 1947-1958 0.3 % (3/872) were considered to have died as a result of lead poisoning; however, the proportion was higher at 4 % (9/224) between 1963 and 1969 and 2.7 % (6/222) during 1970-1992. Over the whole time period 1.4 % were considered to have died as a direct result of lead poisoning (18/1,318). A third of birds with 1 to 3 gizzard pellets and all birds with 4 or more pellets were considered to have died as a result of lead poisoning, but sample sizes were small.

Three studies report modelled mortality rates. Pain *et al*. (2019a) used the data on ingestion rates of lead shot in Common Pheasant and Red-legged Partridge (Butler, 2005; Butler et al., 2005) to estimate mortality rates due to lead ingestion of 0.56 and 0.32 %, respectively, for the UK populations. Pain *et al*. (2019a) consider that this is an underestimation, as they do not include juveniles or account for sub-lethal poisoning; mortality is also estimated at half the rate of Mallards as an arbitrary figure. A study by Meyer *et al*. (2016) modelled the percentage mortality for Grey Partridge to be 4 % for deaths directly related to lead shot ingestion in continental Europe based on results from pathology reports. Meyer et al (2022) estimated a combined mortality rate for species of gallinaceous birds that may ingest lead shot when foraging for grit or seeds. The UK species included were Red-legged Partridge, Grey Partridge, Common Pheasant, Red/Willow Grouse. Mortality rates were based on published pathology reports diagnosing lead poisoning as the cause of death or indicative of sub-lethal effects. For the UK, the reported mortality was 0.99 % for mortality directly due to lead ingestion and 2.06 % for mortality indirectly due to lead ingestion as sub-lethal effects increased the chance of death due to other causes. Meyer et al. (2022) also note that when they applied their method to estimate mortality of UK Red-legged Partridge and Common Pheasant they calculate a direct mortality rate of 0.4 % which is similar to that reported by Pain et al. (2019a) using different method.

Based on the data on mortality rates of terrestrial birds, and for the purposes of this assessment, the Agency has selected a range of values between 0.1 and 5 % to represent those terrestrial birds potentially exposed and at direct risk of death due to the primary ingestion of lead shot. A range has been selected as there is uncertainty in this number and the number of studies on which this is based is limited and does not cover all species potentially at risk. This range is considered to be a reasonable estimate based on the data available. ECHA (2021b) follow a similar approach and select a central value of 1 % (range 0.5 to 2 %) based on the mortality data alone. It is important to note that this estimate relates to mortality only, and does not account for the fraction of birds that experience symptoms of lead-induced toxicity but do not die.

A list of the terrestrial species at most risk of lead poisoning is provided as Table 1-29 in ECHA (2021b). This list is based on evidence of ingestion of lead shot by these species, extrapolation from species in the same taxonomic group based on similarity of feeding ecology and an assessment by the United Nations Environment Programme Convention on Migratory Species (UNEP/CMS) ad hoc Expert Group. The number of wild birds in the UK for each of these species has been taken from the data submitted to the European Environment Agency (EEA) under Article 12 of the Birds Directive for the period 2013 to 2018 (available at https://nature-art12.eionet.europa.eu/article12/report?period=3&country=UK, accessed 14/12/21).

Data are reported as 'individuals', 'breeding pairs' or the 'number of calling males'. To provide an estimate of the total breeding population (*Table 1.21*), data reported as pairs or number of calling males was doubled (although this is an underestimate for data based on number of calling males).

Table 1.21 UK population of terrestrial bird species identified as being at high risk of lead poisoning due to primary ingestion

Latin name	Common name	Breeding population estimate
Alectoris rufa	Red-legged Partridge	145,494
Columba livia	Rock Dove (wild)	6,000
Columba livia	Rock Dove (feral)	920,930
Columba oenas	Stock Dove	643,560
Columba palumbus palumbus	Common Woodpigeon	10,310,120
Coturnix coturnix	Common Quail	748
Lagopus lagopus hibernica	Willow Grouse	404
Lagopus lagopus scotica	Red Grouse	529,530
Lagopus muta	Ptarmigan	17,000[a]
Lyrurus tetrix britannicus	Black Grouse	9,654
Perdix perdix	Grey Partridge	74,254
Phasianus colchicus	Common Pheasant	1,681,458
Scolopax rusticola	Eurasian Woodcock	114,216
Streptopelia decaocto	Eurasian Collared Dove	1,617,794
Streptopelia turtur	European Turtle Dove	7,176
Tetrao urogallus	Western Capercaillie	1,114
TOTAL breeding population		**16,079,452**

Numbers at risk of death assuming 0.1% mortality rate		**16,100**
Numbers at risk of death assuming 0.5% mortality rate		**80,400**
Numbers at risk of death assuming 1% mortality rate		**161,000**
Numbers at risk of death assuming 5% mortality rate		**804,000**

[a] The population estimate is provided as a minimum to maximum estimate of 2,000 to 15,000 breeding pairs. The mean value is used here.

Assuming a mortality rate due to lead exposure via primary ingestion of between 0.1 and 5 %, this equates to between 16,100 and 804,000 individuals at risk of death. These bird population estimates are for the whole of the UK and lead shot is not used over the whole land area, so they may overestimate actual numbers. However, as these values relate to the breeding population, they do not include the immature population. In addition, the winter population of Woodcock increases substantially due to immigration, with an additional 1.4 million individuals estimated to be present (Woodward et al., 2020). Other ground foraging species (especially those with a granivorous diet such as larks, finches and buntings) may also be affected by lead exposure, but evidence is lacking. These figures may therefore underestimate the actual number of impacted birds that suffer and die because they consume lead shot pellets.

These figures do not include terrestrial gamebirds bred and released for the purposes of hunting. The numbers are very large and in excess of the wild populations described above. For example, it is estimated that between 8.1 and 13 million partridges and 39 and 57 million pheasants are released annually in the UK, with 85 % released in England (Madden and Sage, 2020). Although these birds are a commodity, rather than a wild population, the risks to them are the same as for wild birds, or potentially even greater as they are located in areas used for shooting. Even if only a small proportion of the released population ingest lead shot then large numbers of birds may die from an avoidable cause. For example, if it is assumed that between 0.1 and 5 % of these two types of gamebird are exposed to lead shot via primary ingestion, this equates to between 47,100 and 3,500,000 individuals at risk of death. Pain et al (2019a) used a method based on Bellrose (1959) to estimate losses of 232,000 Common Pheasants and Red-legged Partridges in the UK annually based on the total population of birds bred and released for hunting each year and the wild population. Pain *et al*. note that as the numbers bred and released were based on data from 2006 this is likely an underestimate as numbers are reported to have increased since that date.

In addition to terrestrial birds, aquatic birds that feed outside of wetlands may also be exposed to lead shot. A list of the wetland species at most risk of lead poisoning due to exposure via the terrestrial environment is provided as Table 1-28 in ECHA (2021b). This list was produced using the same methodology as for the terrestrial birds. Table 1.22 reports the size of the UK population based on the data submitted to the EEA. Most of the data was for the number of over-wintering individuals. Some species were reported as breeding pairs, and in this case the numbers have been doubled.

Table 1.22 UK population of wetland bird species identified as being at high risk of lead poisoning due to primary ingestion via the terrestrial environment

Latin name	Common name	Estimate of number of individuals potentially affected
Anas acuta	Northern Pintail	20,062
Anas crecca	Common Teal	435,710
Anas platyrhynchos	Mallard	674,885
Anser albifrons	Greater White-fronted Goose	2,100
Anser albifrons flavirostris	Greater White-fronted Goose	10,942
Anser anser	Greylag Goose	91,000
Anser brachyrhynchus	Pink-footed Goose	510,000
Anser caerulescens	Snow Goose	8
Anser fabalis fabalis	Taiga Bean Goose	230
Anser fabalis rossicus	Tundra Bean Goose	300[b]
Branta bernicla bernicla	Dark-bellied Brent Goose	98,000
Branta bernicla hrota	Pale-bellied Brent Goose	5,000
Branta canadensis[a]	Canada Goose	109,048

Branta leucopsis	Barnacle Goose	100,745
Cygnus atratus[a]	Black Swan	38
Cygnus columbianus bewickii	Bewick's Swan	4,371
Cygnus	Whooper Swan	19,590
Cygnus olor	Mute Swan	13,912
Grus grus	Common Crane	56
TOTAL population		**2,095,997**

[a] Not listed by ECHA but has a similar feeding ecology to other geese and swans.

[b] Not listed in data submitted to the European Environment Agency (EEA) under Article 12 of the Birds Directive, but included in Woodward *et al*. (2020).

As with terrestrial birds, these numbers may be an underestimate. For example, Woodward *et al*. (2020) report an additional 230,000 Greylag Geese, 75 Snow Geese, 32,000 Brent Geese, 165,000 Canada Geese and 52,500 Mute Swans overwintering in the UK.

An estimate has not been made by the Agency of the potential exposure and risk to these wetland birds from the use of lead shot in terrestrial environments because uptake of lead shot from terrestrial environments cannot be distinguished from that used illegally over wetlands or present due to historic use. However, the potential exposure pathway is clear and even if only a small proportion of the population ingest lead shot then large numbers of birds may suffer and die because they consume lead shot pellets.

Pain et al. (2014) used a method based on Bellrose (1959) to estimate the number of deaths as a result of the ingestion of lead shot for 16 species of wetland bird for which there is UK evidence of lead shot ingestion. These 16 species make up 90 % of the total population listed in Table 1.23. The number of deaths was estimated to be 50,000 to 100,000 each winter, which represents 1.5 to 3 % of the wintering population. Data on the levels of compliance with the ban on the use of lead shot to kill ducks in England indicates that compliance is low, with between 68 and 87 % of ducks sampled killed with lead shot between 2008 and 2019 (Cromie et al., 2022, 2015, 2010). If it were assumed that the current regulations are 25 % effective for wetland species, then the estimate made by Pain et al. (2014) could be revised down to between 37,500 and 75,000 waterbird deaths each winter. This estimate does not include birds that die outside the winter shooting season or birds that die as an indirect result on lead poisoning, and does not include birds that may suffer sub-lethal effects as a result of lead exposure.

1.4.6.1.2 Secondary exposure of birds

Natural (e.g. geological) and anthropogenic (e.g. leaded fuel, or lead ammunition) exposures of wildlife to lead will vary geographically. However, in places where lead ammunition is used, the available data indicate that for scavenging and predatory birds a high proportion (for some species the majority) of lead exposure is likely to originate from ammunition. An exception is in places where high point source exposure to lead contamination exists (e.g. in historical lead mining areas).

For example, Helander et al. (2021) studied the contribution of ammunition-derived lead to exposure of Golden Eagles (*Aquila chrysaetos*), White-tailed Eagles (*Haliaeetus albicilla*) and Eurasian Eagle Owls (*Bubu bubo*) in Sweden. Excluding an influence from ingestion of lead shot and bullet fragments, Helander et al. (2021) estimated an environmental background liver lead concentration of up to 0.6 µg/g dw (approximately 0.18 µg/g ww) for White-tailed Eagles. Their analysis concluded that, at least for this species in Sweden, background levels with no influence from lead ammunition are very low, an order of magnitude lower than previously suggested for birds by Franson & Pain (2011), and that lead from ammunition contributes a substantial amount to the total lead body burden of a large proportion of the White-tailed Eagles.

Several UK studies have reported on the concentrations of lead in the liver, bones or blood of wild scavenging or predatory birds that were found dead or dying and collected for analysis (*Table 1.23*). These concentrations can be compared to the thresholds provided in Table 1.8 to provide an indication of the biological significance of the concentrations measured. A liver lead concentration in excess of 6 µg/g dw (~2 µg/g ww) indicates an abnormally high exposure to lead and will likely result in sub-clinical poisoning, and a concentration exceeding 20 µg/g dw (~6 µg/g ww) in liver is likely to have caused mortality. For bone, a concentration in excess of 10 µg/g dw is viewed as being elevated and likely to result in sub-clinical poisoning, and a concentration exceeding 20 µg/g dw is compatible with lethal poisoning. For blood, lead concentrations greater than 20 µg/dL are indicative of sub-clinical poisoning and concentrations over 50 µg/dL are likely to have caused mortality.

Table 1.23 Comparison of lead concentrations in wild UK birds of prey to thresholds of biological significance

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
Common Buzzard (*Buteo buteo*)	1981-1992	Liver: 1.34* (NA-909.1) n=56	Liver: 5% (3/56)	Liver: 2% (1/56)	Suggested ingestion of ammunition	Pain et al., 1995
	2007-2018	Liver: 2.573 (<0.011-85.4) n=187 Bone: 5.46 (0.146-110) n=125	Liver: 8% (15/187) Bone: 9.6% (12/125)	Liver: 2.7% (5/187) Bone: 4% (5/125)	Ingestion of shot based on isotope analysis	Taggart et al., 2020
Eurasian Sparrowhawk	1981-1992	Liver: 0.55* (NA-12.33) n=150	Liver: 0.7% (1/150)	Liver: 0%	NA	Pain et al., 1995
(*Accipiter nisus*)	2007-2014	Liver: 0.69 (0.035-16.8) n=172	Liver: 1.2% (2/172)	Liver: 0%	NA	Environment Agency, 2021

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
Goshawk (*Accipiter gentilis*)	1981-1992	Liver: 1.21* (NA- 4.63) n=6	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Golden Eagle (*Aquila chrysaetus*)	1981-1992	Liver: 0.34* (NA- 2.96) n=5	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Hen Harrier (*Circus cyaneus*)	1981-1992	Liver: 2.17* (NA- 5.71) n=7	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Hobby (*Falco subbuteo*)	1981-1992	Liver: <0.1* (NA- 12.33) n=7	Liver: 29% (2/7)	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
Kestrel (*Falco tinnunculus*)	1981-1992	Liver: 0.69* (NA-10.32) n=32	Liver: 3% (1/32)	Liver: 0%	NA	Pain et al., 1995
Little Owl (*Anthene noctua*)	1981-1992	Liver: 0.82* (NA-14.15) n=27	Liver: 7% (2/27)	Liver: 0%	NA	Pain et al., 1995
Long-eared Owl (*Asio otus*)	1981-1992	Liver: <0.1* (NA- 2.67) n=22	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Marsh Harrier (*Circus aeruginosus*)	1981-1992	Liver: <0.1* n=1	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Merlin (*Falco columbarius*)	1981-1992	Liver: <0.1* (NA-14.93) n=63	Liver: 10% (6/63)	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
Montagu's Harrier (*Circus pygargus*)	1981-1992	Liver: 2.12* (NA- 2.9) n=2	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Peregrine Falcon (*Falco peregrinus*)	1981-1992	Liver: 0.48* (NA-22.03) n=26	Liver: 15% (4/26)	Liver: 4% (1/26)	Suggested ingestion of ammunition	Pain et al., 1995
Red Kite (*Milvus milvus*)	1981-1992	Liver: 1.52* (NA- 3.06) n=6	Liver: 0%	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
	1995-2003	Blood: 24.07 (0.8-333.78) n=125[a]; Bone: 18.28 (5-187.5) n=86; Liver: 6.26 (0.5-46.7) n=44	Blood: 36.8% (46/125) Bone: NS Liver: 16% (7/44)	Blood: 2.4% (3/125)[b] Bone: 21% (18/86) Liver: 14% (6/44)	Ingestion of shot based on isotope analysis	Pain et al., 2007
	1989-2007	Bone: NS (NA – 187.5) n=86; Liver: NS (NA – 46.7) n=44	NS	Bone: 13% (11/86) Liver: 14% (6/44)[c]	1 bird with lead shot in the oral cavity	Molenaar et al., 2017
White-tailed Eagle (*Haliaetus albicilla*)	1981-1992	Liver: <0.1* n=1	Liver: 0%	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above sub-clinical toxic threshold	Above clinical threshold	Lead source	Reference
Short-eared Owl (*Asio flammeus*)	1981-1992	Liver: 1.61* (NA-7.25) n=15	Liver: 7% (1/15)	Liver: 0%	NA	Pain et al., 1995

[a] Blood samples were from juvenile kites (5-12 weeks old) collected from the wild and held in captivity but fed on shot carcasses with attempts made to remove pieces of lead shot.

[b] Authors use a threshold of 20-100 µg/dL and 100-500 µg/dL, so this is an underestimate of those above the clinical threshold of 50 µg/dL.

[c] Authors use a slightly lower threshold of 15 µg/g dw, so this is worst case.

Based on GB data for liver, blood and bone concentrations, there is evidence to suggest that deaths of wild Common Buzzards, Peregrine Falcons and Red Kites are being caused by lead poisoning. In samples of birds found dead, the proportion with elevated lead concentrations that are associated with mortality was up to 4 % in Common Buzzards, 4 % in Peregrine Falcons and 21 % of Red Kites (although only 9 % of Red Kite deaths were attributed to lead poisoning in this study; Pain *et al.*, (2007)). A larger proportion of the bird samples and a larger range of species were found to have levels of lead above background concentrations, in the range at which sub-clinical effects may be expected. However, these thresholds may not be sufficiently protective (see references in Section 1.4.2.4; (Helander et al., 2021)) and so the proportions here may be an underestimate of impacts.

Studies have linked the sources of the lead in liver and bone to lead from ammunition by the use of lead isotope analysis (Pain et al., 2007; Taggart et al., 2020; Walker et al., 2012). Birds have also been found with lead shot in their oral cavity (Molenaar et al., 2017) and lead shot has been found in regurgitated food pellets (Pain et al., 2007). Although other species have not been found to have such high lead concentrations in the carcasses submitted for study, the samples are unlikely to be fully representative for each species and so should not be taken to mean that higher lead concentrations are never present. Samples are biased to those dead birds found and then submitted for analysis, so the geographical location of the samples may not match with those areas of highest exposure, and are often small in number.

A list of the species at most risk of lead poisoning due to secondary exposure is provided as Table 1-29 in ECHA (2021b). This list was produced using the same methodology as for the terrestrial and wetland birds. *Table 1.24* reports the size of the UK population based on the data submitted to the EEA. When data were reported as a range of minimum to maximum population, a mean was calculated. Some species were reported as breeding pairs or breeding females, and in this case the numbers have been doubled. As these values relate to the breeding population, they do not include the immature population.

Table 1.24 UK population of bird species identified as being at high risk of lead poisoning due to secondary poisoning

Latin name	Common name	Breeding population estimate
Accipiter gentilis all others	Northern Goshawk	1,168
Accipiter nisus all others[a]	Eurasian Sparrowhawk	60,516
Aquila chrysaetos	Golden Eagle	1,020

Latin name	**Common name**	**Breeding population estimate**
Asio flammeus[a]	Short-eared Owl	2,800
Asio otus[a]	Long-eared Owl	7,800
Athene noctua[a]	Little Owl	7,226
Buteo	Common Buzzard	150,510
Circus aeruginosus	Western Marsh Harrier	1,283
Circus cyaneus	Hen Harrier	1,090
Circus pygargus	Montagu's Harrier	16
Corvus corax	Common Raven	20,054
Corvus corone	Carrion Crow	2,622,918
Corvus frugilegus[b]	Rook	1,963,028
Corvus monedula[b]	Eurasian Jackdaw	3,110,726
Falco columbarius[a]	Merlin	2,324
Falco peregrinus	Peregrine Falcon	3,462
Falco subbuteo[a]	Eurasian Hobby	4,142
Falco tinnunculus[a]	Common Kestrel	62,384
Haliaeetus albicilla	White-tailed Eagle	216
Milvus	Red Kite	8,776
Pica pica[bc]	Eurasian Magpie	1,217,764
TOTAL breeding population		**9,249,223**

[a] Not listed in ECHA but listed in (Pain et al., 1995)

[b] Not listed in Table 1-29 in ECHA but listed in (ECHA, 2021b)

[c] Not listed in ECHA but listed in (LAG, 2015a)

Pain et al. (2019a) used a method based on Bellrose (1959) to estimate losses of four species of raptor in Europe annually due to secondary lead poisoning. The four species were White-tailed Eagle, Golden Eagle, Griffon Vulture and Red Kite. A total of 530 – 1,135 individual adult birds were calculated to die annually across Europe as a result of lead poisoning. These values do not include deaths of immature birds.

Green et al. (2022a) modelled the population level impact of lead exposure on European (including UK) raptor species and as part of this estimated the number of individual birds that may die as a result of lead poisoning. Exposure levels were based on measured concentrations of lead in liver samples collected from dead or dying wild birds reported in previously published studies, and impacts on the individual causing or contributing to death were assumed when the concentration exceeded a threshold of 20 mg/kg dw (the same threshold used here). Of the 22 species for which there were data, 10 had measured concentrations above the threshold, ranging from 0.3 to 16.5 %. The additional annual mortality of each of the 10 species was calculated, assuming that the proportion of individuals with lead concentrations above the threshold was equal to the proportion of deaths attributable to lead poisoning, and the expected annual survival rate in the absence of lead poisoning was estimated using this figure and published annual survival rates based on observations. Green *et al*. (2022a) report that for the 10 species with measured liver lead concentrations above the threshold, the modelled number of adult deaths attributable to lead poisoning ranged from 1 (Bearded Vulture) to 2,597 (Common Buzzard) across Europe. The total annual number of deaths for the 10 species was 5,498 birds across Europe. Although the source of the increased liver lead concentrations could not be identified conclusively, countries with higher hunting rates (in terms of number of hunters/area) were positively correlated with the prevalence of lead poisoning. The authors also note that those species that are known to regularly scavenge or prey on game animals, birds or waterfowl had a higher annual probability of death from lead poisoning than those with different feeding habits.

Additional data were provided by a RISEP expert after the first Challenge Panel using the same method as Green *et al*. (2022a) to model the annual number of deaths of adult raptors in the UK. The fitted model parameters, method and dataset from Green *et al*. (2022a) were used to estimate the additional annual mortality rate for each of the eight species of raptors which breed in the UK for which at least one individual with levels of lead above clinical thresholds in the liver was found in Europe. The UK population of each species was based on the number of breeding pairs reported by Woodward *et al*. (2020) multiplied by two (to give the number of individuals) as these are the most recent available data, but the values are comparable to those used in Green *et al*. (2022a) for UK populations. In addition, the annual number of deaths of immature raptors in the UK was modelled. The same approach was used as for adults, but the annual survival of immature birds was based on a mean value from a review of demographic rates in stable populations of

32 species (Ricklefs, 2000) as this input was not used in the Green *et al*. (2022a) paper. The population size of immature birds was calculated using a Leslie matrix with species-specific adult survival rates and age at first brood and assuming that the population was stable.

The annual mortalities for each species are shown in Table 1.. Although the highest number of individual deaths for both adult and immature birds were for Common Buzzards, Eurasian Sparrowhawks and Red Kites, this reflects the larger UK populations of these species. The highest additional mortality rates were modelled for the less common species; Golden Eagle, Western Marsh Harrier, Northern Goshawk and White-tailed Eagle. Again, this takes no account of sub-lethal impacts.

Table 1.25 Estimated number of adult and immature raptor deaths attributed to lead poisoning in the UK *(Green et al., 2022a)*

Species	Number of adult mortalities attributable to lead poisoning	Number of immature mortalities attributable to lead poisoning
Golden Eagle	7	23
Eurasian Sparrowhawk	55	157
Northern Goshawk	9	28
Western Marsh Harrier	8	25
Red Kite	38	98
White-tailed Eagle	3	8
Common Buzzard	359	1,093
Peregrine Falcon	15	39
All species	493	1,471

Meyer et al (2022) modelled the population level impact of lead exposure on European (including UK) raptor species and as part of this estimated a combined mortality rate for species of diurnal raptors that may ingest lead shot or fragments of lead bullets from their prey. The UK species included were Red Kite, Common Buzzard, Peregrine Falcon, Golden Eagle, Northern Goshawk, Eurasian

Sparrowhawk and Hen Harrier. Mortality rates were based on published pathology reports diagnosing lead poisoning as the cause of death and measured liver lead concentrations in carcasses indicative of sub-lethal effects. For the UK, the reported mortality was 0.80 % for mortality directly due to lead ingestion and 5.25 % for mortality directly and indirectly due to lead ingestion as sub-lethal effects increased the chance of death due to other causes. Based on the breeding population for these species reported in Meyer et al. (2022) this equates to 1,720 deaths from direct ingestion and 11,292 deaths directly and indirectly due to ingestion across Europe.

The available observational data indicate that a proportion of the deaths of scavengers and avian predators in the UK results from lead poisoning arising from the use of lead ammunition. Data to support the possible exposure pathways that are thought to exist in the UK are presented in Section 1.4. Some GB raptor species have been shown to have increased lead concentrations that can be linked to lead ammunition, and the same exposure pathway can be assumed for species that have similar feeding habits. Three recent studies (Green et al., 2022a; Meyer et al., 2022; Pain et al., 2019b) have modelled the number of birds dying due to secondary poisoning from lead ammunition across Europe (including the UK) and Green (2022) calculated values for the UK population. The studies reviewed here have focussed their analyses on mortality, but greater number of birds would be expected to experience sub-lethal effects. The potential exposure pathway is clear and even if only a small proportion of the population ingest lead via secondary poisoning then large numbers of birds may be adversely affected.

1.4.6.1.3 Conclusion on impacts on individual birds

In summary, due to the complex nature of the hazards posed by lead and an inability to quantify oral uptake of lead shot and ammunition fragments, it is not possible to conduct a reliable quantitative assessment of the total risks to birds from the use of lead in ammunition. However, based on the evidence of exposure via both primary and secondary ingestion, and even assuming only a small proportion of the bird populations are exposed, large numbers of terrestrial and wetland birds are expected to suffer from increased mortality, sub-lethal and welfare effects.

The Agency estimates that between 16,100 and 804,000 individual terrestrial birds are at risk of death annually from primary ingestion of lead shot. This does not include juvenile populations, some overwintering species or other ground foraging species. An additional 47,100 to 3,500,000 gamebirds bred and released for the purposes of hunting are at risk of death annually from primary ingestion of lead shot. Pain et al. (2014) estimated the number of wetland birds that die annually due to ingestion of lead shot. This value has been adjusted by the Agency on the assumption that 25 % of lead shot used over wetlands has been replaced with alternatives to result in an estimate of 37,500 to 75,000 waterbird deaths annually.

Scavenging birds, including raptors, will also be at risk from secondary poisoning from the use of all forms of lead ammunition. Green (2022) estimated approximately 2,000 adult and juvenile deaths across eight species of raptor in the UK following the method in Green et al. (2022a), whilst Meyer et al. (2022) estimated 1,720 adult deaths from direct ingestion and 11,292 adult deaths directly and indirectly due to ingestion for seven species of raptor.

A higher number of individual birds would be expected to experience sub-lethal and welfare impacts than die. LAG (2015a) conclude that millions of birds experience sub-lethal and welfare impacts as a result of exposure to lead from ammunition in the UK.

The Agency therefore considers that the use of lead shot (Uses #1 and #4) and lead airgun ammunition (Uses #3 and #6) has been demonstrated to pose a risk of primary and secondary ingestion by birds that is not adequately controlled and the use of other lead ammunition for live quarry shooting (Use #2) has been demonstrated to pose a risk of secondary poisoning of birds that is not adequately controlled.

1.4.6.2 *Impacts on bird populations – primary and secondary*

An adverse effect on a population may be observed as a decline or as a reduction in the rate of population increase and may result in changes in population distribution. In chemical risk assessment under UK REACH, an adverse effect on a population relevant endpoint observed in a laboratory test is assumed to have the potential to cause a risk at the population level (ECHA, 2008). Population relevant endpoints are reported from chronic ecotoxicity tests and an assessment factor is applied to derive a Predicted No Effect Concentrations (PNEC). The PNEC is generally compared to modelled exposure concentrations to determine whether a risk can be ruled out, but population modelling is not required as part of the risk assessment. The population modelling calculations made by academic researchers and reported in this section are therefore provided for additional illustration only. In this dossier, a population level effect is defined as a reduction in population size relative to the population size that would be expected in the absence of exposure to lead from ammunition.

Adverse effects on population-relevant endpoints have been observed in laboratory studies with birds at concentrations below those at which maternal mortality is seen (see Section 1.4.2.3.1). For example, exposure to lead can reduce reproductive success (Buerger et al., 1986) (Vallverdú-Coll et al., 2016) (Gil-Sánchez et al., 2018) and reduce juvenile survival (Vallverdú-Coll et al., 2015a). These four studies report adverse effects at exposure levels that are observed in the GB environment, for example after ingestion of between 1-3 shot by the adults or are from field observational studies in countries with similar exposure pathways to GB). A reduction in individual survival rates (see Sections 1.4.5.2 and 1.4.5.3) and adverse effects on population-relevant endpoints will affect the overall population size of a species, unless they are perfectly compensated for by complete density-dependent enhancement of other demographic variables (for example if remaining birds had increased rates of survival or breeding success due to increased food availability). If density dependence is incomplete but sufficiently strong then the population will stabilise at a lower level. If density dependence is weak or does not occur, then the population will reduce, and potentially reach extinction. The point at which population level effects may occur will vary from species to species, and between locations and time, depending on what other stressors or compensatory factors are in place. However, complete density dependence has not been demonstrated for birds exposed to lead from ammunition (e.g. Nichols et al., (2015)), nor has it been demonstrated frequently for other species and stressors more generally (Pain et al., 2019b). Therefore, the Agency considers that the population size of at least some bird species will be lower than that which would be expected in the absence of lead exposure from ammunition, but that the size of the reduction in population size is uncertain.

The additional mortality due to lead poisoning that could be compensated for by two theoretical raptor populations and allow a steady population size was estimated in LAG (2015b) following the Demographic Invariants Method (DIM) of Niel and Lebreton (2005). The DIM model allows an estimate to be made of the additional mortality, beyond that which would occur naturally, that can be adjusted for by density-dependent mechanisms. LAG (2015b) modelled a long-lived raptor with annual adult survival of 0.95 and a mean first age of breeding of 5 years, and a second shorter-lived raptor with an annual adult survival of 0.8 and a mean first age of breeding of 2 years. These values were selected to cover most UK species of raptor. For the long-lived raptor an additional annual mortality of 2.2 % per year could be compensated for. This value was 8.2 % for the short-lived raptor. When converted to the proportion of all adult deaths due to the modelled lead poisoning, this equated to around 30 % for both species. The proportions of scavenger or raptor samples with concentrations of lead above levels expected to result in clinical poisoning (Table 1.24) are all below 30 %, suggesting that population level effects in the UK would not be anticipated. However, LAG (2015b) note that the modelling approach is based on many assumptions to provide an approximate maximum level of additional mortality that could be compensated for and the measured data also have limitations as data are limited or not available for all species of interest, and does not cover all locations where greatest exposure via lead ingestion may be expected.

Following an alternative method, Meyer *et al*. (2016) modelled populations of Grey Partridge in continental Europe, Common Buzzard in Germany and Red Kite in Wales to estimate how mortality due to poisoning (including lead) could alter the population sizes. Exposure estimates for each species were based on levels seen in observational studies and ranged from 4 to 16 % for lead shot ingestion. For Grey Partridges, the population size was reduced by 10 % due to lead shot alone. For Red Kites, the population growth rate was reduced from 6.5 % annual increase to 4 % due to lead shot. Effects on the population of Common Buzzard were much smaller, with a decrease of <1 % modelled for both lead shot and other poisons combined. Although the significance of this paper to the UK is unclear, it does demonstrate that different species respond differently based on levels of exposure, life history and resilience of the population.

Green *et al*. (2022a) modelled the population level impact of lead exposure on European (including UK) raptor species (see details in Section 1.4.6.1.2). Additional annual mortality of 10 species was calculated, assuming that the proportion of individuals with lead concentrations above the threshold was equal to the proportion of deaths attributable to lead poisoning, and the expected annual survival rate in the absence of lead poisoning was estimated using this figure and published annual survival rates based on observations. These values together with demographic data for each species (e.g. age at first breeding) were used to model population size over time both with and without lead poisoning and the difference between these values was reported as the expected proportion by which the European population of each species may be reduced due to lead. Reductions in adult population size were modelled to be between 0.2 % (Eurasian Sparrowhawk) and 14.4 % (White-tailed Eagle). When compared to the population sizes modelled in the absence of lead exposure, the total reduction in population size across all 10 species was 2.2 % which equates to around 55,000 birds across Europe. Separate estimates for GB were not reported.

Meyer et al (2022) modelled the population level impact of lead exposure on European (including UK) gallinaceous birds and raptor species. The authors note that their paper is primarily to demonstrate their method, rather than to definitively quantify reductions in bird populations due to lead exposure. Mortality rates (see details in Section 1.4.6.1) and changes in reproduction rates due to lead exposure were used as inputs to the models previously used in Meyer *et al*. (2016). Results are reported for European populations; separate estimates for GB were not reported.

Grey Partridge was used as a representative species for gallinaceous birds. The stochastic model indicates that ingestion of lead shot reduced the breeding population size by 1.74 % when both direct and indirect mortality is included but reproductive effects are excluded and 1.75 % when reproductive effects are included. When applied to all populations of gallinaceous birds in Europe this equates to between 219,207 – 219,936 breeding pairs lost.

Common Buzzards and Red Kites were used as the representative species for raptors relevant to the UK. The stochastic model indicates that ingestion of lead shot reduced the breeding population size of Common Buzzards by 1.1 % when both direct and indirect mortality is included but reproductive effects are excluded and 1.9 % when reproductive effects are included. The stochastic model indicates that ingestion of lead shot reduced the breeding population size of Red Kites by 4 – 8.1 % when both direct and indirect mortality is included but reproductive effects are excluded and 5.8 – 11.1 % when reproductive effects are included, depending on whether the Red Kite population was stable or increasing. When applied to all populations of raptors in Europe this equates to between 32,655 – 85,922 breeding pairs lost, although this value also includes species of vultures which are not present in the UK.

Niel and Lebreton (2005), Meyer *et al*. (2016) and Green *et al*. (2022a) focus on how increased mortality due to lead exposure may affect the population. However, sub-lethal effects can also alter the reproduction rate, and therefore result in changes to the population size. Indeed, Meyer *et al.* (2016) note that when additional effects on reproduction rate were also included in their model the predicted effects were slightly greater. It should therefore be remembered that adverse effects that may be population relevant are not restricted to mortality, so estimates based on mortality alone are a “best case” and are unlikely to be realistic. Meyer *et al*. (2022) include sub-lethal effects resulting in indirect mortality and effects on reproduction rates in their modelling.

The results from all these studies indicate that the life history of the bird species is important in determining what the effects on population levels may be. Differences in feeding ecology, life span, age at first breeding and annual survival rate (from all causes of death) will all influence the scale of any adverse effects on population. The number of individual birds killed or the reduction in stable population size is of relevance but another consideration is whether the population can be sustained. Meyer *et al*. (2022) note that the absolute number of individual birds dying due to exposure to lead from ammunition will be greater in the more abundant species. However, bird species with lower population sizes are more at risk of extinction. Population level effects are most likely to occur in species such as raptors that have lower natural annual mortality rates and lower annual reproductive rates (Pain et al., 2019b). Green *et al*. (2022a) also note that species with high adult survival, late age at first breeding and high additional mortality due to lead exposure will experience the greatest population reductions. Population level effects would therefore be most expected in species that are exposed via secondary poisoning as they are the species with these characteristics.

The use of lead ammunition has been linked to population level effects in several raptor species from outside GB. The strongest evidence is for the California Condor, which would be predicted to have become extinct due to the mortality caused by lead from ammunition if it were not for the mitigation measures put in place to protect this species (references in LAG, 2015b and Pain *et al.*, 2019b). Modelling studies have also indicated that population level effects may be occurring in Bald Eagles in

America (Hanley et al., 2022) and Steller's Sea Eagles in Japan (Saito, 2009; Ueta and Masterov, 2000), both of which have ecological similarities to the White-tailed Eagle which is found in GB. For all three species, the studies have linked the lead associated mortalities of individual birds to a decline in population, rather than sub-lethal effects on reproduction rate.

An assessment of the population status of UK birds is made in the fifth review of the Birds of Conservation Concern (BOCC) (Stanbury et al., 2021). Species are assigned to either a red, amber or green list, based on an objective set of criteria. A green listing indicates that there is no significant concern for conservation, and amber and red indicate increasing levels of concern due to declines in number or range based on the available monitoring data. In addition to the BOCC listing, the International Union for the Conservation of Nature (IUCN) criteria have been applied by Stanbury *et al*. to produce a regional Red List assessment of extinction risk for GB. The IUCN listing is based on the risk of extinction of a species, rather than conservation status in a broader sense. The BOCC and IUCN listing for each of the terrestrial bird species considered at highest risk of primary and secondary lead poisoning are shown in .

Table 1.26 BOCC and IUCN listing from *(Stanbury et al., 2021)* for the terrestrial and wetland birds at most risk of primary and secondary poisoning from lead in ammunition from terrestrial exposure

Latin name	Common name	BOCC listing	IUCN listing
Terrestrial species at risk from primary ingestion			
Alectoris rufa	Red-legged Partridge	Not included	Not included
Columba livia	Rock Dove	Green	NT
Columba oenas	Stock Dove	Amber	LC
Columba palumbus palumbus	Common Wood Pigeon	Amber	LC
Coturnix coturnix	Common Quail	Amber	EN
Lagopus lagopus hibernica	Willow Grouse	Not included	Not included
Lagopus lagopus scotica	Red Grouse	Green	LC
Lagopus muta	Ptarmigan	Red	VU

Latin name	Common name	BOCC listing	IUCN listing
Lyrurus tetrix britannicus	Black Grouse	Red	VU
Perdix perdix	Grey Partridge	Red	VU
Phasianus colchicus	Common Pheasant	Not included	Not included
Scolopax rusticola	Eurasian Woodcock	Red	VU
Streptopelia decaocto	Eurasian Collared Dove	Green	NT
Streptopelia turtur	European Turtle Dove	Red	CR
Tetrao urogallus	Western Capercaillie	Red	EN
Wetland species at risk from primary ingestion			
Anas acuta	Northern Pintail	Amber	CR
Anas crecca	Common Teal	Amber	LC
Anas platyrhynchos	Mallard	Amber	VU
Anser albifrons	Greater White-fronted Goose	Red	EN
Anser anser	Greylag Goose	Amber	LC
Anser brachyrhynchus	Pink-footed Goose	Amber	LC
Anser caerulescens	Snow Goose	Not included	Not included
Anser fabalis	Taiga Bean Goose	Amber	EN
Branta bernicla	Brent Goose	Amber	LC
Branta canadensis	Canada Goose	Not included	Not included
Branta leucopsis	Barnacle Goose	Amber	LC
Cygnus atratus	Black Swan	Not included	Not included
Cygnus columbianus	Bewick’s Swan	Red	CR

Latin name	Common name	BOCC listing	IUCN listing
bewickii			
Cygnus cygnus	Whooper Swan	Amber	EN
Cygnus olor	Mute Swan	Green	LC
Grus grus	Common Crane	Amber	VU
Terrestrial species at risk from secondary poisoning			
Accipiter gentilis	Northern Goshawk	Green	NT
Accipiter nisus	Eurasian Sparrowhawk	Amber	VU
Aquila chrysaetos	Golden Eagle	Green	NT
Asio flammeus	Short-eared Owl	Amber	EN
Asio otus	Long-eared Owl	Green	LC
Athene noctua	Little Owl	Not included	Not included
Buteo buteo	Common Buzzard	Green	LC
Circus aeruginosus	Western Marsh Harrier	Amber	LC
Circus cyaneus	Hen Harrier	Red	EN
Circus pygargus	Montagu's Harrier	Red	CR
Corvus corax	Common Raven	Green	LC
Corvus corone	Carrion Crow	Green	LC
Corvus frugilegus	Rook	Amber	NT
Corvus monedula	Eurasian Jackdaw	Green	LC
Falco columbarius	Merlin	Red	EN
Falco peregrinus	Peregrine Falcon	Green	LC
Falco subbuteo	Eurasian Hobby	Green	NT
Falco tinnunculus	Common Kestrel	Amber	VU
Haliaeetus albicilla	White-tailed Eagle	Amber	EN

Latin name	Common name	BOCC listing	IUCN listing
Milvus milvus	Red Kite	Green	LC
Pica pica	Eurasian Magpie	Green	LC

IUCN threat status categories: CR critically endangered, EN endangered, VU vulnerable, NT near threatened, LC least concern.

For those terrestrial species at highest risk of primary ingestion, six species are red listed on the BOCC and a further three are amber listed. One species is critically endangered, two are endangered and four are vulnerable based on the Regional IUCN listing.

For those wetland species at highest risk of primary ingestion, two species are red listed on the BOCC and a further ten are amber listed. Two species are critically endangered, three are endangered and two are vulnerable based on the Regional IUCN listing.

For those species at highest risk of secondary poisoning, three species are red listed on the BOCC and a further six are amber listed. One species is critically endangered, four are endangered and two are vulnerable based on the Regional IUCN listing.

The reasons for the status of the threatened species are varied, and this assessment does not attempt to link exposure to lead from ammunition as a specific cause for any of them. However, some populations of bird species that have feeding ecologies that increase the likelihood that they will be exposed to lead from ammunition, either via primary or secondary exposure, are already threatened.

Effects on individual survival rates and population relevant endpoints have been observed in laboratory tests at concentrations that are observed in the GB environment. This therefore indicates a risk of population level effects. Published studies that have modelled population level impacts indicate that life history traits will influence the scale of the adverse effects, with the greatest impacts expected in those species that are longer lived and later maturing (which are typically exposed via secondary poisoning) and with lower population sizes. A number of bird species that are already identified due to concerns over their population status are potentially at risk of lead exposure due to their feeding habitat. It is precautionary to avoid additional pressures on already vulnerable populations (for example due to sub-lethal effects of lead) where possible. In addition, a large number of individual birds are at risk from suffering and increased mortality from an avoidable cause.

The Agency therefore considers that the use of lead shot (Uses #1 and #4), lead airgun ammunition (Uses #3 and #6) and the use of bullets for live quarry shooting (Use #2) has been demonstrated to pose a risk of population level effects in terrestrial birds that is not adequately controlled.

1.4.6.3 *Impacts on other animals*

1.4.6.3.1 Impacts on livestock (and other grazing wildlife) – primary and secondary exposure

Exposure of livestock (and potentially wildlife) has been identified as a potential exposure pathway for areas that are regularly shot over or which have intensive use, i.e. live quarry shooting with lead shot (Use #1) and shooting ranges (Uses #4, #5 and #6) (Section 1.4.5). Exposure may occur via the direct ingestion of lead ammunition, or via ingestion of soil, soil-dwelling organisms or vegetation that has increased lead content. In addition, a potential exposure pathway via ingestion of silage contaminated with lead shot (Uses #1 and #4) has been identified (Section 1.4.5). These exposure pathways are not considered relevant for the other uses included in this assessment.

Payne and Livesey (2010) report on lead poisoning of livestock in the UK due to the direct ingestion of lead shot. Braun *et al*. (1997) and Muntwyler (2010) also report on direct ingestion of lead shot by cattle in two studies in Switzerland that resulted in acute poisoning and mortality. A report from New Zealand stated that around 20 of 100 cattle had died or been euthanised following exposure to lead shot that was embedded in fodder beet grown on a shooting range (Macnicol, 2014).

Cases of lead poisoning resulting in sub-lethal and lethal impacts on cattle have been reported in the UK (Frape and Pringle, 1984; Payne et al., 2013), New Zealand (Vermun et al., 2002) and in the USA (Bischoff et al., 2014, 2012; Howard and Braum, 1980; Rice et al., 1987) after ingestion of silage contaminated with lead shot. In all cases, the plant material used to make the silage had been harvested from areas used for sports shooting with lead shot.

The Agency considers that lead shot ingested whilst grazing or contained within silage can result in risks to livestock that are not adequately controlled. By extension, this could also affect mammalian wildlife e.g. deer.

Several GB studies have reported on the uptake of lead by plants growing in areas of intensive shooting. Grass samples were found to have concentrations up to 95 mg/kg dw (RPS Environmental Sciences Ltd, 1989), 360 mg/kg dw (RPS Clouston, 1991), 121.75 mg/kg dw (Clements, 1997) and 38.4 mg/kg dw (Sneddon et al., 2009). None of these studies attempted to model or measure the exposure of livestock ingesting these plants.

Some thresholds have been set for the acceptable concentrations of lead in forage and feed. Directive 2002/32/EC on undesirable substances in animal feed that has been retained in GB law sets a lead concentration of 30 mg/kg for forage (including hay, silage, fresh grass, etc.) with a moisture content of 12 % and 10 mg/kg in other feed materials with a moisture content of 12 %. These thresholds are equivalent to 34 mg/kg dw and 11.4 mg/kg dw, respectively. All four GB studies that reported on concentrations in grass have maximum lead concentrations above the forage threshold, with one study having a maximum concentration ten times higher (RPS Clouston, 1991).

The Agency considers that the concentration of lead in grass growing on sites used for intensive or regular shooting for extended periods of time can reach levels that result in risks to grazing livestock. By extension, this could also affect mammalian wildlife. Bennett et al. (2007) modelled the exposure of rabbits (*Sylvilagus floridanus*) via contaminated grass at a rifle and pistol shooting range in the USA. Samples of grass were analysed for lead content and a risk assessment made based on ingestion rate, bioaccessibility and varying foraging ranges to account for the variation in grass lead concentrations. Risks were modelled when assuming that all foraging took place at the highly contaminated areas of the range, but when a wider foraging range was modelled risks were below acceptable thresholds. The authors note that risks to individual animals from species with similar habits could be unacceptable, depending on the receptors true foraging range.

CPSA estimate some 180 registered shooting grounds have no agricultural activity (BSSC, Organisation #100; CPSA, Organisation #101). The NRA report that based on a survey of range operators 6% of ranges have crops grown or animals grazing on them (NRA, Organisation #127). Although the geographic scale of this risk may be small, the potential impacts to the livestock (or wildlife) affected can be severe. The Agency therefore considers that the use of agricultural land for live quarry shooting with lead shot (Use #1) and sports shooting with lead ammunition (Uses #4, #5 and #6) has been demonstrated to pose a risk to livestock and other grazing animals that is not adequately controlled.

1.4.6.3.2 Impacts on mammalian scavengers – secondary exposure

Exposure of mammalian scavengers to lead ammunition through contaminated prey and gut piles, discarded meat or unrecovered game has been identified as a potential exposure pathway for uses which involve the shooting of live quarry (i.e. Uses #1, #2 and #3) (Section 1.4.5). This exposure pathway is not considered relevant for the other uses included in this assessment.

The Agency considers that this exposure pathway is exists in GB. However, the scale of the risk as a result of this exposure pathway is unknown.

The Agency therefore considers that the use of lead ammunition for live quarry shooting (Uses #1, #2 and #3) can pose a risk to scavenging mammalian wildlife that is not adequately controlled.

1.4.6.3.3 Impacts on companion animals – secondary exposure

Exposure of companion animals has been identified as a potential exposure pathway for uses which involve the shooting of live quarry (i.e. Uses #1, #2 and #3) (Section 1.4.5). Exposure may occur when hunters feed their own dogs off cuts or surplus game. This exposure pathway is not considered relevant for the other uses included in this assessment.

The Agency considers that exposure of companion animals via this route occurs in GB. Hogasen et al. (2016) report a modelled risk assessment for dogs fed the trimmings of lead-shot game and conclude that exposure may result in effects, including death. Knutsen et al. (2019) modelled the risk of effects in dogs fed on deer and moose meat shot with lead ammunition. They concluded that the risk of chronic effects was high, but that the risk of adverse effects from a single dietary exposure was low.

The Agency therefore considers that the use of lead ammunition for live quarry shooting (Uses #1, #2 and #3) can pose a risk to companion animals that is not adequately controlled.

1.4.6.4 *Risks related to soil*

Increased soil lead concentrations due to the input of lead ammunition has been identified as a potential exposure pathway for areas that are regularly shot over or which have intensive use, i.e. live quarry shooting with lead shot (Use #1) and shooting ranges (Uses #4, #5 and #6) (Section 1.4.5). This exposure pathway is not considered relevant for the other uses included in this assessment.

A small number of GB studies have measured the concentrations of lead in soil samples collected from shooting ranges that had been in use for between 10 and 40 years. Three studies were from clay pigeon sites and reported concentrations of up to 10,600 mg/kg dw (Mellor and McCartney, 1994) and 8,172 mg/kg dw (Clements, 1997) and a mean concentration of 6,410 ± 2,250 mg/kg dw (Reid and Watson, 2005). One study from a shooting ground used for game and intensive pheasant shooting reported mean concentrations of 160 mg/kg dw in a woodland copse used for shooting and 68.3 mg/kg dw in a meadow used for shooting (Sneddon et al., 2009).

There are no UK soil environmental quality thresholds for lead. A generic PNEC for soil of 212 mg/kg dw is presented in the EU REACH CSR (2020), based on ecotoxicity data for soil-dwelling organisms (Section 1.4.2.2). All three studies from GB clay pigeon sites report soil concentrations that are significantly greater than this

PNEC. The single study from a game shooting ground did not exceed the PNEC, although how representative this study is of other sites is unknown. The Agency notes that even at a single shooting range, soil lead concentrations would be expected to be highly variable depending on the proximity to the target and the site conditions. Variability between sites would also be expected due to the length of service life, intensity of shooting at the site and type of shooting. The limited number of GB soil monitoring studies clearly demonstrate that soil lead concentrations can be elevated considerably above background at shooting ranges, and achieve concentrations that are a trigger for risk management action. A single study from a game shooting ground does not allow this risk to be ruled out for that use.

Dinake *et al*. (2019) reviewed over 100 studies on the concentrations of lead in soils from shooting ranges published between 1983 and 2018. Elevated concentrations of lead were found at shooting ranges globally, ranging from 11 to 300,000 mg/kg dw, with the highest concentrations found in berms. Dinake *et al*. (2019) note that in nearly all the studies they reviewed the lead concentrations were orders of magnitude greater than the available regulatory limits.

Repeated shooting at a site, without any risk management measures in place to capture or collect and remove the lead ammunition, will result in increasing soil lead concentrations over time. The Agency considers that the concentration of lead in soil at sites used for intensive or regular shooting for extended periods of time can reach levels that result in risks to soil that are not adequately controlled.

1.4.6.5 *Risks related to surface and groundwaters*

Increased lead concentrations in surface and ground water as a result of lead ammunition use has been identified as a potential exposure pathway for areas that are regularly shot over or which have intensive use, i.e. live quarry shooting with lead shot (Use #1) and shooting ranges (Uses #4, #5 and #6) (Section 1.4.5). This exposure pathway is not considered relevant for the other uses included in this assessment.

There have been no GB studies investigating the concentration of lead in surface waters or groundwaters from sites where lead ammunition is used. Therefore, there are no GB monitoring data for lead in the aquatic environment as a result of lead ammunition use that can be compared to the Environmental Quality Standard or Predicted No Effect Concentration to determine if risk would be identified.

Studies investigating the movement of lead through the soil at shooting ranges outside GB have reported limited movement of lead down through soil layers due to its fate properties. However, the potential for lead contamination of groundwater will depend on a combination of the type and amount of lead ammunition emitted to the environment, soil chemistry and groundwater vulnerability that is site-specific.

Increased lead concentrations have been reported in surface run-off, especially during times of increased water movement, either due to precipitation or snow melt. Increased lead concentrations in surface waters as a result of lead ammunition use have been linked to observations in fish, such as increased gill and liver lead concentrations and a suppression in ALA-D[2] activity (e.g. (Heier et al., 2009) and increased bone, kidney and gill lead concentrations and a suppression in ALA-D activity (Mariussen et al., 2017a).

This exposure pathway is expected to occur in GB, but its scale and any associated risk will depend on the site-specific details (e.g. the amounts of lead emitted to the environment, site conditions, proximity of surface water courses or groundwaters and time since deposition). The long history of lead ammunition use in GB means that some sites which have been used for extended periods of time may have accumulated a large stock of lead on their sites, including sites that were used for training exercises by the military. This may make it difficult to determine the extent to which any measured concentrations relate to legacy use compared to more recent use.

1.4.6.6 *Summary of environmental risks*

The identified environmental risks are summarised in Table 1.28, and are considered to be plausible in the absence of any risk management measures. Risk management measures to mitigate against the identified risk are further considered in Section 1.3.3 and Section 1.3.4.

Risks to birds via primary ingestion has been identified as a key environmental risk for lead shot and lead airgun ammunition. Throughout this dossier the risks have been considered from all uses combined, but it is useful to consider whether the relative risks between uses can be determined qualitatively for this endpoint.

For lead shot, a risk has been identified for both live quarry shooting and target shooting. Live quarry shooting uses a smaller tonnage of lead than target shooting (approximately 1,600 tonnes compared to 5,400 tonnes). Compared to permanent target shooting ranges, it is reasonable to assume that a larger number of birds that are known to ingest grit are present in areas where live quarry shooting occurs. However, a proportion of the tonnage used for target shooting is used for sports shooting which often occurs in and around woodland, or for clay pigeon shooting at mobile sites, so exposure for these uses may be more similar to that of live quarry

[2] ALA-D activity is a biomarker that is used to indicate cellular changes as a result of lead exposure that are observed before acute toxic effects are seen.

shooting than permanent trap and skeet ranges. Different sizes of lead shot are used for each use (typically 2.03 – 2.6 mm diameter for target shooting compared to 2.2 – 4.01 mm diameter for live quarry shooting). Smaller sized lead shot may be available to a greater number of grit-eating bird species than larger shot. The relative risk between these two uses is therefore difficult to assess.

For airgun ammunition a theoretical risk has been identified from primary ingestion and AHVLA (2008) reports ingestion of lead airgun pellets. However, the risk from this exposure pathway for both live quarry shooting and target shooting is considered to be much lower than that of lead shot for the following reasons. The tonnage of airgun ammunition used in GB is much lower than that of lead shot (13 tonnes compared to 6,990 tonnes annually). Airgun pellets are larger than lead shot (typically 4.5 - 5.5 mm diameter compared to 2 – 4 mm diameter), meaning that a smaller proportion of bird species will mistake them for grit in the preferred size range and to be able to ingest pieces of this size. In addition, when used for target shooting against a solid target, lead airgun ammunition will deform into flatter shapes, that may be less easily mistaken for grit and ingested. Due to the manner of use, with a single projectile being fired each time from an airgun compared to a large number of shot from each firing, the number of airgun projectiles available in a close area will be much lower than the number of lead shot, reducing the likelihood of ingestion of multiple pieces of lead. When used for live quarry shooting or target shooting, the aim is for each airgun pellet fired to hit the target and there is the potential for some to be removed from the environment, either by the collection of killed quarry or use of risk management (e.g. collection traps on ranges, hand collection for home users) for target shooting. Overall, although this exposure pathway cannot be ruled out, and so a theoretical risk has been identified, the scale of this risk is considered to be low for GB.

Risks to birds from secondary poisoning has been identified as an important environmental risk for all forms of lead ammunition. Throughout this dossier the risks have been considered from all uses combined, but it is also useful to consider whether the relative risks between uses can be determined qualitatively for this endpoint.

The risk from lead shot for secondary poisoning results from its use for both live quarry shooting and target shooting, with exposure via lead shot embedded in prey or carrion or ingested shot in the alimentary tract of prey. When using lead shot for target shooting all of the lead shot is emitted to the environment. When used for live quarry shooting, as the shot spreads out as it leaves the muzzle, the majority of shot will not hit the live target and will be emitted to the environment. Some of the emitted lead shot will be ingested by birds, but most will not enter the food chain. Many of the quarry killed using lead shot will be retrieved (e.g. PACEC (2014) report that 97 % of edible quarry shot in 2012/13 was destined for the food chain), so any embedded lead would not be relevant to secondary poisoning of birds. However, some will not be retrieved and quarry that are wounded but not killed may be more likely to be preyed upon and the lead shot embedded in them ingested. Overall, only a small proportion of the lead shot used annually is considered relevant for secondary poisoning.

As discussed for primary ingestion, the identified risks for airgun ammunition are the same as for lead shot, but the scale of the risk is anticipated to be much lower. For lead airgun ammunition, the scale of primary ingestion in GB is considered low. Therefore, the main pathway for secondary poisoning would be via its use for live quarry shooting. The aim is for each airgun projectile to hit the quarry with a single shot to the head or heart resulting in death. As the quarry are typically pests, these may not be retrieved from the environment, and the lead airgun ammunition could potentially be eaten by scavengers. However, due to the larger size of the airgun ammunition the likelihood of ingestion by scavengers will be lower than that for lead shot and each carcass would be expected to contain only a single larger projectile.

The risk from lead bullets for secondary poisoning results from use in live quarry shooting, with scavengers eating the discarded quarry or gut piles that are contaminated with bullets or bullet fragments. For live quarry shooting the aim is for each bullet to hit its target e.g. Aebischer et al., (2014) report that 95 % of shots taken by the deer stalkers in their UK survey hit the quarry. On impact, the bullet expands and fragments but generally remains within the carcass. Many of the animals killed using lead bullets will be retrieved (the 97 % edible quarry that enter the food chain reported by PACEC (2014) also includes quarry shot with bullets), so any embedded lead would not be relevant to secondary poisoning of birds. However, some carcasses will not be retrieved, and the viscera of those that are retrieved will generally be removed and discarded which is likely to contain lead bullet fragments (e.g. Knott *et al*., 2010) and which is a known food source for scavenging raptors.

Therefore, the Agency considers that for an equal tonnage of lead used as lead shot compared to lead bullets a considerably higher proportion of the bullet tonnage is relevant for secondary poisoning than the proportion of shot tonnage.

Differences in the feeding ecology of raptor species in GB will also affect the likelihood of exposure to different types of lead ammunition. For bird species which feed on smaller game animals, exposure will primarily be through ingestion of lead shot in prey or carrion. In other species, for example Golden Eagle and White-tailed Eagle which scavenge primarily on carrion and discarded viscera from larger game (particularly deer), exposure to large calibre bullets and bullet fragments will occur. Impacts at a population level are expected to be greater in those species that are longer lived and later to mature and with lower population sizes. These are generally the larger raptor species. Therefore, although the tonnage of lead bullets used for live quarry shooting is much lower than the tonnage of lead shot emitted from live quarry shooting and target shooting, the impact on population sizes of the larger raptor species that are exposed to bullet or bullet fragments will be greater than the impacts on smaller raptor species that are exposed to lead shot.

Table 1.27 Summary of the risks identified related to the use of lead ammunition.

Use	Use name	Annual emissions (tonnes)	Birds - primary	Birds - secondary	Ruminants/ Grazing wildlife	Mammalian scavengers/ Companion animals	Soil	Water
1	Live quarry shooting with shot	1,601	+	+	+	+	+	+
2	Live quarry shooting with bullets	3	NA	+	NA	+	NA	NA
3	Live quarry shooting with airgun ammunition	1	+	+	NA	+	NA	NA
4	Outdoor target shooting with shot	5,359	+	+	+	NA	+	+
5	Outdoor target shooting with bullets	111	NA	NA	+	NA	+	+
6	Outdoor target shooting with airgun ammunition	12	+	+	+	NA	+	+

NA: not applicable

1.4.7 Uncertainties in environmental assessment

The following uncertainties are identified.

- A number of estimates were provided for the tonnages of each ammunition type for each use, each with uncertainties depending on the estimation method used. In particular, estimates of airgun ammunition are very uncertain. Tonnage values selected for use in this assessment should not be seen as definitive, but are sufficient for the purposes of this assessment for the reasons described in the background document

- A single study reports ingestion of airgun pellets by birds. It is unclear whether this exposure pathway is significant in GB.

- No GB data on primary ingestion by grazing mammals have been identified, although it is assumed to be a possibility based on evidence from other countries.

- No GB data on secondary poisoning of predatory or scavenging non-avian species have been identified

- GB data on lead concentrations in surface or groundwater associated with the use of lead ammunition are not available.

- Although a risk has been identified for primary and secondary poisoning of birds, estimates of the numbers of birds at risk are uncertain (N.B. the number of organisms at risk has not been a factor in any environment-focussed restriction of other substances under REACH).

- Throughout the dossier the risks posed have been considered for all uses of lead ammunition combined. Where the same risk is identified for different uses we have considered whether the relative risks can be determined qualitatively, but this assessment is uncertain. Tonnage used annually is used as a general indicator of relative risk. However, for secondary poisoning of birds in particular, the use of annual tonnage is not considered a suitable proxy to determine the relative partitioning of risks from lead derived from shot and lead derived from bullets.

1.5 Human health assessment

The following sections are summarised from Section B of the Annex to the Background Document, which details ECHA's assessment and information that has been made available since, including information received from the UK REACH public consultation.

1.5.1 Human health hazards

The health effects of lead have been summarised in several reviews and restriction reports, including by the EFSA CONTAM Panel (EFSA, 2010a), the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2011), Public Health England (PHE, 2017a), the UK Committee on Toxicity (COT, 2013) and ECHA (2021b, 2018c, 2017b, 2016, 2014a, 2011).

The main routes of absorption of lead are via inhalation and ingestion. Dermal absorption is reported to be low (estimated to be ≤ 0.06% by PHE (2017b) and ECHA, (2021c)). The absorption of lead depends on its physical and chemical state and is also influenced by various factors, including a person's age, physiological status, nutritional status and genetic characteristics (PHE, 2017b). Inhalation exposure can result in up to 100% absorption, whereas absorption is normally up to 15% of orally ingested lead in adults and approximately 50% in children; however, absorption via the gastrointestinal tract can be up to 45% in adults under fasting conditions. Absorbed inorganic lead is mainly transported in blood and is distributed to soft tissues and organs (e.g. liver, kidneys) and mineralising systems (bones, teeth), where it accumulates. PHE (2017b) reported that, in adults, approximately 90% of the lead body burden is in bone, whilst in children this value is approximately 70%. These values were consistent with those reported by ECHA (2021c). The ATSDR (2020) reported half-lives of about 40 days in blood and soft tissue and several decades in bone.

Both PHE (2017b) and ECHA (2021c) reported that during periods of bone resorption or increased calcium demand (i.e. pregnancy, lactation, menopause and osteoporosis), lead can be released from the bones into the bloodstream; this can result in an increase in blood lead levels (BLLs) after the original exposure has ceased. Lead can also be passed from mother to infant *in utero* (placenta to foetus), with the concentration of lead in cord blood being up to 90% of the level in maternal blood. Lead transfers to breast milk, although maternal milk is estimated to be a minor source of exposure for infants (PHE, 2017b). Bradbury and Deane (1993; cited in ECHA, 2021c) reported that the blood-brain barrier is permeable to lead ions.

Inorganic lead is not metabolised or bio-transformed in the body, but forms complexes with various proteins and non-protein ligands. Organic lead compounds are metabolised to inorganic lead (PHE, 2017a). Lead is primarily excreted in the urine (> 75%), whilst approximately 15-20% is excreted via bile and faeces (ECHA, 2021c). BLLs are an indicator of recent exposure (approximately the past 30 days), whilst lead in bone is regarded as a biomarker of long-term exposure (COT, 2013).

There are limited data on the acute toxicity of lead in humans, but ECHA (2021c) and PHE (2017b) report abdominal pain, constipation, nausea, vomiting and kidney effects. Very high exposures have been associated with encephalopathy in children and adults. Inorganic lead is not irritant to the skin or eyes and is not a skin sensitiser.

Chronic exposure to lead is associated with a wide range of health effects, as summarised in Annex B.5 (extract from (ECHA, 2021c)) and by Public Health England (PHE, 2017b). These effects include toxicity to the blood system, nervous system, kidneys, cardiovascular system, liver and the immune system. The most sensitive organs and tissues are the cardiovascular system (especially elevation of systolic blood pressure), the kidneys and the nervous system.

Variable results have been obtained from *in vitro* and *in vivo* genotoxicity studies (PHE, 2017b). The International Agency for Research on Cancer (IARC) identified lead as a Group 2A carcinogen (probably carcinogenic to humans) based on sufficient evidence of carcinogenicity to animals from inorganic lead compounds (IARC, 2006). EFSA concluded that human exposure to lead through food was unlikely to represent a significant cancer risk owing to tumours being induced in rodents at doses that exceeded human intake (EFSA, 2010b).

Lead powder and lead massive have mandatory classifications under CLP in category 1A for reproductive toxicity. There is strong evidence from humans and experimental animals of adverse effects on male fertility upon repeated exposure. Chronic exposure to lead during pregnancy is associated with spontaneous abortion, premature birth, foetal growth restriction and maternal hypertension (PHE, 2017a). The critical effect in the developing foetus and young children is developmental neurotoxicity; even at low levels of lead exposure, cognitive development and intelligence quotient (IQ) are reduced.

1.5.1.1 *Key effects of lead*

As noted above, the critical effect in the developing foetus and young children is developmental neurotoxicity. Elevation of systolic blood pressure and nephrotoxicity are the most sensitive endpoints in adults. A summary of the critical effects is presented below.

1.5.1.2 *Neurotoxicity*

The nervous system is the main target organ for lead toxicity and in the developing foetus. Young children are the most vulnerable population to lead-induced neurotoxicity. Consequently, the primary human health concern of lead is its effect on the nervous system in young children arising from exposure *in utero* and during early childhood. Even at low levels of exposure, there is evidence of cognitive impairment in children aged seven and younger. The Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2011) concluded that the negative impact on IQ is the most sensitive end-point for neurodevelopmental effects, and that there was no indication of a threshold for this effect; this position was supported by EFSA (2010b), the UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT, 2013) and in several RAC assessments of lead for both restriction and occupational exposure limits (see below).

JECFA (2011) and EFSA (2010b) modelled dose-response relationships for neurodevelopmental effects from the same analysis of IQ tests and four measures of BLLs amongst children followed from infancy (see Annex B.5). JECFA estimated that the chronic dietary exposure of a 20 kg child that corresponded to a 1 IQ-point decrease was 0.6 µg Pb/kg bw/day, with a 90% confidence interval of 0.2-7.2 µg Pb/kg bw/day. In its risk assessment, EFSA also used a 1% change in full-scale IQ score (a decrease in IQ by one point) as a point of departure, from which it derived a $BMDL_{01}$ of 12 µg Pb/L (which by modelling converted to an exposure of 0.5 µg Pb/kg bw/day). The COT (2016) regarded the consequence of this impact on the distribution of IQs in the population to be an increase in the number of individuals with learning difficulties and a decrease in those with an exceptionally high level of intellectual ability.

Other neurotoxic effects have also been reported after lead exposure, as summarised by PHE (2017b) and ECHA (2018d).

1.5.1.3 *Kidney effects*

Lead exposure in humans is associated with a dose-dependent increase in nephrotoxicity with increasing BLLs. At lower BLLs (< 20 µg/dL), decreased glomerular filtration rate (GFR) has been observed, whilst changes in enzymuria and proteinuria occur at levels above 30 µg/dL. Severe deficits in renal function and pathological changes occur at BLLs > 50 µg/dL. Those with on-going renal disease or hypertension may be more vulnerable to the effects of lead. EFSA (2010) determined that 15 µg Pb/L (converted to 0.63 µg Pb/kg bw/day) was associated with a 10 % increase of chronic kidney disease (CKD) in the population (measured as reduction in the GFR to values below 60 mL/min). EFSA also concluded that there was no threshold for these renal effects in adults.

1.5.1.4 *Cardiovascular effects*

Lead exposure has been associated with several adverse effects on the cardiovascular system in animals and humans. The most studied dose-response relationship relates to the effect of lead on blood pressure, in particular systolic blood pressure. EFSA (2010b) concluded that a PbB level of 36 µg Pb/L (which corresponds to 1.50 µg Pb/kg bw/day) is associated with a 1% increase in systolic blood pressure in normotensive adults; the dose-response relationship amounted to an increase in systolic blood pressure of approximately 1 mm Hg with each doubling of BLL, without an identifiable threshold (ATSDR, 2007; EFSA, 2010a). EFSA's CONTAM panel concluded that the change in blood pressure could have significant consequences on human health on a population basis.

JECFA (2011) also concluded that a threshold for cardiovascular effects in adults could not be established (the critical effect being increase in systolic blood pressure). The committee reported that a lead exposure level of 3.0 µg Pb/kg bw/day would cause a population increase in systolic blood pressure of approximately 2 mm Hg, an increase that was associated with moderate increases in the risk of ischaemic heart disease and cerebrovascular stroke. The committee considered this to be of concern, but less so than the neurodevelopmental effects in children.

ECHA (2021c) reported that information provided in the EU REACH registration, submitted in 2015, indicated that there was a weak association between BLL and blood pressure in the general population and in occupational studies where average BLL were below 45 µg Pb/dL. As the dossier highlighted a lack of dose-dependency between environmental lead exposure and blood pressure, ECHA considered it not to be a suitable health endpoint for quantitative risk assessment.

1.5.2 Human health exposure

Exposure of humans to ammunition-derived lead in game meat is assessed in this dossier. The highest consumers of game-meat are hunters and their families. Employees of shoots are also likely to be high consumers.

1.5.2.1 *Consumption of game meat*

Game meat of relevance to this dossier is wild game that has been killed with lead ammunition. Farmed game animals are not killed with lead ammunition and so consumption of their meat does not contribute to this source of lead exposure.

Lead in game meat

Lead ammunition that hits an animal often fragments into small particles upon impact. The degree to which this occurs, and the consequent lead contamination of the meat, depends upon the type of ammunition and its velocity. The use of different types of ammunition in hunting versus vermin control is also relevant to potential human-health impacts.

Many publications report contamination of game meat with ammunition-derived lead particles (see section B.9.2.1 of the annex). For example, a survey identified that 76% of six UK game bird species purchased from supermarkets, game dealers / butchers and directly from shoots (121 birds in total) contained fragments derived from shotgun pellets that were too small to be detected by the human eye and that, in some cases, were scattered throughout the bird (Pain et al., 2010). Additional data on lead levels in raw tissues of wild game birds and deer were obtained from the Veterinary Medicines Directorate Statutory Surveillance Programme. A high proportion of the meat samples had lead concentrations that exceeded 100 ppb w/w (0.1 mg/kg w/w, the maximum level permitted in bovines, sheep, pigs and poultry). For example, 56% and 47% of fresh meat samples from partridge and pheasant, respectively, exceeded 0.1 mg Pb/kg, 21% and 18% exceeded 1.0 mg Pb/kg, and 5.7 % and 2.4 % exceeded 10 mg Pb/kg. Although some differences between mean lead concentrations between the six species of game bird examined were recorded (from 341 ppb in a whole meal per unit of meat with mallard to 8054 ppb with partridge), these were not statistically significant. The arithmetic mean lead concentration of 1181 ppb derived from this study was used by Green and Pain (2012) to estimate lead concentrations in game-bird meals (shot with lead) generally in the UK.

Other UK data reported metal fragments (most likely to be lead) in deer (Knott *et al*., 2010). The Veterinary Medicines Directorate National Surveillance Scheme (2004 – 2011 data; cited in FSAS, 2012) determined that half of the sampled pheasants and partridges and 17% of wild deer had an average lead concentration exceeding the EU maximum level for non-game meats. Publicly-available but not peer-reviewed research, in which the lead content of game meat bought from UK supermarkets was analysed, indicates that some samples contained high lead levels even after whole shot pellets were removed (the Agency notes the small sample sizes bought from select UK and Irish outlets of one supermarket) (Wild Justice, 2023).

The concentration of lead and extent of particle distribution detected in meat from animals shot with lead bullets depends upon the type of bullet used. Lead bullets that are designed to expand or partially expand upon impact are more likely to result in larger numbers of particles/fragments that are dispersed further from the wound channel, and hence are more difficult to detect and remove (e.g., (M. Grund et al., 2010; Martin et al., 2019; Norwegian VKM, 2013)). The Norwegian Scientific Committee on Food Safety (Norwegian VKM, 2013) reported an average radius of 15 cm from the wound channel of fragments from these bullet types, with a maximum penetration of visible fragments of about 29 cm. In another study, lead from bullets that were designed to rapidly expand and fragment was detected in some tissue samples collected up to 45 cm from the exit wound (M. D. Grund et al., 2010). In contrast, fragments from more stable types of lead-containing bullets were detected at distances less than 5 cm from the shot site (Norwegian VKM, 2013). A similar finding was also reported by authors from the German Federal Institute for Risk Assessment (Martin et al., 2019), who reported that the use of lead deformation bullets (deform without causing loss of small fragments) resulted in elevated lead concentrations close to the wound channel, whereas lead partial fragmentation bullets (bullets whose front part fragments) gave rise to smaller fragments that were released into more distant tissues. There also tend to be more, smaller fragments when the projectiles hit bone (Broadway et al., 2020; Dobrowolska and Melosik, 2008). Investigating wild ungulates shot with hunting-rifle bullets, Trinogga *et al*. (2019) found that the use of lead-based bullets causes a broad contamination of the carcass and the viscera with bullet material. Lead nanoparticles have also been reported in game meat shot with expanding lead-core bullets (Kollander et al., 2017), although only two animals (one roe deer and one wild boar) were investigated.

In its restriction dossier, ECHA (2022a) reported higher average lead levels in game shot with bullets than with shot. The average values for lead content in game meat that ECHA used (0.366 mg/kg for game hunted with shot and 2.516 mg/kg for game hunted with bullets) came from unpublished EFSA data on the European consumption of game meat hunted with lead shot and bullets (it did not include UK data; see Annex B.10.2 for more information). Some responders to ECHA's public consultation questioned the validity of the reported values, citing scientific literature in which higher average lead levels were recorded in birds than in large game species (for example, FACE cited AESAN, (2012) and FSAS, (2012)). RAC (ECHA, 2022d) acknowledged there were uncertainties in the comparative impacts of bullets versus shot on lead concentrations in game meat. The EFSA value for lead concentrations in small game was reported to be lower than of previously published reports, as also noted by Pain *et al.* (2022), who calculated an arithmetic mean of 5.205 mg/kg from a review of literature published between 1990 and 2021. RAC (ECHA, 2022e) noted that, owing to the skewed distribution of lead levels in game meat, the dossier submitter's approach to use the mean values for game-meat lead levels might have resulted in an over-estimation of the risks. However, RAC considered that this was balanced by the possible under-estimation of lead concentrations in small game-meat in the EFSA dataset.

Overall, the impacts of ammunition on lead concentrations in game meat tend to be unevenly distributed, especially in large game hunted with bullets (see also later). For example, Martin *et al*. (2019), who measured lead levels in different edible parts from red deer hunted with lead and non-lead bullets, found that individual meat samples from lead-shot animals had elevated lead contents, especially in edible meat close to the wound channel; overall, however, the median differences in lead concentration between lead and non-lead shot animals were not statistically significant. This variation in lead concentrations in different cuts of game meat contrasts with potential levels in meat from domestic livestock. The maximum lead level set by European Commission Regulation (EC) No. 1881/2006 [as retained in GB law] is intended to capture other routes of lead exposure to animals, such as dietary, that are likely to result in more uniform lead concentrations (i.e., biologically-incorporated lead). LAG (2015b) concluded that mean lead concentrations are likely to be generally higher in game meals made from small game (e.g. game birds and waterfowl) shot with lead gunshot than meals made from large game (e.g. deer) shot with lead bullets.

Meat hygiene measures and stewardship schemes are in place to minimise the amount of metal in meat sold for human consumption in the UK; these include accreditation through approved bodies before hunters can supply game to an approved game-meat handling establishment (AGHE), veterinary-officer inspection and FSA guidance. Game handling to remove obvious ammunition fragments by hunters and their families / friends is reasonably widespread (FSAS, 2012; LAG, 2015a, 2015b).

Despite these measures, meat can still contain small fragments and particles of metal that cannot be easily detected and might be far from the shot site (e.g., (Trinogga et al., 2019). More recently, Green *et al*. (2022b) found that fragments (< 2 mm diameter), assumed to be metallic lead, were present in eight pheasant carcasses sold for human consumption in the UK and many were considered too small (< 0.1 mm diameter) and too distant from the nearest shotgun pellet to be removed without discarding much of the meat.

The Food Standards Agency (FSA), referring to the sale of small game, stated in a risk assessment (FSA, 2012) that:

'Regarding sale of small game, colleagues from the FSA Operations Group have indicated that the lead pellets are very small and it would be impractical to ensure they are removed during the dressing procedure: trying to remove them would be very time consuming and would cause damage to the birds which would likely make them unsellable.'

Another consideration is the cooking method: roasting of whole birds is reported to be typical (FSAS, 2012), which does not permit the removal of lead fragments before cooking (LAG, personal communication).

Ammunition for use at lower velocities (e.g., airgun ammunition) is unlikely to represent a risk to human health, since it generally does not expand and fragment upon impact (see Section B.9.2.1 of the annex, which includes information received during the public consultation). In its opinion, RAC concluded that non-expanding ammunition and small-calibre bullets used for the hunting of small game ‘may not result in similar lead contamination of the game meat as observed with expanding ammunition’ (ECHA, 2022d).

Game-meat consumption in the UK

Some information on game consumption in the UK is available. In a survey by Taylor *et al*. (2014), 2.7% of participants reported eating game birds. Consumption by women of child-bearing age and children ≤ 6 years old was relatively low. Data collected from high-level consumers of game meat in Scotland indicated that 51% ate lead-shot game at least once during the main shooting season (FSAS, 2012b). The average game-meat consumption of high-level consumers in the UK, as estimated by National Diet and Nutrition Survey (NDNS) data, was cited to be 47.4 g daily (equivalent to 331.5 g weekly or 17.2 kg per year) (FSAS, 2012). More recent data from a UK population survey indicated that a typical meat portion size is 95 g/day in adults and 57 g/day in children aged up to 18 (any red or processed meat, not specifically game meat) (Public Health England, 2021). The Agency was not able to identify information on the quantities of non-bird game hunted with shot that is consumed in GB amongst either hunters and their families or the general population. Likewise, there was no information on the consumption of game species hunted with shot versus other ammunition, e.g., lead bullets.

Green and Pain (LAG, 2015c) estimated the quantity of game-bird meat consumed annually in the UK from NDNS data. The Agency notes that the NDNS sample size was small (87 individuals who consumed game meat; not stated if this was wild-shot or farmed). Also, the survey used a 4-day average to derive gamebird consumption, which may not account for fluctuations throughout a 7-day period or seasonal differences. This analysis resulted in an estimate of 11,232 tonnes of game-bird meat consumed annually in the UK (95% C.I. 9,162 – 16,251). The authors undertook an independent check of the results by a comparison with data from PACEC (2006), which indicated that 4,940 – 9,880 tonnes of game bird were consumed annually in the UK and noted that this overlapped with the confidence interval when the NDNS data were used.

BASC and Countryside Alliance estimated in 2014 that 9,000 (midpoint of the range 5,500 – 12,500) children under the age of 8 from the UK shooting community consumed at least one game meal per week (all types of game, one portion assumed to be ≥ 100 g), averaged over the year (cited in (Green and Pain, 2019; LAG, 2015b)). The percentage of high-level consumers of game in the UK (adults and children) seems to lie between 0.084 – 2.52% of the population (Green and Pain, 2019).

Relative partitioning between lead exposure from shot and bullets

In response to questions from some RISEP members, the Agency attempted to compare exposure to humans from meat contaminated with lead derived from shot and lead derived from bullets to inform on the human-health impacts of a restriction on lead bullets in live quarry shooting. This was in response to an assertion that humans will be exposed to considerably more lead via secondary exposure per tonne of lead bullets used for LQS than per tonne of lead shot used for LQS.

As reported in section 1.4.3, for the purposes of this restriction proposal the annual releases of lead from shot and from bullets used in LQS are assumed to be 1601 tonnes and 3 tonnes (2 tonnes small calibre, 1 tonne large calibre; Table 1.17 in section 1.4.4), respectively. As noted by RISEP members during Challenge Panel 2, the majority of risk from lead bullets will be from large-calibre bullets.

For shot, the shot:kill ratio is estimated to be between 4:1 to 5:1 (section 1.4.3). From this, a RISEP member calculated that it requires on average about 4.4 cartridges to shoot a pheasant. A no. 6 cartridge contains about 300 shot, which would equate to 1,320 individual shot used per bird killed. From an average of 3.36 shot retained in each pheasant killed (estimated from Pain *et al*., 2010 and Green *et al*., 2022), a retention in the body of 0.25% of the shot used to kill each pheasant was calculated. An annual quantity of 1,601 tonnes of gunshot to shoot wild quarry would result in about 4 tonnes of lead entering and being retained by quarry animals. The Agency notes that this assumes that all lead shot for LQS is used to shoot pheasant; the average number of shot per bird varies between species, with, for example, the overall values for six species and for woodpigeons reported as 2.17 and 0.95 shot/bird, respectively (Pain *et al*., 2010). It also assumes that the vast majority of animals shot will enter the human food chain. Estimates of game-bird tonnage consumed in the UK per year range from 4940 to 9880 tonnes (PACEC) to 11,000 tonnes (LAG, 2015c).

Whole shot is likely to be removed at the table or during food preparation. Pain *et al*. (2010) estimated that 0.308% of shot would need to be present as small fragments to result in the lead concentrations found in the meat of game birds from which whole shot had been removed prior to analysis. Of a 3.6 tonne estimate of shot remaining in prey available for human consumption (if 10% of birds hit are unretrieved or escape injured), this would represent a potential annual exposure to humans of approximately 11 kg of lead fragments in food, once shot have been removed at the table or during food preparation.

The shot:kill ratio for bullets is far higher than for shot. Aebischer *et al.* (2014) reported that 95.5% of first shots at deer hit the target. In twelve deer each shot in the thorax with a single copper-jacketed lead-core bullet, on average 17% of the weight of the bullet was present in the carcass as fragments (Knott *et al*., 2010). The fragments were presumed by the authors to be primarily lead, although they didn’t distinguish between this and copper (which comprises about 30% of this bullet type); it was noted, however, that since copper is less frangible than lead, it was less likely to form the small fragments that were detected by X-ray. If 1 tonne of lead in large-calibre bullets were used annually to shoot deer, it might be predicted that 0.96 tonnes would hit a deer target (the main target species) and that about 0.163 tonnes (163 kg) would be present in the quarry as lead fragments. Knott *et al*. (2010) reported that 86% of bullet fragments (which would equate to 140 kg) were found in the non-viscera part of the carcass (14% in the viscera, or gralloch), although it was acknowledged that some of these would be too large to be consumed by people.

The estimated quantities of lead in different meat types are, in some cases, calculated from relatively small surveys and rely upon several assumptions. As noted by a RISEP member, the proportion of the species shot with bullets that enter the human food chain might be small. The Agency was not able to identify information on the tonnage of large game that is consumed annually in the UK, nor on the number of high-level large-game consumers or proportion of small-game versus large-game consumption amongst this population.

Pain and Green (2022) reported relatively little variation in lead concentrations in different European small game species (game birds, hare, rabbits) when sample sizes are very large; they reported the arithmetic mean to be 5.205 mg/kg. Some reported average lead concentrations in deer meat include 0.377 mg/kg (Pain *et al*., 2010), 0.195 mg/kg (FSAS, 2012), 0.323 mg/kg (AESAN, 2012) and 0.582 mg/kg (95th percentile; Gerofke *et al*., (2018)). These average levels are lower than those reported above for game birds killed with lead shot. However, as noted earlier, the lead contamination in large game varies widely: Martin *et al*. (2019) reported maximum lead concentrations in lead-bullet-killed deer of 3442 mg/kg close to the wound channel, 1.14 mg/kg in the saddle area and 0.09 mg/kg in the haunch; the 95th percentiles reported by Gerofke *et al.* (2018) were 2.237 mg/kg close to the wound channel, 0.164 mg/kg in the saddle area and 0.064 mg/kg in the haunch, whilst the maximum reported value close to the wound channel was 4728 mg/kg.

Therefore, it is possible that game-bird consumers might be consistently exposed to elevated lead levels, whereas consumers of large game killed with lead bullets might be exposed to both low levels of lead (below the EUML) and sometimes very elevated lead levels. The differences in health risk between these two potentially different patterns of exposure is not known. Butchery practices and the cuts of meat consumed will have a major impact on human lead exposure via large game hunted with lead bullets. Overall, the Agency concludes that, although the total quantity of lead in large game from bullets is potentially greater than the quantity of lead in small game from shot, this does not necessarily translate into greater human exposure from the former. It cannot be excluded that consumers of large game might sometimes be exposed to high lead concentrations, but the frequency of this occurrence and numbers of people impacted is unknown.

Blood lead levels

The most common and accurate method of assessing lead exposure is by analysis of lead in whole blood. BLLs reflect recent lead exposures, whereas bone-lead measurements are an indicator of cumulative exposure (ATSDR, 2007). Data from Germany has been used to statistically derive reference values (95th percentile) for the general population of 4 µg/L for adult men, 3 µg/L for adult women and 3.5 µg/L for children (HBM4EU, 2019).

The data on BLL increments from game meat consumption only (excluding hunting and shooting activities) are very limited. Some data indicated a small increase in BLL of 3 to 5 µg/L in Swedish adults with consumption of moose meat two to three times a week. For groups relying on subsistence hunting, the blood lead contribution from game meat consumption seems to be higher; in one study the increment for females (assumed to be non-hunters) was 6 and 15 µg/L (Tsuji et al., 2008). In Italian hunters, Fustinoni *et al.* (2017) found an association of increased BLL with hunting even outside the hunting season. However, there was no such association between the consumption of game meat and sustained increases in BLL in non-hunting family members (peak increases in BLL were avoided by collecting samples from individuals who had not eaten game within the previous week). Data from a Swiss study indicated that the individual BLL of 25 hunters did not correlate with the number of weekly game meals consumed (Haldimann et al., 2002), although LAG (2015b) noted some study limitations, such as blood sampling outside the main hunting season.

No reliable BLL measurements in children from hunter families are available. No UK-specific measured data information on the impact of game-meat consumption on BLL have been identified.

Some information on the impact of ammunition-derived lead on BLL is available from animal feeding studies, although the relevance of these to even high-level game-consuming humans is unclear. Hunt *et al.* (2009) fed lead-fragment-containing venison to four pigs, whilst four controls received venison without fragments from the same deer. Mean BLL were statistically significantly higher than the controls and peaked two days following exposure, returning to baseline values after 7 days. The Agency notes the unknown amount of lead in the meat samples and the small group sizes. The amount of meat fed to each pig exceeded the typical amount consumed by humans, at 500 g per meal and 1.26–1.54 kg of meat over two feedings 24 hours apart, with other food sources withheld for 24 hours prior to the trial.

In a study that explored associations between game consumption and dog health status, lead concentrations were quantified in blood and hair and haematological parameters of 31 dogs fed game meat and offal from wild boar (Sus scrofa) and axis deer (Axis axis) culled with lead ammunition in El Palmar National Park, Argentina (Fernández et al., 2021, p. 20). Despite variable weekly frequency in game consumption, dogs had detectable blood and hair lead levels, demonstrating recent and chronic exposure. Body condition was associated with hair lead, with dogs in good condition presenting higher lead levels. This could be related to greater game consumption by those dogs, resulting in higher lead ingestion. Dogs fed game meat and offal at very low or low frequency (≤4 times per week) showed higher blood lead levels, suggesting to the authors that there might not be a risk-free frequency for game provision to dogs. The Agency notes the discrepancy in some of these findings and also the presumed high consumption of game meat amongst this group of dogs.

In a study in Finnish dogs, higher lead concentrations in hair and blood were correlated with wild game consumption (Rosendahl et al., 2022). The ‘high consumption’ group comprised dogs that were fed game meat (of unknown lead concentrations) monthly, weekly or daily. This group comprised only six animals and the individual data weren’t presented; therefore, the difference on blood lead levels between monthly consumption and daily consumption, for example, is unknown. One dog stated to be an extreme outlier for high hair lead levels was not fed game meat, but had an owner who worked at a metal recycling plant.

Green and Pain (2012) used observations from two dietary surveys of Greenland adults (Bjerregaard et al., 2004; Johansen et al., 2006) to correlate by linear regression modelling the mean daily intake of dietary lead from the meat sources to the mean concentration of BLL in UK adults and children. The average mean lead concentration in the Greenland meals was almost double that of the presented average concentration in UK game birds (Bjerregaard et al., 2004). Information on how the birds were killed or how they were prepared for cooking and then cooked was not reported. Furthermore, the data for males and females weren't reported separately in the Bjerragaard study (only males were included by Johansen *et al*.), and the contribution of lead from hunting activities was not considered in either study. Consequently, the impacts on BLL could not be attributed solely to dietary exposure.

Whilst there was a strong relationship in the Greenland data between mean BLL and the estimated mean rate of intake of dietary lead from sea birds specifically (which aren't representative of game birds consumed in the UK), the regression model indicated that the effect of ammunition-derived lead in adults was 39% lower than that expected for lead from non-ammunition sources. Possible explanations were that a proportion of ingested ammunition lead might remain as metallic fragments after cooking and processing in the gastrointestinal tract; and that metallic lead, especially if in larger fragments, might not be totally dissolved or absorbed as readily as more soluble lead salts and complexes. Taking into account the higher bioavailability of lead in the ordinary diet of children compared with adults, Green and Pain (2012) used assumptions from the calculations on adults to estimate a value of 0.306 for the absolute bioavailability to children of dietary lead derived from the cooked meat of wild birds.

The Agency notes that the number of subjects in the Greenland studies that were high-level consumers were small: in the study by Bjerregaard *et al*. (2004), 15 subjects consumed sea birds 4 – 6 times per week, whilst five subjects consumed it daily; in this paper the confidence intervals for the BLL of these latter groups were large and overlapping with those who consumed sea birds 1 – 3 times per week. In Johansen *et al*. (2006), there were only five subjects in the highest-consumption group (> 30 bird equivalents per month) and only four in the control (no consumption) group. These small group sizes increase the uncertainty in the regression models and ensuing calculations.

In a recent review, Green and Pain (2019a) summarised the available evidence as giving an indication of increased human BLLs in association with the consumption of game meat that contains ammunition-derived lead; however, the observations did not indicate what proportion of the ammunition-derived lead is absorbed or how much BLLs are increased per unit of dietary lead ingested.

Absolute bioavailability is a function of the bioaccessibility of lead in a medium and the absorption of soluble lead. Bioaccessible lead is soluble and available for absorption. Cooking under acidic conditions (e.g., in vinegar) has been reported to increase the absolute bioavailability of ammunition-derived lead (Mateo et al., 2011, 2007; J. H. Schulz et al., 2021), presumably because of an increased chemical transformation of metallic lead to lead salts that are more bioavailable. An *in vitro* gastrointestinal simulation applied to meat from red-legged partridges hunted with lead shot indicated that the percentage of lead that was bioaccessible was greater in meat cooked with vinegar (6.75%) or wine (4.51%) compared with uncooked meat (0.7%) (Mateo et al., 2011); whole lead pellets in the meat were left *in situ* during cooking but removed before mincing and the simulated human digestion. Schulz *et al*. (2021) investigated the bioavailability of lead derived from bullets in pigs. 'Marketable' meat from close to the wound channel of roe deer hunted with lead bullets was fed to growing pigs as a model for humans, specifically children. For the meat that was cooked in water, the absolute bioavailability of lead was 2.7%; when the meat was marinated in wine and vinegar before cooking, it was 15%. In another study that simulated the stomach environment (chloric acid of the same concentration as in the human stomach), the bioaccessibility of metallic lead in the form of shavings varied from 2 - 8%, depending on the time in the acid (0 – 4 hours) (Swedish NFA, 2014).

In the EU restriction proposal, the Dossier Submitter modelled the impacts on BLL of game-meat consumption in adults and young children from EFSA data on the consumption of game meat in Europe, concentrations of lead in game meat hunted with lead shot and lead bullets, and assuming 50% bioavailability of metallic lead compared with lead ions in children and 10% bioavailability for adults. RAC concluded that this exposure modelling suggested up to medium increases in BLL were likely in young children under high game-meat consumption scenarios but only minor increases in adults.

Potential health impacts of exposure to lead in game meat

LAG (2015b) estimated that adults in the UK consuming 200 g of wild game bird per week could result in an increase in dietary lead exposure by approximately 7 - 8 times compared with all other dietary components combined. Children aged 1.5 - 4.5-years old consuming 60 g of pheasant per week could result in an estimated increase of 5 times the background dietary lead exposure. Furthermore, 2 – 5-year-olds consuming 100 g of gamebird meat could result in approximately 7.4 times the background dietary lead exposure; 6 – 9-year-olds consuming 118 g of gamebird meat could result in approximately 7 times the background dietary lead exposure.

FSAS (2012) concluded that adults consuming two 100 g portions of gamebird per week throughout a year could increase their dietary exposure to lead by up to 8 times, complementing the figure derived by LAG. FSAS also considered that toddlers consuming two 30 g portions of gamebird meals per week could increase their dietary exposure to lead by up to 5 times. Adults consuming two 120 g portions of large game (venison) per week throughout the year could increase their dietary exposure to lead by approximately 2 times, with exposure levels increasing if meat close to the would channel was regularly consumed. The study identified individuals involved in game management, including shooters, gamekeepers, game beaters, and their families to be high consumers of game meat.

The COT has assessed the risks of lead in the diet for infants (aged 0 to 12 months) and children aged one to five years (COT, 2016, 2013). Calculated exposures from various sources were compared with a reference point for dietary intake of 0.5 µg/kg bw/day, which, as noted above, was the $BMDL_{01}$ value estimated by EFSA to correspond to a decrease of 1 IQ point. The COT took information on lead levels in different food sources from the Total Dietary Study (FSA, 2014) (which did not sample game meat); and on consumption of different foods from the Diet and Nutrition Survey of Infants and Young Children (Department of Health and Food Standards Agency, 2011). The latter included game meat in the 'other meat and meat products' category, although the proportion of those sampled that consumed this meat type was not separately reported. Game-meat consumption was therefore not specifically investigated by COT, but lead exposures from breast milk, infant formulae, complementary infant food, common foodstuffs, drinking water, soil, dust and air were estimated. Margins of exposure (MOE) for infants of 0 - 6 months were generally ≥ 1, indicating that any risk was likely to be small, unless fed exclusively on infant formula prepared with water that contained lead at the upper end of the reported concentration range. In infants of 6 - 12 months and young children aged 1 - 5 years, the MOE for aggregated exposures (dietary, soil, dust, air) indicated that a risk at the population level and to some infants and young children could not be excluded, although risks from diet alone were small. EFSA (2010b) did consider the contribution of lead in game meat to total dietary lead exposure and concluded this to be low overall, given the low levels of consumption of this meat in the European population.

Green and Pain (2015a) estimated the size of the at-risk UK populations for health effects at the levels of adversity specified by EFSA's BMDL values (i.e., the benchmark responses – BMRs). To calculate the high estimates, they combined data on lead concentrations in UK game birds (Pain *et al.* 2010), UK food consumption (NDNS) and lead concentration data (FSA, 2009) to evaluate the number of game-bird meals (of 200 g for adults; 118 g for a 6.9-year-old and 100 g for a 2.5-year-old child) consumed weekly that would be expected, based upon published studies, to result in specified changes at the EFSA BMDL values (i.e., the benchmark responses, BMRs). To calculate the low estimates, they took the mid-point of the BASC study (which refers to all game, not just that shot with lead ammunition) as the high-level consumer population, estimates of the threshold intake rates of game-bird meat required to be at potential risk of incurring the critical responses and FSAS (2012) data to estimate minimum numbers of individuals in the UK potentially exceeding the thresholds. In each case the predicted size of the at-risk population was heavily dependent on the statistical model and bioavailability value used to estimate the number of meals required to give the BMR.

Green and Pain (2012) concluded that the consumption of 0.4 – 0.7 game-bird meals (size of meat meal portions of children aged 2.5 years and 6.9 years estimated from United States data combined with height and weight data for England) per week might be associated with a one-point decrease in the IQ of children. Assuming small meal sizes (30 g) and the bioavailability for children estimated from their regression model, the minimum number of children (less than 8 years of age) in the UK who were at risk of incurring a one-point or more reduction in IQ as a result of exposure to ammunition-derived lead in game meat was estimated to be 3,800 (95% CI 3,050 – 4,374) (Green and Pain, 2015a). The upper estimate was 28,710 (95% CI 12,684-47,846) children.

The number of adults in the UK estimated to be a 10% increase in risk of CKD ranged from none to hundreds of thousands, depending on the methodology, model and meal-size used (Delahay and Spray, 2015; Green and Pain, 2015a). The number of people consuming 6.5 meals of game-bird meat per week (calculated to be the exposure required for the BMR with the regression-modelled bioavailability value) was reported to be 129 to 338, depending on the assumptions made of high-level game-meat consumers in the UK (Green and Pain, 2015a).

Assuming low bioavailability of ammunition-derived lead as modelled by Green and Pain (2012), the authors calculated that 5.2 game-bird meals of 200 g would lead to a 1% increase in SBP (the BMR). The number of adults in the UK estimated to be at risk of this BMR was 403 – 1060 as reported in Green and Pain (2015a), depending on the assumptions made of high-level game-meat consumer numbers in the UK. In the *Proceedings of the Oxford Lead Symposium*, the numbers of adults at risk presented ranged from none to 12,320, depending on the meal size and the methodology used (Delahay and Spray, 2015; Green and Pain, 2015a).

1.5.2.2 *Additional indirect exposures to humans*

Other potential sources of indirect exposure pertinent to the scope of this dossier are drinking water and other food types. The impact of these exposure pathways on human health is not investigated in the current dossier, but measures to restrict the use of lead ammunition would be expected to also reduce secondary human exposure via the environment through reduced environmental contamination with lead.

1.5.2.3 *Direct exposure to humans*

Direct exposure to humans can occur by the oral and inhalation routes. For example, hand-to-mouth exposure might occur where hunters self-fill their own cartridges with lead gunshot, if the lead shot is handled without the use of adequate protective equipment and hygiene practices. Inhalation exposure can occur from melting of lead to home-cast ammunition. Other sources of inhalation exposure can be from lead particles, which form from some disintegration of the lead projectile and are ejected at high pressure from gun barrels. Such exposures are outside the scope of the present assessment and information on their impact is limited (ECHA, 2021b, 2021c); therefore, they have not been further assessed in this dossier. These oral and inhalation exposures make it difficult to isolate the impact of game-meat consumption on the BLL of hunters.

1.5.3 Risk characterisation

The primary human health risk to be addressed in this dossier is that to consumers of game meat that has been shot with lead ammunition (i.e. wild game). The highest consumers of game-meat are hunters and their families. Employees of shoots are also likely to be high consumers.

RAC has previously assessed the human health effects of lead in several restriction proposals, including lead in jewellery (ECHA, 2011), lead in consumer articles (ECHA, 2014b), lead in PVC (ECHA, 2018d), lead in gunshot over wetlands (ECHA, 2018d) and substances in tattoo inks and permanent make-up (ECHA, 2019). In these assessments RAC agreed there was no threshold for the neurotoxicological and other key effects of lead and that any exposure constitutes a risk. RAC supported a qualitative approach in some of these assessments (lead in PVC; lead in shot over wetlands; substances in tattoo inks and permanent make-up) in accordance with REACH Annex I 6.5, as DNELs could not be derived owing to the non-threshold nature of these effects. RAC did, however, apply a (semi-)quantitative approach to some of these assessments (lead in jewellery; lead in consumer articles) by the use of a maximum lead exposure level for children of 0.05 µg lead/kg bw/day; this was based on the $BMDL_{01}$ determined by EFSA (2010a), since EFSA considered that a margin of exposure of 10 or greater in relation to this BMDL would be sufficiently low to present no appreciable risk.

In June 2020, RAC adopted an opinion on occupational exposure limits (OEL) for lead and its compounds in which it recommended an 8-hour time-weighted average OEL of 4 µg lead/m^3 (inhalable fraction) and a biological limit value of 150 µg/L blood for lead and its inorganic compounds (ECHA, 2020a). RAC noted that neither of these values protected against the risk of developmental toxicity.

The RAC and Socio-Economic Analysis Committee (SEAC) opinion on the proposal to restrict lead and its compounds in the EU was published in March 2023 (ECHA, 2022d). From information received during the ECHA public consultation, RAC considered that non-expanding bullets and small calibre bullets might not result in similar lead contamination of meat as occurred with expanding ammunition.

Overall, RAC concluded that for adults, exposure modelling showed only minor increases in BLL even in high-consumption scenarios; this was in accordance with the limited biomonitoring data, which did not show a clear association between game-meat consumption and BLL. RAC employed a conceptual model approach to its qualitative risk assessment, which combined the severity of effects with the probability of their occurring to give a risk category from very low to very high.

For CKD risk in adults, RAC noted that this was low, given the conservative nature of EFSA's BMDL and because of the need for long-term (> 5 years) constant exposure via highly contaminated game meat. RAC also concluded that some cardiovascular effects in adults were possible, but the level of adversity of these effects was not clear and hence the risks were low. Overall, therefore, RAC considered the risk to adults from the consumption of game-meat hunted with lead ammunition to be low.

For children, RAC noted that exposure modelling suggested up to medium increases in BLL were likely in high game-meat consumption scenarios (hunter families). RAC's assessment indicated that this scenario resulted in a moderate to high risk for neurodevelopmental effects in children. RAC considered the risk for pregnant women to also be at least moderate, considering the potential developmental neurotoxic effects on their offspring. This conclusion took into account the sensitivity of small children to the effects of lead; and the possibility of high levels of lead in some pieces of game meat.

As lead is a non-threshold neurotoxic substance, a qualitative risk assessment is appropriate according to REACH Annex I (paragraph 6.5). Risks to humans (primarily children and the offspring of pregnant women) from the consumption of game shot with lead ammunition cannot be excluded.

1.5.4 Uncertainties in human-health assessment

The following uncertainties are identified.

- Some estimates of the numbers of people in the UK that consume gamebirds were based on data that did not differentiate between wild-shot birds (potentially contaminated with lead) and farmed birds (not killed with lead ammunition).
- There is a lack of information on consumption of game meat by children and pregnant women.
- Large variations in lead concentrations in different game-meat samples and cuts of meat, particularly for large game killed with bullets, because lead contamination from the ammunition is not evenly distributed throughout the animal; some samples might have highly elevated lead levels (for example, close to bullet wound channels), whereas in other samples levels might not be elevated.
- The relative contributions of game hunted with lead shot and game hunted with lead bullets to game-meat consumption in GB, and the annual tonnage of the latter.
- The relative partitioning of human-health risks from lead derived from shot and lead derived from bullets, considering the impacts of released

quantities, shot-to-kill ratios, lead distribution in the animals, proportion of hunted animals destined for human consumption, butchery practices and cuts of meat consumed.

- Uncertainty about the proportion of ammunition-derived lead that is absorbed or how much BLLs are increased per unit of dietary lead ingested.
- Very limited information on how game-meat consumption affects BLL in hunter families.
- A lack of reliable measurements of BLL in children of high game-meat consuming (hunter) families.
- Impacts on human health of possibly different exposure patterns from the consumption of small game hunted with lead shot and large game hunted with lead bullets.

1.6 Justification for a GB-wide restriction measure

The Agency has concluded that the use of lead ammunition presents a risk to both the environment (particularly birds) and human health (via secondary exposure through the consumption of lead-shot game) that is not adequately controlled and needs to be addressed.

1.6.1 Environmental hazard, exposure and risk

Lead is a non-essential, toxic element. The range of possible adverse effects of lead exposure have been investigated in experimental laboratory studies and evidence of the effects of lead on wildlife is available from pathology reports and observational studies. As well as causing mortality, lead exposure can result in sub-lethal effects on behaviour, development and reproduction. In addition to the lethal and sub-lethal effects that can be measured, there will also be welfare impacts that are less easy to measure.

A fully quantitative risk assessment for the various uses of lead in ammunition has not been attempted for the purposes of this dossier. Instead, the Agency has considered the available data on hazard, exposure pathways and reported impacts on individuals and populations to produce a description of the risk. As the source of the lead does not alter the impact, the various uses are considered together in a single environmental risk assessment.

The available evidence indicates that shooting occurs over a significant proportion of rural land in GB and therefore there is widespread deposition of lead shot and bullets. Some areas are used for regular shoots (e.g. for gamebirds) so are repeatedly exposed. The highest density of shot and bullets is found close to fixed shooting positions such as clay pigeon or target ranges.

There is strong evidence from both GB and international studies that there is direct ingestion of lead shot by terrestrial and wetland birds. An assessment of the available evidence results in an estimate of 16,100 to 804,000 terrestrial wild birds in the breeding population being at high risk of death annually from primary ingestion of lead shot in the UK. These figures do not include terrestrial gamebirds bred and released for the purposes of hunting. Owing to the very large number of gamebirds bred and released annually the numbers at risk are higher than for wild birds, with a minimum estimate of 47,100 birds at risk in the UK. It is known that compliance with the existing ban on the use of lead shot over wetlands in GB is low, and wetland birds that feed on terrestrial areas are also considered to be at risk. An estimate of 37,500 to 75,000 annual waterbird deaths due to lead shot ingestion is made. Higher numbers of birds would be expected to suffer sub-lethal or welfare effects.

There is also strong evidence from both GB and international studies that secondary exposure of predatory/scavenging birds is a key exposure pathway for lead ammunition. This exposure pathway is relevant to all forms of live quarry shooting, and to all uses which may result in primary ingestion as this can then pass up the food chain. The available observational data indicate that a proportion of the deaths of scavengers and avian predators in GB results from lead poisoning arising from the use of lead ammunition. Published studies have modelled the number of deaths that may occur due to this exposure pathway to be in the thousands in the UK, but greater numbers of birds would be expected to experience sub-lethal and welfare effects. The potential exposure pathway is clear and even if only a small proportion of the population ingest lead via this route then large numbers of birds may be adversely affected.

Adverse effects on population-relevant endpoints have been observed in laboratory studies with birds at concentrations below those at which mortality is seen. A reduction in individual survival rates and adverse effects on population-relevant endpoints will affect the overall population size of a species, unless they are perfectly compensated for by complete density-dependent enhancement of other demographic variables. The point at which population level effects may occur will vary from species to species, and between locations and time, depending on what other stressors or compensatory factors are in place.

The life history of the bird species is important in determining what the effects on population levels may be. Differences in feeding ecology, life span, age at first breeding and annual survival rate (from all causes of death) will all influence the scale of any adverse effects on population. Although the number of individual birds killed or the reduction in stable population size is of relevance, another consideration is whether the population can be sustained. Population level effects are most likely to occur in species such as raptors that have lower natural annual mortality rates and lower annual reproductive rates, and bird species with lower initial population sizes are more at risk of extinction.

Many of the bird species at risk of primary and secondary poisoning are migratory species, which spend winters in GB before migrating back to Europe or Africa. International treaties such as the African-Eurasian Waterbird Agreement (AEWA, 1999) and the United Nations Environment Programme (UNEP) Convention on Migratory Species (CMS) recognise that the risks posed by exposure to lead in one country can lead to impacts globally.

Risks have also been identified for other taxonomic groups. Wild mammals may ingest lead if scavenging quarry that has been killed but not retrieved or consuming contaminated gut piles. Companion animals are expected to ingest lead if fed offcuts from shot game or fed game-based commercial food. There is evidence that other animals may ingest lead shot whilst grazing. This is considered a relevant exposure pathway for livestock (and likely wild animals) that feed in areas with high lead shot use (e.g. on a shooting range). Concentrations of lead in vegetation grown in areas of high lead ammunition use (e.g. on a shooting range) are also reported to exceed thresholds set for lead in forage and feed, indicating that there may be a risk of secondary poisoning of livestock via this route. Measured concentrations of lead in soil in areas of high lead ammunition use (e.g. on a shooting range) are reported to be above the soil PNEC, indicating risks to soil organisms at these sites. Increased lead concentrations in surface and groundwaters may also result in exposure of aquatic organisms and contaminated drinking water.

1.6.2 Human hazard, exposure and risk

Chronic exposure to lead is associated with a wide range of health effects in humans. These effects include toxicity to the blood system, nervous system, kidneys, cardiovascular system and reproductive systems (male and female fertility, adverse effects on development following exposure during pregnancy). The critical effect in the developing foetus and young children is developmental neurotoxicity; even at low levels of lead exposure, cognitive development and intelligence quotient (IQ) are reduced. Elevation of systolic blood pressure and kidney toxicity are the most sensitive effects in adults. It is generally accepted that none of these effects has a threshold. The most relevant human health impact of the proposed restriction is that on developmental toxicity (neurotoxicity) in the most vulnerable population to the adverse effects of lead, i.e. young children, including those exposed *in utero*.

The primary human health risk addressed in this dossier is that to consumers of game meat that has been shot with lead ammunition (i.e. wild game). The highest consumers of game meat are hunters and their families. Estimates of high-level consumers of game (at least one portion ≥ 100 g of game meat per week) in the UK range between 0.084 – 2.52% of the population (adults and children). Further estimates have indicated that 4,000 – 48,000 children in the UK are at a potential risk of incurring a one point or more reduction in IQ from exposure to ammunition-derived lead.

Meat hygiene measures and stewardship schemes are in place to minimise the amount of metal in meat sold for human consumption in the UK and the removal of obvious ammunition fragments by hunters and their families / friends appears to be reasonably widespread. Nevertheless, meat can still contain small fragments of metal that cannot be easily detected and that might be far from the shot site. The Food Standards Agency advises that the consumption of game meat be minimised, particularly in vulnerable populations such as toddlers, children, pregnant women and women trying to conceive.

As lead is a non-threshold neurotoxic substance, risks to humans from the consumption of game shot with lead ammunition cannot be excluded and exposure to lead should be reduced as far as possible.

1.6.3 Existing risk management

In GB, each of the devolved administrations has already enacted a ban on the use of lead shot over wetlands in response to the African-Eurasian Waterbird Agreement (AEWA, 1999). These bans were introduced between 1999 and 2004 with the aim of protecting waterbirds from the impact of lead poisoning.

The existing regulations in England and Wales are based on species and habitat. The use of lead shot is prohibited:

- on or over any area below the high-water mark;
- on or over certain Sites of Special Scientific Interest;
- for the shooting of ducks, geese or swans of any species, coots or moorhens on or over both wetlands and terrestrial habitats.

In Scotland, the use of lead shot is prohibited on or over all wetland areas (but excluding peatlands with no visible water, which are within scope of the EU restriction).

There is evidence that compliance with the current restrictions on the use of lead shot over wetlands is low. Two studies were undertaken which both estimated a non-compliance rate of approximately 70% (Cromie *et al*. (2010) and (2015)). Stroud (2021) suggested that the low compliance may ‘*relate to the restriction being only partial, in that they cover only the shooting of certain species (largely ducks and* *geese) and/or in certain places (listed wetlands and the foreshore)*'. A wider restriction where the sale and use of lead shot was banned would ensure that compliance over wetlands was also increased.

Nine of the major UK shooting organisations have signed up for a voluntary phase out of lead shot used for hunting live quarry, with a five year phase-in from February 2020. Research shows that the voluntary measures have had no significant impact so far. Green et al (2023) found that 94.0 % of the 235 pheasants from which shotgun pellets were recovered in 2022/23 had been killed using lead ammunition, compared to 99.5% in 2021/22 and 99.4 % in the 2020/21 season.

1.6.4 Justification for consistent action across GB

Some legally binding risk management measures are already in place at a devolved administration level to mitigate the risks from the use of lead shot over wetlands in order to meet our commitments under the African-Eurasian Waterbird Agreement (AEWA, 1999). The wetland restrictions across GB vary between the administrations and do not uniformly apply to all wetland habitats or protect wetland birds that feed in terrestrial habitats (such as grazing swans, geese and ducks) from ingestion. There is also evidence that compliance with the current restrictions on the use of lead over wetlands is low.

The UK is also a contracting party to the United Nations Environment Programme (UNEP) Convention on Migratory Species (CMS). The UK hosts 31 species that are included in CMS Appendix I or II indicating that they are at high or moderate risk of primary poisoning from lead shot and 10 Appendix I and II raptor species at high or moderate risk of secondary poisoning. Increased risk management of lead ammunition would reduce the risks both to GB bird populations, but also to migratory species. The Conference of the Parties to CMS adopted the Guidelines to Prevent the Risk of Poisoning to Migratory Birds through Resolution 11.15 (Rev.COP13), which includes the recommendation to "Phase-out the use of lead ammunition across all habitats (wetland and terrestrial) with non-toxic alternatives […] To reduce problems with monitoring, compliance and enforcement, such processes should not be partially restrictive".

The main justifications for a GB-wide restriction are therefore:

- to ensure a harmonised high level of protection of the environment and human health to address the identified risks which are common to all the devolved administrations.
- to increase compliance with the existing bans on some uses of lead shot to meet our commitments under the African-Eurasian Waterbird Agreement (AEWA, 1999).

- to fulfil the UK’s obligations as a contracting party to the United Nations Environment Programme (UNEP) Convention on Migratory Species (CMS).
- to ensure free movement of goods within GB.
- to ensure a level playing field for all engaged in sports shooting within GB.

2 Impact assessment

2.1 Introduction

Market failures currently exists whereby the use of lead ammunition results in negative externalities, as well as likely constituting an information failure. The societal costs associated with widespread pollution from spent lead ammunition are not currently internalised within the market. Additionally, those who use lead ammunition may not be fully aware of the associated environmental and human health risks.

The negative externalities vary by each use of lead ammunition, but can be summarised as risk to:

- Birds (primary poisoning)
- Birds (secondary poisoning)
- Ruminants/Grazing animals
- Mammalian scavengers/companion animals,

and risk of:

- Soil contamination
- Water contamination.

Greater detail on these environmental risks arising from the uses of lead ammunition in scope of this Annex 15 document can be found in Section 1.4.6.

In addition to this, human health risks exist from dietary exposure to lead in game meat, namely:

- Neurodevelopmental impacts in children
- Chronic Kidney Disease impacts
- Cardiovascular impacts.

Correction of these market failures and risks to human health form the rationale for intervention.

This impact assessment (IA) investigates the impacts of a restriction on the use of lead in ammunition. It will first explore the current alternatives to lead ammunition. Their availability, in addition to technical and economic feasibility, is evaluated. Following this analysis of alternatives, the Agency details its socioeconomic analysis (SEA). Initially, an options analysis is undertaken to identify which risk management options would be effective, practical, monitorable, and enforceable. Options that meet these 4 criteria are then taken forward for further analysis, whereby the impacts of their implementation are compared to the 'do-nothing' option (baseline). Based on this SEA, the Agency concludes its recommendations for proportionate action to mitigate the risks from the uses of lead ammunition in scope. These recommendations are summarised in Section 2.1.1.

2.1.1 Executive summary of impact assessment findings

The restriction proposal focuses on two outdoor uses of lead ammunition: live quarry shooting (LQS) and outdoor target shooting (TS). Within each of these uses there are three types of lead ammunition that are assessed: gunshot, bullets, and airgun ammunition. These are detailed in *Table 1.4*, replicated in table 2.1 below:

Table 2.1: Overview of uses

Sector of use	Use #	Use title
Live quarry shooting	1	Live quarry shooting with shot
	2	Live quarry shooting with bullets
	3	Live quarry shooting with airgun ammunition
Outdoor target shooting	4	Outdoor target shooting with shot
	5	Outdoor target shooting with bullets
	6	Outdoor target shooting with airgun ammunition

The IA assesses the case for restriction in each use on an individual basis. The assessment is underpinned by information on uses, releases, availability of alternatives and socio-economic impacts. As mentioned in section 2.1, risk management options are analysed against the criteria outlined in the Annex 15 to UK REACH for assessing the appropriateness of a REACH restriction: effectiveness (including proportionality), practicality (including enforceability) and monitorability. Full details of this can be found in section 2.5.

Within the IA, the Agency has conducted a monetised assessment of impacts where sufficiently robust and available data allow for it. Where this is not possible, the Agency has sought to quantify impacts without monetisation, or has opted for a qualitative assessment where more appropriate. Sensitivity analysis has been undertaken on key uncertainties, in addition to conservative assumptions being employed throughout the Agency's modelling, outlined throughout Section 2.

The following conclusions are drawn from the Agency's SEA:

- LQS with shot: The Agency considers restriction on this use to be a proportionate measure to addressing risk**.** As such, the **Agency recommends this use be restricted**, with a 5-year transition period.

- TS with shot: The Agency considers restriction on this use to be a proportionate measure to addressing risk**.** However, the Agency recommends a derogation on the use of lead shot for a small number of individual athletes as identified by the appropriate sporting body, noting this to likely be a more cost-effective intervention than a blanket restriction for target shooting. **As such, the Agency recommends this use be restricted with an athlete derogation**, with a 5-year transition period.

- LQS with large calibre bullets (≥6.5mm): The Agency's cost-effectiveness analysis suggests a significantly greater cost per tonne of lead emissions avoided when compared to restrictions on the shot uses. The Agency is unable to conclude, qualitatively or quantitatively, whether the societal benefits of restricting this use outweigh the costs, and has not been able to explicitly demonstrate the proportionality of a restriction on this use. Further work undertaken during the public consultation period will seek to provide greater clarity on the proportionality of such restriction.

  In light of this, **the Agency does not recommend that this use be restricted at this time.**

- LQS with small calibre bullets (<6.5mm): The Agency's cost-effectiveness analysis suggests a significantly greater cost per tonne of lead emissions avoided when compared to restrictions on the shot uses. The Agency also deems the small-calibre alternatives currently available to perform less well, and the costs of a restriction on this use is likely be greater than those of large calibre bullets.

  The Agency is unable to conclude, qualitatively or quantitatively, whether the societal benefits of restricting this use outweigh the costs, and has not been able to explicitly demonstrate the proportionality of a restriction on this use. Further work undertaken during the public consultation period will seek to provide greater clarity on the proportionality of such restriction. In light of this, **the Agency does not recommend that this use be restricted at this time** subject to information received during the public consultation.

- Furthermore, there are additional uncertainties regarding both large and small calibre bullets:
    - A restriction on the placing on the market of lead-based bullets in general would not be possible, since they would still be required for indoor shooting (which is out of scope).
    - Enforcement challenges may arise from 'target shooting' ammunition being available for live quarry shooting.
    - Practical challenges can arise from alternative ammunition not being permitted on ranges. This means 'zeroing' of rifles and practising on ranges with newer ammunition may not be possible.

  The Agency are seeking to resolve some of these challenges during the second public consultation.

- TS with large and small calibre bullets: The Agency does not consider a blanket restriction to be the most cost-effective measure to reduce risk, and instead **recommends a restriction on the use of lead bullets for target shooting with a derogation for licensed ranges with appropriate environmental protection measures.** Most ranges already have RMMs in place for health and safety purposes and so the Agency considers it to be likely that such intervention be proportionate. A blanket restriction, however, would likely be disproportionate due to most of the risk from this use already being adequately controlled.

- Airguns (both uses): The Agency has been unable to identify any monitorable or enforceable option to manage the risk from this use. As such, **the Agency does not recommend a restriction on this use**.

Table 2.2 provides various summary statistics arising from the Agency's analysis, providing a comparison of scale of use and impacts for each use:

Table 2.2: SEA summary statistics

Intervention	Reduced emissions (t lead, 20yrs)	Estimated present value costs (20 years)	Estimated present value benefits (20 years)	Benefit-cost ratio	Cost-effectiveness ratio (£/t* lead)	Notes

Restriction-LQS with shot	21,600	£112.9m	£206.4m	1.7	£5,700	Several environmental benefits have not been monetised and so are not included in this monetised comparison of impacts.
Restriction w/ athlete derogation-TS	79,800	£415.5m	£580.4m	1.4	£5,200	As above.
Restriction-LQS with LC bullets	21	£2.4m	N/Q	N/A	£89,700	
Restriction-LQS with SC bullets	27	£1.1m	N/Q	N/A	£41,400	Several costs have not been monetised. The Agency considers restriction on this use to be less cost-effective than for large calibre bullets.
Restriction with derogation for sites with suitable RMMs-TS with bullets (all calibres)	93	£0.6m	N/Q	N/A	£5,900	Estimated emissions reduced reflects 5% of the total volume of lead relevant to this use, due to 95% recovery under the baseline.

Restriction-air weapon (both uses)	>13	N/Q	N/Q	N/A	N/A	

*Different risks are attributed to different uses of lead ammunition, meaning that a given cost-effectiveness ratio will represent a different ratio of costs to risk dependant on the use it is calculated for. This caveat applies throughout the IA as a result of the Agency using tonnage as a proxy for risk. All cost-effectiveness ratios presented in the IA are rounded to the nearest £100.

The Agency estimates that the recommended interventions would eliminate the risk associated with **99.2%** of annual emissions from lead ammunition in scope of this restriction dossier, with the remaining 0.8% of emissions attributable to LQS with bullets and both airgun uses (where no restriction has been recommended).

2.2 Analysis of alternatives

This section summarises information on alternative substances to lead in ammunition that are already on the market. It also includes information regarding accuracy implications and other potential concerns (e.g., noise levels, ricochet, safety, efficacy and supply chain) around the replacement of lead ammunition with lead-free alternatives. The primary information sources were Appendices C and D of the Annex to the European Annex XV restriction dossier ECHA (2022b), (LAG, 2015a) and the responses to the GB call for evidence and public consultation.

2.2.1 Identification of potential alternative substances fulfilling the function

2.2.1.1 *Function of lead in ammunition*

Ammunition in the sense of this restriction comprises shot, bullets, slugs and pellets, which are projectiles accelerated by detonation of a propellant charge (or release of compressed gas in the case of airguns) from the barrel of a weapon by the act of discharging the weapon. The projectiles are fired towards the target, penetrating and/or passing through it.

Traditionally lead has been used in ammunition because of the following properties (LAG, 2015a; TemaNord, 1995):

- softness and lubricating features (resulting in low abrasion of the barrel)
- low melting point (making it easy to transform into shot, bullets or pellets)
- high density (yielding high momentum after firing and maintaining strike energy down-range)
- relatively low price and high abundance (resulting in low production cost)

Based on these properties, lead is often considered to be an ideal material for use in ammunition. Other materials often have somewhat different ballistic behaviour to lead but this does not necessarily result in a conclusion that they are technically or economically inferior to lead ammunition. The technical feasibility of the use of alternatives to lead is outlined in the sections below.

Shotgun pellets have traditionally been made of lead with traces of other metals to achieve performance specification, depending on manufacture (LAG, 2015a).

Lead is the major constituent of traditional rifle bullets, but it may be shaped and cased (jacketed) in a metal such as copper or copper alloys (e.g., gilding metal or tombac), and for shooting animals will have a hollow or soft nose configuration (in which the copper casing does not extend to the tip but leaves a soft lead tip or nose exposed). The soft nose, shaping, casing and tip design produce distinctive performance, mushrooming and fragmentation characteristics of the chosen bullet, and will critically affect its stability and performance when fired at differing speeds and ranges (LAG, 2015a).

The softness and lubricating properties of lead allow airgun projectiles (i.e., pellets or slugs) to expand on firing to engage the barrel to provide a gastight seal and stabilise the projectile.

2.2.1.2 *Non-lead alternatives function and properties*

Alternatives to lead in ammunition are based on materials with similar density and softness resulting in similar ballistic characteristics.

Steel, tungsten-polymer and bismuth are the most common alternatives to lead shot. Whilst bismuth and tungsten-polymer are generally safe to use in older non-steel rated shotguns, they are comparably more expensive than lead or steel shot.

Non-lead bullets might be either monolithic, semi-jacketed or jacketed with other metals to facilitate the passage through the barrel. Most non-lead bullets are made from copper or brass, with or without other metal jacket coatings (Paulsen et al., 2015; Thomas et al., 2016). Generally, whilst suitable alternatives for larger calibres exist, the ballistic properties associated with smaller projectiles mean that availability of suitable non-lead alternatives is restricted for smaller calibre ammunition (i.e., small calibre rimfire and airgun ammunition).

Bismuth and its alloys

Approximately 84 % of the world's bismuth is sourced from China and it is deemed to be a Critical Raw Material (i.e., raw materials which are economically and strategically important for the European economy but have a high-risk associated with their supply) with limited abundance (ECHA, 2022b). Bismuth is produced from lead concentrates which are obtained from lead and complex ores and also as a by-product in the extraction of other metals such as copper, molybdenum, tin and tungsten (Ojebuoboh, 1992).

Bismuth has good ballistic properties but requires an increased shot size to account for its lower density compared to lead (9.78 g/cm^3 versus 11.34 g/cm^3 for lead). It is slightly harder than lead. A letter from the Banco Nazionale di Prova (Italian proofing organisation) provided by the Anglian Muzzle Loaders (Organisation #63) claims that hardness is 7 HB (70-94 MPa) for bismuth vs 4 HB (38-50 MPa) for lead on the Brinell Hardness scale (HB number converted to MPa by the Agency). It has a lower melting point 271°C vs 327.4°C for lead, and is more friable than lead, although this may be compensated for by addition of binders.

According to ECHA (2022b), bismuth is suitable in all shotguns as a drop-in alternative for lead without barrel compatibility concerns. However, there are many more historic weapons in use in GB than in the EU. The owners of many weapons with historic value do not want to take the risk of damaging their gun by using anything other than the lead ammunition it was designed for (The Agency/Shooting Organisations Stakeholder Meeting September 2022). Originally, bismuth was used in shot in an almost pure form, but to prevent the bismuth shot fragmenting it is usually alloyed with tin (3-6 %). The four major UK shotgun cartridge manufacturers now supply bismuth in both 12 and 20 bore with only Eley currently supplying a 16 bore load. Additionally, Eley and Lyalvale Express make 28 bore bismuth alternatives. Bismuth cartridges are approximately 3 times the price of lead (Bull, 2022). The Lead Ammunition All Party Parliamentary Group (APPG, 2022) report by the Wildlife & Countryside Link (Organisation #117) cites a recent product 'BioAmmo Blue' which comprises a new alloy mixture of bismuth, aluminium, tin and zinc. It is available in 2.75 inch cartridges, both wad and case are plastic free and it is significantly more expensive than lead (APPG, 2022; Bull, 2022). While bismuth is approved for shotgun shot in the USA and Canada and considered non-toxic, it is not considered appropriate for rifle ammunition use due to its tendency to break apart on high velocity impact (Thomas, 2019a).

There is no GB mandatory classification for bismuth but some suppliers self-classify bismuth as Aquatic Chronic 4. Testing of commercial bismuth shot indicated no detectable leaching rate and no impact on immobilisation of *Daphnia magna* in the 48-h acute toxicity test (Fäth et al.(2019). The ECHA bismuth registration dossier (2023a) reports that reliable data are available for the acute toxicity of bismuth subnitrate and bismuth metal on freshwater fish, invertebrates and algae. Because of its limited solubility, the aquatic organisms were exposed to the water-accommodated fraction of bismuth subnitrate after seven days stirring. No toxic effects were observed up to the highest concentration tested (equivalent to 100 mg Bi/L), resulting in unbounded L(E)C50 and NOEC values.

Shot made from bismuth-tin alloy is fully approved as non-toxic in relation to wildlife in the USA and Canada. (Sanderson et al., 1998, 1997) demonstrated that ingesting bismuth-tin shot or implanting bismuth-tin alloy into the breast muscle of ducks did not have any toxic impact on the birds and did not affect their reproduction. In-vivo studies with bismuth-tin alloy indicated distribution and accumulation of bismuth in tissues (Pamphlett et al., 2000; Stoltenberg et al., 2003). *"These authors also reported that although mobilization of bismuth from the shot occurred over months, no detrimental effects on weight gain, movements, and appetite were observed. Nevertheless, these authors urged caution concerning uptake of bismuth from embedded shot"* (Thomas, 2019a). The ECHA registration dossier (2023a) indicates that a single dietary toxicity study with Leghorn hens was identified, reporting unbounded NOEC values of ≥1000 mg bismuth /kg diet for egg production, individual feed intake and body weight change after 8 weeks feeding with a corn-soy laying mash supplemented with bismuth trioxide (Hermayer et al., 1977). This study was judged not assignable (Klimisch 4) because of the lack of sufficient information on both methods and results. However, the results were used in a weight-of-evidence approach indicating the limited risk for chronic dietary toxicity of bismuth metal and compounds.

No human health risk is expected from the consumption of meat from game hunted with bismuth (ECHA, 2022b). Bismuth metal is not acutely toxic via oral, dermal or inhalation route. The ECHA registration dossier for bismuth indicates an oral Derived No Effect Level DNEL of 13.3 mg/kg bw/day for the general population based on a NOAEL of 1000 mg/kg bw/d from a 28 day repeated dose oral toxicity study (ECHA, 2023a).

Copper and its alloys

Approximately 29 % of the world's copper comes from Chile and 12 % from Peru. It is not characterised as being a Critical Raw Material, although there are numerous competing uses (ECHA, 2022b).

Copper shot is harder than lead which prevents deformation and provides more shot in the shot pattern. Depending on the choke, the pattern will be tighter/less dispersed at longer distances which is a consideration for hunting high-flying birds.

The majority of the non-lead bullet alternatives are made from pure copper or copper-zinc alloy (brass, where the zinc content comprises approximately 5 %), with or without other metal jacket coatings. Other variants included copper plated zinc core or compressed copper/polymer bullets, particularly for smaller calibre rimfire bullets. Monolithic copper bullets are also used as slugs fired from shotguns. Like lead bullets they are capable of rapid expansion providing a hydrostatic shock wave that travels out from the bullet's path causing significant injury to tissue and organs and the increased diameter and sharp edges cause more internal physical damage to the target animal (Norma Academy, 2022). However, unlike lead they do not fragment or generate dusts (Paulsen et al., 2015; Stroud, 2009; Thomas et al., 2016).

Tombac is a brass alloy with an increased zinc content (>5 to 20 %), and it always contains arsenic which governs hardness. It comprises the jacket of most jacketed bullets (Gerofke et al., 2018). The Agency expects that there will be no increase in the level of risk due to the use of tombac in non-lead bullets compared to lead bullets.

The lead content in copper bullets is generally up to 1 % (ECHA, 2022a). However, some brass bullets contain approximately 3% lead (ECHA, 2022a). Forestry England (organisation #111) noted that some of the lead-free bullets it uses contains small percentages of lead (≤3 %), for example bullets or jackets constructed with '360' brass.

Bronze is an alloy of copper and tin where the tin comprises approximately 5 %. Bronze is potentially suitable for bullets, although increased metal hardness compared with copper may be an issue (Thomas, 2019a).

In GB, copper flakes (coated with aliphatic acid) have a mandatory classification of Aquatic Acute 1 (H400) and Aquatic Chronic 1 (H410) with an M factor of 10 for the environment. Granulated copper [particle length: from 0.9 mm to 6.0 mm; particle width: from 0.494 to 0.949 mm] has a mandatory classification of Aquatic Chronic 2 (H411) (HSE, 2021). The aquatic toxicity of copper and high leaching potential means that the use of copper shot should be avoided over wetland areas because of the potential risk to the aquatic environment (Fäth et al., 2018; Fäth and Göttlein, 2019).

The US Fish and Wildlife Service (US FWS, 2000) has approved the use of Corrosion Inhibited Copper (CIC) shot (i.e., surface-treated with benzotriazole (BTA) to obtain insoluble, hydrophobic films of BTA-copper complexes) for hunting waterfowl and coots and conclude "*that this type of shot left in terrestrial or aquatic environments is unlikely to adversely affect fish, wildlife, or their habitats*." According to the ECHA Registration Dossier, BTA is very persistent (vP) and may also be a very persistent very mobile (vPvM) substance (ECHA, 2022f).

Bronze lowers the mobility of copper in acid aqueous media and therefore exhibits less potential toxicity to animals which might ingest it, or to the freshwater environment (Thomas, 2019a).

The potential toxicity to wildlife from ingestion or exposure to copper is considered to be minimal. American Kestrels dosed experimentally with copper shot exhibited no signs of toxicity (Franson et al., 2012). A study where Mallards were fed shot made from copper resulted in 4 % mortality, which was below the mortality of control birds fed plastic (20 %) (Irby et al., 1967). Feeding of copper or brass shots to ducks did not result in relevant body weight loss during a 4 week retention period (Krone, 2009).

The potential human health risk from copper for average consumption of game meat is considered to be minimal; the release of copper from shot game would not contribute much released metal to humans and the daily recommended daily intake of copper would not be exceeded, (Hunt et al., 2009; Irschik et al., 2013; Paulsen et al., 2015; Schlichting et al., 2017; Stokke et al., 2017). The general population on average eats more meat and / or products of farm animals where copper is added as feed additive, therefore the intake of copper through the consumption of these products is much higher than it is through the consumption of hunted game meat, irrespective of whether lead or non-lead ammunition was used for hunting (Schlichting et al., 2017).

Nickel

Nickel is not characterised as a Critical Raw Material, and it is recyclable (ECHA, 2022b). Nickel plating is also used as a bullet jacket coating and also as a coating for lead shot. Nickel is used as an alloy component with other metals for a number of different types of shot, including tungsten-nickel formulations. It is also used as a bullet jacket coating.

Nickel powder [particle diameter < 1 mm] has a GB mandatory classification as Carc. 2, STOT RE 1, Skin Sens. 1 and Aquatic Chronic 3 (HSE, 2021). Due to the potential carcinogenicity concerns it should be avoided as a component of shot (Thomas, 2019a).

Polymers

Polymers can be used as the bullet tip, to preserve ballistics whilst improving the ‘hollow point’ expansion of the bullet. They generally comprise polyoxymethylene, or polyester urethane-methylenebis(phenylisocyanate) copolymers.

Alternatively, metal-polymer composites (e.g., tungsten, which is discussed later in this section) may be used as the major component of the bullet. Typical properties of metal-polymer bullets compared to equivalent metal bullets include reduced weight, higher velocity, less friction, less smoke, less barrel debris, and the potential to be used where lead bullets are restricted (ECHA, 2022b).

Steel (soft iron)

Steel shot is actually ‘soft iron’ (i.e., iron with a low carbon content) rather than steel, which may have a carbon content ≤2 % and be alloyed with other elements. Iron is abundant and recyclable and not characterised as a Critical Raw Material, although it has numerous competing uses (ECHA, 2022b).

Steel shot is widely available and is generally seen to have an equivalent performance to lead, but requires use in compatible guns due to its comparatively greater hardness (Pierce et al., 2015; A. M. Scheuhammer and Norris, 1995). It is also the most commonly used alternative due to its relatively low price. China is the world's largest supplier of steel and steel shot (ECHA, 2022b).

Steel shot is manufactured by annealing iron containing approximately ≤1 % carbon and has different ballistic properties to lead shot (Thomas, 2019b). It is harder (4-4.5 Mohs scale hardness versus 1.5 for lead) and has approximately 70 % of the density of lead (7.87 g/cm^3 for iron vs 11.34 g/cm^3 for lead). Steel shot may be coated with copper or zinc (which is discussed later in this section) to inhibit corrosion (US FWS, 1997). Some adaptation to the different ballistic properties of steel may be required by hunters to achieve equivalent performance. For example, typically used shot size would need to be increased to account for the lower density of steel (ECHA, 2022b).

There is no GB mandatory classification and labelling for iron (HSE, 2021). In the EU, iron does not have any harmonised or self-classification and available data do not indicate a risk of iron for the aquatic environment (ECHA, 2022c; Fäth and Göttlein, 2019).

The potential toxicity to wildlife from ingestion or exposure to iron was demonstrated to be minimal (Brewer et al., 2003; Irby et al., 1967; Thomas, 2019b). The potential toxicity to wildlife from ingestion or exposure to iron was demonstrated to be minimal (Thomas, 2019a). A study where Mallards were fed shot made from pure iron, zinc-coated iron, or molybdenum-coated iron resulted in some mortality (12 % for iron, 4 % for zinc-coated iron), but this was below the mortality of control birds fed plastic (20 %) (Irby et al., 1967). Twenty Mallards were dosed by oral gavage with steel shot. No mortality was observed, mean bird weight did not change, and there were no significant abnormalities of the liver and kidney (Brewer et al., 2003; Thomas, 2019a).

The potential human health risk from iron from the consumption of game meat shot with steel ammunition is expected to be minimal (ECHA, 2022b). According to the ECHA Registration Dossier, no hazard is identified for acute / short term exposure and a DNEL of 710 µg/kg bw/day for iron was derived for long term oral exposure (ECHA, 2023b).

Tin

Tin is relatively abundant and not characterised as a Critical Raw Material (ECHA, 2022b).

A letter from the Banco Nazionale di Prova (Italian proofing organisation) provided by the Anglian Muzzle Loaders (Organisation #63) claims that tin has a similar hardness to lead (4 HB (51-75 MPa) on the Brinell hardness scale vs 4 HB (38-50 MPa) for lead (HB number converted to MPa by the Chemicals Agency)). It has a lower melting point 231.9°C vs 327.4°C for lead and loses ductility on heating, becoming more brittle. The low density of tin (7.31 g/cm^3) compared with lead (11.34 g/cm^3) *"does not predispose it for use as gunshot …* [nor] … *bullets"* (Thomas, 2019c)*.* Tin is, however, used in alloys with other metals, for example tungsten-tin-iron (TTI) shot composed of 58 % tungsten, 38 % tin, and 4 % iron is approved by the US Fish and Wildlife Service for hunting waterfowl and coots (US FWS, 2000).

There is no GB mandatory classification and labelling for tin (HSE, 2021). In the EU, tin does not have any harmonised classification for aquatic endpoints. According to the EU REACH registration dossier for tin *"no aquatic toxicity was observed that could be attributable to dissolved tin species"* (ECHA, 2023c). ECHA (2022c) states "*available data indicate no aquatic toxicity of tin in shots under aerobic conditions; the reported risk of aquatic toxicity of tin under anaerobic would require further investigations"* Fäth and Göttlein (2019) observed low leaching potential from tungsten-based shot releasing small amounts of tin in anaerobic environments (<1.2 µmol Sn/L), which was almost negligible considering the EC50 for Daphnia magna of 182 µmol/L. The authors consider that tin is a suitable substitute for lead from an ecotoxicological perspective, because of its corrosion resistant properties.

Available data indicate that after force-feeding of pure tin shots, Mallards did not show a significant body weight loss and did not die within 30 days (ECHA, 2022c; Grandy et al., 1968).

In relation to potential human health risk, tin *"has no practical bioavailability via any route, and is not acutely toxic via the oral, dermal or inhalation route"* (ECHA, 2023c). According to the ECHA Registration Dossier, no hazard is identified for acute / short term exposure and a DNEL for tin of 5 mg/kg bw/day was derived for long term oral exposure (ECHA, 2023c).

Tungsten and its alloys

Tungsten is relatively abundant but deemed a Critical Raw Material for the EU. Major producers are China, Russia, Portugal, Spain and Austria (ECHA, 2022b).

The density of tungsten (19.25 g/cm^3) is significantly higher than lead and it is a much harder metal. This density lends to good ballistics but requires appropriately proved guns.

Tungsten shot is available either as the pure metal, as a mixture of powdered metal matrix with a high-density polymer, or as a composite mixed (sintered or alloyed) with other metals. Bullets may be made from any proportion of tungsten (which contributes increased density) plus any other approved material (Thomas, 2019a). Examples unconditionally approved for hunting waterfowl and coots by the US Fish and Wildlife Service include iron-tungsten, iron-tungsten-nickel, tungsten-bronze, tungsten-iron-copper-nickel, tungsten matrix (95.9 % tungsten and 4.1 % polymer), tungsten-polymer (95.5 % tungsten and 4.5 % Nylon 6 or 11), tungsten-tin-iron, tungsten-tin-bismuth, tungsten-tin-iron-nickel and tungsten-iron-polymer (41.5 – 95.2 % tungsten, 1.5 – 52.0 % iron, and 3.5 – 8.0 % fluoropolymer) (ECHA, 2022b). Gamebore (UK) make Impact Tungsten Matrix (ITM) for 12 bore only in a fibre shot cup in 32 g, #5 shot, 2.75 inch (70 mm) cartridge. ITM has approximately the same density as lead (with antimony) and therefore should exhibit similar performance. It is approximately five times the price of lead (Bull, 2022).

There is no GB mandatory classification and labelling for tungsten (HSE, 2021). According to ECHA, tungsten does not have any harmonised or self-classification for aquatic endpoints and "*based on the available data there are no indications for aquatic toxicity, or other environmental hazard of tungsten used in shots"* (ECHA, 2022b). The Advisory Committee on Hazardous Substance (ACHS) Twenty fourth meeting (6 March 2007) (ACHS, 2007a) noted that '*there may be cause for concern in areas with concentrated shooting, where estimates of likely concentration in soil range up to 10%'*, which appears to be a result of tungsten causing acidification of the soil. Such high rates of shooting are only likely where game (e.g. grouse) are beaten towards shooters or perhaps sporting (clay pigeon) shooting ranges. Acidification will depend on the buffering capacity of the soil and should be amenable to appropriate management strategies. According to Strigul et al. (2005)**,** dissolution of tungsten powder significantly acidifies soils. Tungsten powder mixed with soils at rates higher than 1% on a mass basis, trigger changes in soil microbial communities resulting in the "death of a substantial portion of the bacterial component and an increase of the fungal biomass." These effects appear to be related with the soil acidification occurring during tungsten dissolution.

Data suggest that the risk to wildlife from consumption or exposure to pure tungsten is low and that observed toxicity with tungsten alloys derive from the other metal components of the alloy, such as cobalt and nickel (Brewer et al. (2003); Thomas, (2016)). The ACHS update on tungsten ammunition (2007b) stated that **"***elemental tungsten does not pose risks of toxicity, carcinogenicity or teratogenicity to wounded birds themselves, or in predators or scavengers which may feed off them***."**

According to (ECHA, 2022b) *"due to missing information on tungsten concentrations in game meat, no conclusion on human health risk can be drawn".* ECHA (2023) states the long-term DNEL for the general population for the oral route is 0.48 mg/kg bw/day. The ACHS update on tungsten ammunition (2007b) discusses evidence for developmental toxicity and concludes the risks of developmental toxicity to humans from ingestion of elemental tungsten are very low. There is some information on the carcinogenicity of tungsten alloys implanted into the muscle of laboratory animals, to mimic humans wounded with ammunition. Implantation of a tungsten/nickel/cobalt alloy resulted in localised tumours in rats (also metastases to the lungs) and mice, whereas a tungsten/nickel/iron alloy did not cause tumours in mice (not tested in rats) (Kalinich, 2011). The tumour induction could not be linked to a single metal in the alloy, and the study authors concluded that a synergistic effect was likely (Emond et al., 2015). The relevance of these findings to humans exposed via the diet is questionable.

Zinc and its alloys

Zinc is relatively abundant and not classed as a Critical Raw Material. Most of the world's zinc is produced by China (39 %), Australia (11 %) and Peru (10 %) (ECHA, 2022b). It is used as an alloying metal in shot and bullets (Thomas, 2019). Its low melting point (419.5 °C) means that it can be cast into shot and bullets in similar processes to lead and its density of 7.14 g/cm^3 is comparable with iron and tin as ballistic substitutes. Non-lead airgun ammunition alternatives may include tin-zinc alloy.

For GB, zinc powder – zinc dust stabilised and zinc oxide have mandatory classifications and labelling of Aquatic Acute 1 (H400) and Aquatic Chronic 1 (H410). In the EU, zinc has a harmonised classification as Aquatic Acute 1 and Aquatic Chronic 1. Due to the demonstrated acute toxicity of ingested zinc shot to birds, shot should not be made of this pure metal (Thomas, 2019a). For example, ingested zinc shot has been demonstrated to be acutely toxic to Mallards (Grandy et al., 1968; Levengood et al., 2000, 1999).

Zinc can be alloyed with copper to make brass, which lowers the mobility of zinc in solution. Therefore, brass exhibits lower potential toxicity to animals which might ingest it, or to the freshwater environment (Thomas, 2019a). However, a study of the leaching behaviour of metals and their toxicity to *Daphnia magna* (EC50 value for 48-h immobilisation) concluded that zinc-based as well as zinc-coated gunshot should be avoided because of the high risks they pose to the aquatic environment (Fäth et al., 2018; 2019). In the USA and Canada, zinc shot is considered to be toxic, and is not permitted to be sold (Putz, 2012; Anton Michael Scheuhammer and Norris, 1995).

A study simulating the release of different metals from non-lead rifle bullet fragments in game meat during storage and ingestion indicated release of zinc from meat posed no toxic risk post-ingestion by humans (Paulsen et al., 2015).

2.2.2 Availability and technical feasibility of alternatives

2.2.2.1 *Safety Standards for Firearms*

The Commission Internationale Permanente pour l'épreuve des armes à feu portatives ("Permanent International Commission for the Proof of Small Arms" (CIP) (https://cip-bobp.org/fr)) is an international organisation which sets standards for safety testing of firearms. The UK is one of 14 member countries. It safeguards that all firearms and ammunition sold to civilian purchasers in member states are safe for the users ((ECHA, 2022b) , LAG, (2015a)). Decisions taken by CIP have the force of law in all member countries. Each CIP member country must have at least one Proof House. The Proof House must test the firearms and ammunition placed on the civilian market, following CIP Decisions.

In GB there are two proof houses – one in London and the other in Birmingham – operating as private companies. They provide a public service with set prices. Together they are the British Proof Authority (BPA), and ‘proving’ of firearms is their responsibility under Statute. It is an offence to sell or to offer for sale an unproofed firearm anywhere in GB. The ‘Rules of Proof’ are a schedule of the Proof Acts and together with the CIP decisions comprise the working instructions for the BPA (Birmingham Proof House, 2023; Worshipful Company of Gunmakers, 2023). Airguns are exempt from the Proof Act.

The proving process involves an initial visual inspection and gauging of key dimensions including the chamber, barrel and cartridge headspace dimensions to determine whether everything is to the correct specification and there is no damage. This is followed by test firing an overpressure ‘proving’ load 25 – 30 % larger when compared with a standard pressure ‘service’ load to pressure test the gun barrel to see if it fails, effectively a ‘destructive’ test. For shotguns this comprises two shots per barrel for Standard lead proof and three shots per barrel for High Performance Steel using steel shot (i.e., Steel Mark). For rifles it is two shots per barrel, but only of lead or lead core bullets. If the weapon does not fail, it is marked with the appropriate proof mark for the tested proof load. Just because a firearm is in proof at time of proving, it may not stay in proof for its entire lifetime. Firearms previously proven and bearing proof marks are deemed out of proof if any pressure bearing component has been weakened. Any modification to any pressure bearing element of the firearm will require submission for re-proving (The Agency / Worshipful Company of Gunmakers Stakeholder Meeting, September 2022).

For shotguns, the CIP system uses a “Standard Mark” (marked ‘N’), a “Superior Mark” (marked ‘S’) and a “Steel Mark” (marked with a Fleur de Lys) and these proof marks are stamped into the gun barrel. These terms apply to the performance (pressure) of the cartridges that can be used in a gun. All guns manufactured after 1954 will be stamped with the relevant proofing mark. British proof marks have evolved over time for the two proof houses and there are numerous historic markings. Originally proof marks related to black powder (often denoted with ‘BP’) but with the development of smokeless nitrocellulose powders generating higher pressures, firearms could be ‘nitro-proofed’ (often denoted by ‘NP’ or ‘BNP’) (Birmingham Proof House, 2023; Worshipful Company of Gunmakers, 2023). The proof marking can be interpreted equally for lead shot and non-lead shot types, including steel, bismuth and tungsten (matrix types) and guns that can fire standard lead shot cartridges safely can also fire standard non-lead shot cartridges safely, assuming equivalent length and load weight (Thomas et al., 2015). Failure to use correct specification ammunition with the correct proofed barrel can result in ‘ring bulging’ (putatively cosmetic, but also at which point the weapon is automatically out of proof), increased wear, overload or even catastrophic failure (i.e., a rupture or disintegration of the chamber or barrel of the gun when firing).

For rifled firearms, CIP provides the Tables of Dimensions of Cartridges and Chambers (TDCC), approved tables that contain *“the data needed to establish those technical standards, the aim of which is to meet all the CIP requirements for the proof of small arms”* (CIP, 2023). For rifles, proof marks comprising the Proof House mark, year of proof, calibre and cartridge case length complying with the TDCC are applied (Birmingham Proof House, 2023; Worshipful Company of Gunmakers, 2023). In the TDCC, each calibre and type of gun / ammunition has specified maximum service pressures (PTMax) for ammunition and the mean proof pressure (PE) to which the gun is tested. Providing non-lead alternative bullet ammunition matches the TDCC and does not exceed stated the pressures, then it can be fired safely from an appropriately proofed rifle (GTA, Organisation #132). As yet the BPA have not provided a guidance document on the use of non-lead alternative bullets. The Birmingham Proof House confirmed that for several years lead-free ammunition has been available in limited supply for some main-stream calibres, but for other calibres there are still implications for non-lead alternative bullet use, such as increased barrel erosion [Birmingham Proof House; Personal Communication, May 2023].

Another ammunition standard is SAAMI (Sporting Arms and Ammunition Manufacturers’ Institute) which is an American voluntary standard. The CIP Technical Subcommittee is in contact with the Technical Committee of SAAMI. By collaborating, CIP and SAAMI work together to develop internationally recognized standards to ensure the safety of the shooter (ECHA, 2020b).

It is understood by the Agency that SAAMI shotgun ammunition is useable in the UK but needs to be compatible with CIP specifications for the firearm being used. The Birmingham Proof House confirmed that CIP and SAAMI regulate ammunition at different pressure regimes. CIP regulated Standard Steel shot is lower in maximum pressure than all SAAMI products, including lead shot. CIP regulated High Performance Steel shot has a service pressure in excess of SAAMI 12 bore 2.75 inch and 3 inch service loads. However, CIP currently have restrictions on momentum (mass x velocity) of the shot [Birmingham Proof House; Personal Communication, May 2023].

In CIP Member States, shotguns have traditionally been made with lighter thinner barrels. In the past there has been an issue with using SAAMI specification cartridges in CIP proofed shotguns in the UK with the potential for the lighter thinner designed guns to ring bulge (distort) at the choke (the muzzle area of the barrel).

Under current CIP rules any such distortion would put the gun ‘out of proof’ (and illegal to sell or transfer in GB), as the barrel has been deformed beyond the material’s elastic limits. This topic is under review by a CIP Working Group, however no decision is expected in the near future [Birmingham Proof House; Personal Communication, May 2023]. In Denmark, which is not a CIP member state, ring bulging is viewed as a cosmetic change not covered by any particular legislation and there would be no legal obstacle to sale or transfer of a firearm with a ring bulge [Danish EPA; Personal Communication, April 2023].

The William Powell (2021) briefing note emphasises care must be taken when comparing the performance of non-CIP regulated steel shot cartridges which are available in Denmark, the USA and elsewhere, with those currently available in GB as many of these cartridges are loaded to a much higher specification than can be loaded for GB. According to (GWCT, 2022), the CIP working group is studying the possibility of raising velocity and shot weight limits for steel to those set by SAAMI to increase performance.

2.2.3 Shot

2.2.3.1 *Suitability of lead-free shot*

The existing ban of lead shot over wetlands and for certain bird species (see Section 2.2.3.5) has meant that non-lead alternative shot including steel, bismuth and tungsten are already in use in GB. Steel shot is the most common non-lead alternative, mainly based on cost. In GB, there are two types of steel shot ammunition, Standard and High Performance and the difference can depend on a number of factors including load, case length, shot size, momentum and pressure (Bull, 2022).

The BPA have produced a guide to the use of steel shot cartridge loads (GWCT, 2022); [Birmingham Proof House; Personal Communication, May 2023]): Standard Steel ammunition can be used with any shotgun (other than Damascus/twist barrelled guns), in good order, bearing any relevant CIP, London or Birmingham symbols, provided the ammunition is of the correct length for the chamber and the barrel choking is less than half choke. Ammunition packaging should denote that the ammunition is Standard Steel.

In GB, 12 bore Standard Steel cartridges can be 2.5 inch (65 mm) or 2.75 inch (70 mm) and must have a shot size of 3.25 mm or less, with a maximum velocity at 2.5 m from the muzzle of 425 m/s and a maximum momentum of 12 Ns. Standard Steel can be fired through any gun proofed to the standard level (‘nitro’ proofed guns) (BASC, 2019); (GWCT, 2022); [Birmingham Proof House; Personal Communication, May 2023]).

High Performance Steel ammunition can only be used with shotguns bearing a CIP

Fleur de Lys mark. The ammunition should be of the correct length for the chamber. The CIP recommends less or equal to half choke in relation to a given shot diameter for the Bore. Ammunition packaging should denote that the ammunition is High Performance Steel (GWCT, 2022); [Birmingham Proof House; Personal Communication, May 2023]).

For 12 bore, High Performance Steel cartridges have a shot size larger than 3.25 mm, a maximum velocity at 2.5 m from the muzzle of 430 m/s and maximum momentum of 13.5 Ns, 15 Ns and 19 Ns for chamber sizes of 70, 76 and 89 mm, respectively (BASC, 2019).

Owners are advised if unsure whether ammunition is Standard Steel or High Performance Steel to consult the manufacturer. If unsure whether a shotgun is suitable for use with Standard Steel or High Performance Steel ammunition owners should contact a competent gun dealer, gunsmith or the British Proof Authority for advice, which may involve the submission of the shotgun for inspection (GWCT, 2022); [Birmingham Proof House; Personal Communication, May 2023]).

ECHA (ECHA, 2022b) considers that any modern shotgun (i.e., most guns built after 1961) on the GB/EU market is compatible with Standard Steel gunshot. Guns manufactured before this date would need to be reproofed and may require modification for a new choke. For older, non-proof marked weapons, it does not necessarily follow that use of steel loads is inherently unsafe on the condition that the right cartridges are used (Putz, 2012).

BASC has recommended that when switching from lead to steel shot, a change of shot size (up two increments in size, i.e., No.5 to No.3 shot) is made (BASC, 2019).

According to the William Powell (2021) briefing note, up until 2020 the BPA did not give guidance on pre-1954 proof marks with regard to steel shot use and recommended re-proof of such firearms. In 2021, the Birmingham Proof House recommended that all such 65 mm (2.5 inch) chambered guns should have their chambers extended to 70 mm (2.75 inch) with a long forcing cone, reduce the choke cone angle and ease the chokes to less than half and then rejoint and reproof for Standard Steel shot. William Powell (2021) emphasise that this is specific and in contrast to *“what many people, including Cartridge Manufacturers and Gunsmiths have all been saying.”* However, the Birmingham Proof House subsequently confirmed that the British Proof Authority will not give guidance on pre-1954 marks and recommends re-proof of such arms [Personal Communication, Birmingham Proof House; May 2023].

Many older shotguns were built with ‘Damascus’ barrels, which were manufactured by forge-welding soft iron around a mandrel into a tube. Damascus barrels are softer than modern barrels and are irreplaceable, and therefore not suited to steel shot, which may cause damage to the barrel (Historical Breechloading Small Arms

Association (HBSA), Organisation #94; BSSC, Organisation, #100). Similarly, the proof houses in Italy and Hungary, both CIP accredited, have reported that there are no safe alternatives to lead projectiles for muzzle loading arms. The higher hardness of non-lead projectiles could result in increased and potentially unsafe pressures being generated compared with traditional lead projectiles (Anglian Muzzle Loaders, Organisation #63; BSSC, Organisation #100; Muzzle Loaders' Association of Great Britain (MLAGB), Organisation #121).

The William Powell (2021) briefing note states *“NO steel shot cartridges should be used through any gun with twist Damascus barrels and under no circumstances, should ANY gun be shot which is out of proof or with thin barrel wall thickness.”* There is caution that some vintage guns, whilst still bearing marks for previous successful nitro-proofing, may not have either strong enough actions or barrels for even Standard Steel shot cartridge use. The briefing note asserts that many old side-by-side shotguns will fail reproofing for even Standard Steel but could be safely used with bismuth cartridges. It considers that not only minimum barrel wall thickness is relevant, but the strength/condition of the action which will determine whether the gun will stand reproofing. Furthermore, it is doubtful that many old lightweight guns (which most English side-by-sides were built as) will stand reproofing for High Performance Steel shot (William Powell, 2021).

As part of the call for evidence BSSC (Organisation #100) and the Gun Trade Association (Organisation #132) state that within the UK there are approximately 324,000 older shotguns (out of a total estimated 1.5 million licensed shotguns held in the UK, equivalent to about 21 %) which are not suited to steel shot cartridges, for example because they are thinner walled or made of Damascus steel or are smaller calibre (i.e., 28 bore and .410), or have 2.5 inch (65 mm) chambers which are not suited to most currently produced steel shot cartridges. For GB, the Agency assumes that steel shot cartridges are unsuitable in 22% of shotguns, with the explanation behind this assumption outlined in section 2.6.1.1.1. Additionally, heavily choked shotgun barrels may not be suitable for use with steel shot. Nevertheless, some 2.5 inch steel cartridges are available (The Agency Lead in Ammunition case team meeting with Gun Trade Association (GTA), January 2023), and the William Powell (2021) briefing note states “soft iron” shot cartridges are currently available in the UK which are 2.5 inch/65 mm long in 12-bore.

The BSSC (Organisation #100) state that 13.6 % of the shotguns used in the UK are in calibres 28 and .410 (15,092 shotguns in calibre 28 and 171,288 shotguns in calibre .410). In the opinion of BSSC, there are substantial technical difficulties in developing non-lead (i.e., steel shot) loads for these smaller calibre shotguns which are safe, effective and economic.

In response to the GB Public Consultation, several respondents (individuals: #002, #1403, #1528, #2412) highlighted that .410 shotguns were used for pest control, particularly around farm outbuildings and barns, where larger bore shotguns would be unsuitable. Respondents including Dover Clay Pigeon Club (Organisation #001) and the West London Shooting Grounds (Organisation #137) highlight that the smaller calibres (e.g., 16 bore, 28 bore and .410) are often used at junior level and are "*vital in early teaching those of smaller stature or with certain disabilities."* A representative of the GTA confirmed to the Agency that steel shot alternatives were not possible for the smaller bores (i.e., for 28 bore and .410). Due to the constraints of pressure, momentum and velocity associated with steel shot as opposed to lead, it is not possible to modify the ammunition to be able to deliver sufficient energy at the target with the smaller load required when incorporated with the requisite protective wad (The Agency/GTA Stakeholder Meeting September 2022). Non-lead alternatives such as tungsten and bismuth are effective and available for .410 calibre (Shooting UK, (2021). BSSC (Organisation #100) acknowledged that bismuth loads represent an alternative which is effective in terms of downrange lethality, but the stated cost implications rule bismuth out as anything more than a niche product.

APPG (2022) highlights progress in the availability of steel ammunition over recent years, including options suitable for older guns. It gives the example of an Eley product 'Grand Prix Traditional Steel'. This product is described by the manufacturer as designed to ''*open up shooting a Standard Steel load in traditional, nitro-proofed guns, meaning that a future remains for old English shotguns".* The APPG report acknowledges *"a small number of very old guns, made before 1954, may still not be able to use (or be adopted to use) these new steel products, principally Damascus barrelled guns manufactured before the 1880s,"* and asserts that for these guns, softer non-toxic ammunitions are available, albeit at a higher cost.

For antique / historic / heritage shotguns, HBSA (Organisation #94) argue bismuth shot is harder than lead and may cause damage over time, especially for Damascus barrels which are irreplaceable. Once any damage is caused, the firearm is irrevocably degraded as a working historic item. Even if repair is possible, it will not be in its original state and therefore its value as a heritage item is lost. Additionally, use of non-lead ammunition does not allow proper research and study which requires original ammunition to replicate original performance. The preservation and maintenance of heritage of these firearms requires that they should continue to be used with the lead ammunition for which they were designed and built (HBSA, Organisation #94; BSSC, Organisation, #100).

The Wildfowl & Wetlands Trust (WWT; Organisation #134) listed numerous grey literature articles from BASC's Sustainable Ammunition Articles supporting non-lead/steel shot alternatives (BASC, 2023a). These include articles covering the impact of shooting multiple steel cartridges through shotguns, essentially resulting in no damage to the firearm; whether it is safe to use steel shot in shotguns; performance and behaviour of steel shot; advice from GTA and the Birmingham proof house on using steel shot in old shotguns; and how European countries have coped with a lead shot ban. The Agency has reviewed these and included articles of note in the relevant sections.

2.2.3.2 *Ricochet*

All types of shot can ricochet from a hard surface such as rocks, the surface of tree trunks, or even water if they hit the surface at an acute angle. Shot made from soft lead and bismuth-tin may flatten or fragment, whereas some types of lead-free shot have greater ricochet energy due to mass stability. Steel and other hard shot (e.g., tungsten-based shot) have a higher tendency to directly rebound towards the shooter from hard surfaces (ECHA, 2022b).

Many respondents to the GB Public Consultation claimed there is an increased risk of ricochet from steel shot and its unsuitability for use at clay shooting grounds, practical shotgun disciplines and for live quarry/pest control (for example vermin control over stony ground or near buildings), whereas softer lead shot will deform on impact and be less prone to ricochet. Information provided by the Birmingham Proof House – CIP Decision XXXII-45 - Base document for ammunition specifications for lead-free shot (CIP, 2023) require boxes and cartridges of lead-free to bear the inscription: "*Beware of ricochets, never fire at rigid or hard surfaces*" [Birmingham Proof House; Personal Communication, May 2023].

(DEVA, 2011) demonstrated that ricochet occurs both in steel and in lead shot, a conclusion supported by the (GWCT, 2022). Fédération Internationale de Tir aux Armes Sportives de Chasse (FITASC; Organisation #036) provided evidence from research undertaken by the Russian Shooting Union Executive Committee that concluded that the quantity of the ricochet of steel pellets was 2 to 3 times higher than lead pellets for the equivalent 24 g load; ricochet is nearly equivalent for steel and lead up to 4 m from the reflecting surface, but at >5 m, the quantity of ricochet is 2 to 5 times greater for steel cartridges than for equivalent lead cartridges (FITASC and ISSF/ESC, 2021a).

In contrast, Danish experiences from hunting and clay pigeon shooting do not indicate an increased risk of ricochet caused by non-lead shot, including steel shot (ECHA, 2022b). The Dutch shooting federation highlighted that they had not encountered any accidents related to ricochet of steel shot since the introduction of the general ban on the use of lead at shooting ranges; objects on which steel shot could ricochet have been covered with wood (ECHA, 2022b). Such risk mitigation measures may need to be implemented for existing clay pigeon sites in event of transition to non-lead shot. Similarly, LAG (2015a) stated that precautions need to be taken when firing steel shot at a resilient pattern plate (usually a steel targeting plate to assess the shot pattern alignment) as steel shot will rebound to a greater extent than lead. This needs to be factored into clay shooting health and safety risk assessments. In general, there is no evidence of increased ricochet risk from shooting in countries where steel shot has been used for many years of an increase in reported accidents or insurance claims. Generally, "*an unsafe shot with steel is an* *unsafe shot with lead"* (ECHA, 2022b; GWCT, 2022; 2015a).

2.2.3.3 *Impact on forestry*

A concern regarding substitution of lead shot with steel shot is the potential damage steel shot may have on timber and sawmills. Concern that steel shot might damage standing timber was raised when lead was to be prohibited in the 1990s in Denmark, and the forestry authorities had recommended against the use of steel. There is still concern among some woodland owners. However, experience from Scandinavian countries suggests that it has not been a significant problem. The Danish Institute of Forest Technology undertook a series of shooting tests to establish the penetration capacity of steel shot and found no significant difference in depth of penetration for lead shot and steel shot and that at normal shooting distances the shot would remain in the bark of the trees (LAG, (2015a); ECHA, (2022b)). Any shot retained in the bark is usually removed during processing. For shot that penetrates the xylem, negative impacts in terms of loss of quality from discolouration will be similar for lead and steel. The concern that harder steel shot may damage sawblades has not been realised and sawmills and the timber industry utilise metal detectors ranging from handheld devices to fully automatic sorting systems that disregard impacted timber (Association of Finnish Sawmillmen, 2022; König, 2012).

In Denmark, the regulation of gunshot for forest hunting has changed so that the risk to timber production is mitigated against through targeted district-based requirements in areas with particularly valuable timber production (effectively only beech and oak grown for veneer production). Effective organization of hunting can ensure that reforesting and single high-value trees are not affected by hunting ammunition (ECHA, 2022b; Kanstrup, 2018, 2018).

Forestry England, which since 2014 has transitioned to non-lead ammunition for the majority of live quarry applications, confirmed that feedback received from sawmillers is that they consider it no more of a risk than lead shot, nor is the organisation aware of any claims against it relating specifically to steel shot [Forestry England; Private Communication, May 2023].

National Resources Wales (NRW) confirmed in the GB call for evidence that as of February 2022, it was still using lead shot for Grey Squirrel control primarily because of concerns that unlike softer lead if steel shot is embedded in trees it can impact on processing at sawmills and damage blades [NRW; Pers. Comms; February 2022].

2.2.3.4 *Potential effect of steel shot on mobility of lead*

Steel shot is a potential alternative to the use of lead shot. Concerns were raised during the ECHA restriction proposal that the use of steel shot at sites contaminated with lead shot could influence the mobility of the lead already present in the soil. FITASC (Organisation #036) maintain in their submissions to the UK REACH public consultation that mixing lead and steel shot on the same ground may result in decreasing pH and increased migration of lead (FITASC, 2020; and, FITASC and ISSF/ESC, 2021a; The Agency / Shooting Organisations Stakeholder Meeting September 2022).

ECHA (2021c) modelled how this may affect lead mobility in two soil types. Overall, ECHA (2021c) found that the metals which may dissolve from steel shot are unlikely to enhance the mobility of lead:

- Released iron may reduce the mobility of lead through the formation of iron (hydr)oxide precipitates, which have a high affinity for lead sorption.
- In theory, dissolved manganese or nickel ions from steel could increase the conductivity of soil porewaters and enhance the corrosion of lead shot, although there was no evidence from the literature that this occurs or that the amount potentially released from steel shot would have a significant effect.

ECHA (2021c) also considered in detail how steel shot could promote soil acidification via the corrosion of iron and in turn potentially enhance the mobility of lead. They concluded that, assuming both oxidation and hydrolysis reactions of the different iron species occur, the corrosion of iron would not have acidifying effects and therefore enhanced mobility of lead is unlikely. In the unlikely event that the iron in the steel shot is oxidised before being fired (i.e. the shot is rusty), there may be some acid formation, but the buffering capacity of soils means that this is not expected to significantly affect soil pH (and therefore changes in lead mobility are unlikely) (ECHA, 2021c).

This same concern was raised during ECHA's public consultation with a recent study by Lisin et al. (2022) cited to support the potential for lead and other metals to be mobilised in soil after the addition of steel shot. However, a review of the available evidence, together with novel chemical speciation modelling (wca, 2021b) concludes that the binding of lead to iron hydroxide precipitates from steel shot may reduce the potential for lead to be mobilised in soil. ECHA (2022b) also states that 2020 correspondence with the REACH Competent Authorities from Norway, Denmark, The Netherlands and Sweden (i.e., countries where the use of steel shot in sport shooting has already been in place for several years) indicated that no evidence was available at that time about a possible increase of lead migration in the soil as a consequence of the use of steel shot.

The Agency agrees with these conclusions.

2.2.3.5 *Availability of lead-free shot*

The availability of non-lead ammunition is limited by the demand and driven by regulations (Thomas, 2013; Thomas et al., 2014). Kanstrup and Thomas (2019) identified 18 continental European, six North American and four UK manufacturers of non-lead shot cartridges. Most had suppliers in most European countries; the report claimed that non-lead shot alternatives are available or could easily become available in any region or country, subject to demand. According to ECHA (2022b), an online search of the product catalogues of ammunition manufacturers including those that are members of the Association of European Manufacturers of Sporting Ammunition (AFEMS; http://www.afems.org) identified ten manufacturers – including two from the UK – that produce non-lead shot hunting cartridges for a selection of calibres and loads. Additionally, several North American manufacturers produce and export non-lead shot to Europe. One (Kent) is directly affiliated with a British company (Gamebore), which currently has a significant share of the Danish market (ECHA, 2022b).

According to the GTA (Organisation #132), British cartridge manufacturers have been *"leading the international development of lead-free shotgun ammunition for decades"*. As well as market leading non-toxic shot products for the most popular calibres, the industry is at the forefront of bio-degradable wad design and manufacture, removing plastic emissions into the environment. However, whilst current production capacity is at about 10% of total cartridge consumption, the supply chains for lead-free products are immature and the stock available has been loaded at slow rates on non-optimised production lines. Moving from the current 10 % to 100 % of production is a major challenge and cannot be achieved quickly.

Cranfield University Business School (Abushaikha et al. 2022) undertook a supply chain study of the transition to lead-free shotgun cartridge production for the GTA (Organisation #132). The authors employed the Critical Path (CP) method to develop a model for transition to lead-free production, with an indicative timeline for the whole process. Results suggest that an 18-month transition period is not achievable; the best-case scenario for a successful transition is in the region of 4.5 years, and the worst-case scenario is in the region of 6 years. It is not only a question of when the manufacturers can produce substitute products for lead cartridges because they already have the know-how of making steel and bismuth shots, but when they are capable of manufacturing to the current level of lead products. The report argues that consideration of the availability of products at the closest-to-the-end-consumers node of the supply chain (the retailers in this case) does not fully capture the readiness of the whole supply chain.

In addition to using alternative materials for the shot pellets, the transition will require development of components such as propellant and non-plastic 'eco-friendly' wads (as harder non-lead alternatives will require wads to ensure protection of the barrel, whereas lead shot does not) and will need procurement of machinery for production lines. UK manufacturers will be highly dependent on the stability and capability of their component supply chains for a successful transition. For example, supply of steel shot is primarily from China, and this has been negatively impacted by Covid. As China switches to a new green policy, numerous steel manufacturing factories are being closed down, thus making sourcing steel shot even more difficult. The war in Ukraine has demanded propellant suppliers to prioritize their production for military uses and also blocked a critical transportation route for steel shots from China leaving limited options for shipping – cargo on sea freight – which is currently slow and subject to great price volatility (Abushaikha et al. 2022).

Similarly, a report by Blake International Ltd entitled 'Shotgun Cartridge Manufacturing – Transition to Lead Free Production' (Hurley, 2022) for the GTA (Organisation #132) concludes that at its most optimistic a minimum 6-year transition period will be needed to undertake an operational transition from lead to non-lead shot. The report highlights supply chain issues meaning that whilst demand is growing it cannot meet its existing customer demand. Steel shot's physical and handling properties mean that current filling machine filling ports must be sleeved and run at a slower rate, significantly impeding production efficiency, and adversely affecting capacity. Steel shot cartridges necessitate the use of slower combusting binary or slow burn coated powders sourced from France, Italy, or the US. Availability is problematic as slow burn propellants have dual civil and military use. The Ukraine conflict has meant these propellants have been in short supply, severely constraining steel loaded shot cartridge output. At present the industry has only sufficient production or supply chain capacity to meet existing sales for biodegradable wad material. Interruptions in the supply of Russian gas has caused increased pricing and reduced availability of all nitrogen-based chemicals, from fertilizers to explosives and propellants. The UK is not self-sufficient in primary nitrogen-based chemicals having capacity to meet only 40% of its domestic needs.

In contrast, APPG (2022) has claimed that a full phase-out of lead shot for hunting could be achieved by 2024, asserting that alternatives to lead shot will be available in sufficient quantity to meet demand and citing the rapid growth of alternatives to lead shot in GB in just two years (from 2020 to 2022); and evidence of the effect of regulation in countries that have implemented bans and the comparative effectiveness of non-toxic shot for hunting. APPG (2022) additionally claims that there is no evidence that the war in Ukraine or fluctuations in international steel prices are inhibiting the upward trajectory of supply for lead-free cartridges in GB; and, post-Covid, steel production in China is rapidly increasing to meet demand. The report claims that GB manufacturers principally produce ammunition for hunting and sporting purposes, with no military ammunition lines; the production of military ammunition requires different factory processes, different propellants and different projectiles.

The British Veterinary Zoological Society (BVZS; Organisation #90) states that transition times to non-lead shot should be as short as possible, commenting "*even a simple internet search (available to all hunters) finds multiple products on the market for both non-lead gunshot and bullets.*" Similarly, the Wildlife and Countryside Link, (Organisation #117) observe that 2022 retail figures suggest that over 20 % of shot cartridge products on sale online from leading GB manufacturers at the start of the 2022 shooting season were lead-free and is therefore opposed to extending the transition period from 18 months to 5 years. It should be noted that whilst such internet searches indicate the availability of a product range, the Agency do not consider that they indicate the scalable availability of these products.

BASC (Organisation #83) reported the result of a study by Ellis (2019) which found that there is a general trend for a greater variety of non-lead products available for the popular shotgun bores and chambers, i.e., 12, 16 and 20 bore. It also points out that no CIP approval currently exists for ‘standard’ steel shot cartridges in 28 bore and .410 (36 bore), and there are currently no providers in the UK market of steel .410 or 28 bore cartridges. BASC is aware of only one provider globally (Federal Ammunition) that offers a steel load .410 and/or 28 bore cartridge. The options are not available in GB, are more expensive than lead equivalents and it is unknown whether these options would fall within CIP proof requirements. Significant development is required for the GB market for comparable cost .410 and 28 bore steel shot loads to become available.

ECHA (2022b) lists an example of an American .410 non-lead cartridge (Tungsten-alloy Super Shot (TSS)) and states *“it can be anticipated that with regulation in place, demand would increase and consequently availability would increase.”* The four major UK manufacturers now supply bismuth in both 12 and 20 bore with only Eley currently supplying a 16 bore load and Eley and Lyalvale Express making a 28 bore (Bull, 2022).

LAG (2015a) concluded that “*the available variety of non-lead shotgun and rifle ammunition is more restricted than currently available for lead, so optimum loads may not yet exist for all circumstances”*. Furthermore, based on the development of non–lead markets in Denmark, the Netherlands and in North America *“the variety and performance of non-lead ammunition will, if demand exists, improve to meet demand”.*

2.2.3.6 *Alternatives to lead shot in live quarry shooting*

Since September 1999, the Environmental Protection (Restriction on Use of Lead Shot) (England) Regulations 1999 made it illegal to shoot waterfowl species (Coot, ducks, geese and swans (all species of each), Moorhen, Golden Plover, and Common Snipe) in England with lead shotgun ammunition and/or to use it in certain wetland habitats. Similar legislation came into effect in Wales (2001) and Scotland (2004).

By law the use of lead shot for live quarry shooting has been phased out in Denmark since 1996, and its use for hunting migratory waterfowl or use in wetlands is also banned in the USA, Canada and several EU countries (including France). Therefore, non-lead shot (e.g., steel, tungsten or bismuth) is already widely available and should already be commonly used for live quarry shooting over wetlands. The Danish experience has been that the potential drawbacks (e.g., lack of suitable alternative shot types, shot sizes, increased ammunition cost) from the shift to non-lead shot has not changed the overall cost of hunting, the number of hunters, or their harvest (Kanstrup, 2015).

According to the GB Public Consultation response by BASC (Organisation #83), lead gunshot used for 'hunting' cartridges are typically 30 g to 32 g load of #6 shot (2.6 mm diameter pellets) and #5 (2.8 mm) shot and so have *"minimal cross over with lead clay pigeon / sports shooting cartridges,"* which tend to be 28 g loads or less. There is a potential cross over in #6.5 (2.5 mm), #7 (2.4 mm) and #7.5 (2.3 mm) shot size, although BASC states use of these shot sizes for live quarry shooting is highly limited. FITASC (Organisation #036) and CPSA (Organisation #101) rules stipulate that the maximum load for clay pigeon competitions is 28 g. It is worth noting that BASC's own handbook of shooting shot sizes indicate that traditionally different pellet sizes in lead shot have been favoured for different types of shooting, such as: Geese #BB (4.01 mm) / #1 (3.8 mm) / #3 (3.3 mm), Pheasant #5 / #6 / #7; Grouse, Partridge, Teal, Pigeon #6/#7; Grey Squirrel, Woodcock #7; and Snipe #8 (2.2 mm) (BASC, 2023b). BASC suggests it may be beneficial to prohibit the use of lead shot for live quarry shooting and the sale of lead shot of 2.6 mm (#6 lead shot) or larger; and restrict cartridge shot weights to a maximum of 24 grams for lead loads. This would allow sporting use to continue (if so derogated), but prevent shooters from using legally held ammunition for shooting of live quarry (BASC, Organisation #83).

Advice from the shooting community is that when moving to steel shot it is recommended to use a shot size two sizes bigger than the lead equivalent as this delivers more energy from the steel when connecting with the target (BASC, 2019). Steel cartridges with the same weight and shot size contain more pellets, giving denser patterns (Bracci, 2020).

In response to the GB Public Consultation, BASC (Organisation #83) provided comments from a recently completed survey. No information regarding the scope of the survey was provided to the Agency, so there is uncertainty about its representativeness. The survey reportedly showed that 54 % of respondents were using lead-free shot cartridges for at least some of their hunting and 5 % of respondents were exclusively using lead-free shotgun cartridges for hunting. The survey also showed that 16 % of respondents were using lead-free shot for hunting with muzzle loading shotguns for at least some of their hunting and 11 % of respondents were exclusively using lead-free shot for hunting with their muzzle loading shotguns. However, the Agency is unaware of how representative the sampling used in this survey was of the general shooting community.

Studies comparing lead versus non-lead shot for live quarry shooting are abundant in the literature and indicate the performance of steel shot is generally similar to lead shot (Cochrane, 1976; Gundersen et al., 2008; Hartmann, 1982; Kanstrup, 1987; Mondains-Monval et al., 2015; Morehouse, 1992; Nicklaus, 1976; Pierce et al., 2015; Strandgaard, 1993). Pierce et al. (2015) conclude that *"[shot] pattern density becomes the primary factor influencing ammunition performance"*. Hunter behaviour / judgement and wind conditions are also significant factors in a successful shot (Mondains-Monval et al., 2015).

Correspondence with a Danish Environmental Protection Agency (EPA) expert confirmed that Denmark has no production of ammunition for shot guns and that Denmark is not CIP regulated. Danish hunters can buy any ammunition that fulfils the hunters' requirements (legislation as well as performance). No accidents have been recorded in Denmark over the last 25+ years where a shotgun barrel has been destroyed as a result of using steel shot. The Danish view is that there would be no difference between steel shot effectiveness/performance in GB compared to the Danish experience [Danish EPA; Private communication February 2023]. However, it is worth noting the previously mentioned differences in pressure regimes between CIP Standard/High Performance Steel loads and SAAMI shotgun ammunition (see Section 2.2.2.1). Much of the literature and experiences cited are based on American and Danish data. The GTA assert that CIP-regulated Standard Steel loads used in GB will have different ballistic performance characteristics compared with typical Danish or American ammunition loads. A straight comparison between Denmark and GB is therefore not necessarily accurate and may mean that performance for Standard Steel ammunition differs and any requirement to adjust shooter behaviour, shot selection, shot size, etc., may be more significant for GB shooters using Standard Steel (The Agency/GTA Stakeholder Meeting September 2022).

The potential for an increase in 'crippling loss' of birds using non-lead shot is a key concern. Crippling loss refers to birds that have been shot, but are un-retrieved, either because they have not been killed outright (wounded birds), or because they have been killed but the carcass cannot be found (ECHA, 2022b).

LAG (Organisation #125) highlighted that literature (Ellis and Miller, 2022; Noer et al., 2007)) and practical experience (i.e., Denmark) does not support the argument that increased crippling of quarry will be observed with steel shot. Denmark has had many campaigns on reducing crippling rate since 1996. Ellis and Miller (2022) refer to the national action plan introduced in 1997 in Denmark to reduce the crippling rates of wild game (Noer et al., 2007). This is reported to have reduced the crippling rate in Pink-footed Geese from approximately 30 % to 16 % (averaged over adult and juvenile birds), primarily due to reduced shooting distances. Subsequent Danish action plans emphasised reducing shooting ranges (distances), improving shooting skills and mandated the use of retrieving dogs, which again led to reductions in crippling rates. Ellis and Miller (2022) found that the crippling rate declined from 23

% with lead shot to an average of 13 % with steel (APPG, (2022)). Crippling rates are as much a function of the distance at which the quarry is targeted as it is to do with the types of weapons and shot used. Shooters should change their behaviour to stop shooting birds at distances where the risk of 'crippling' is high. Additionally, steel shot offers no lead exposure risk for predators and scavengers consuming prey with embedded shot pellets.

Data from the United States Fish and Wildlife Services Waterfowl Harvest Survey indicate crippling rates were higher in the phase-in period of five years (1987 – 1991) immediately after the ban on lead shot. However, after the phase-in period (1992 – 2001) crippling rates were much lower and declined during the period reported. The increase in crippling rates during the phase-in period probably occurred while hunters switching to steel got used to the differences in ballistics (ECHA, 2022b).

In the EU call for evidence, the Finnish Hunters' Association conducted a test to assess non-lead shotgun ammunition penetration in ballistic gelatine. It concluded that the most efficient High Performance Steel cartridges already outperform the average lead cartridges. However, Standard Steel cartridges for older shotguns were significantly weaker in penetration and therefore at higher risk of increasing the number of wounded animals if used in the same way as lead, highlighting the need to adapt hunting techniques to the shot material that is used (i.e., select targets within the range of the gun and ammunition) (ECHA, 2022b).

Research undertaken by Cranfield University on behalf of BASC comparing lead and steel shot performance against a ballistic gelatine model concluded *"When concerned with lethality to pheasants, at the maximum range tested (50 yards) the average penetration of both steel No.3 and lead No.5 was approximately 30 mm into the gelatine after penetrating the skin and feathers. Therefore, at least up to 50 yards, the lethality of the shot is more a matter of patterning rather than penetration capability"* (BASC, 2021).

Forestry England (Organisation #111) confirmed that internal trials have found that suitable alternatives are available for smaller sized shotgun pellet loads. However, currently no suitable non-lead alternatives for .203 (AAA), which is a *"significant operational challenge*." Forestry England confirmed that it uses AAA extensively under the S.7 exemption to the Deer Act for control within 'enclosed' i.e., fenced areas. This is particularly relevant to areas with high populations of muntjac which readily break into fenced areas, are difficult to locate within the thick vegetation and move very quickly from one fence line to another within the enclosure. Effective management in such areas is essential to limit crop damage. A safe shot 'on the move' is sometimes essential which rules out a rifle shot. The organisation supports rapid and complete transition to non-lead ammunition and would like to see ammunition manufacturers encouraged to develop non-toxic .203 (AAA) shot cartridges. It considers that lack of a suitable non-lead alternative is due to lack of market demand rather than technical infeasibility [Forestry England; Private Communication, May 2023].

LAG (2015a) concludes that alternatives to lead, including steel shot, perform at least as effectively as lead up to maximum recommended field shooting ranges. The variety of non-lead shotgun ammunition is more restricted than that currently available for lead, so optimum loads may not yet exist for all circumstances. The variety and performance of non-lead ammunition will, if demand exists, be expected to improve over time.

2.2.3.7 *Alternatives to lead shot in target shooting*

Clay target shooting

Clay target shooting (clay pigeon shooting) is undertaken with all popular shotgun calibres, though the great majority of shooters use 12 bore shotguns. In GB, uptake of non-lead alternative shotgun cartridges by sports shooters has been limited. Development of steel shot cartridges has been driven by demand from live quarry shooting (i.e., wetland ban), and there has therefore been comparatively less development of cartridges for sports shooting. This is in part because the various sports governing bodies require the use of lead shot in competitions, as described below. The CPSA (Organisation #101) stated of its 22,500 members it estimates less than 100 shooters have chosen to use lead alternatives such as steel shot

In response to the GB Public Consultation, BASC (Organisation #83) provided comments from a recently completed survey. No information regarding the scope of the survey was provided to the Agency, so there is uncertainty about its representativeness. The survey showed that 17 % of respondents were using lead-free shot cartridges for at least some of their clay pigeon / shotgun target shooting and 5 % of respondents were exclusively using lead-free shotgun cartridges for clay pigeon / shotgun target shooting. The same survey showed that 2 % of respondents were exclusively using lead-free shot for clay pigeon / shotgun target shooting with their muzzle loading shotguns.

In comparison to shotgun hunters, clay / target shooters use lighter loads of smaller pellets, typically 24 g of #7.5 shot (2.3 mm). This is because less downrange energy is required to break a clay target than to kill a bird, recoil affects shooter performance and the ranges are shorter. Smaller pellets do not travel so far as the larger ones used for hunting, ensuring better control of fallout areas. The CPSA has proposed to reduce the maximum load for use at clay grounds and at its registered competitions from 28 g to 24 g, and the maximum shot size to #7.5 shot (2.3 mm). It is considered by the CPSA that this change would mitigate the risk of migration/misuse (i.e., cross over) to live quarry/hunting use, as 24 g #7.5 shot is not a viable game load, whilst also bringing its policy in alignment with that of the ISSF Olympic standard cartridge load (BSSC, Organisation #100; CPSA, Organisation #101; BASC, Organisation #83). This proposal would reduce but not remove all risks. It would still entail a significant quantity of lead being emitted into the environment annually and effective lead recovery would not be practical on most sites. Therefore, the Agency does not consider this proposal to be practical.

International clay target shooting includes ten official disciplines under officiating bodies:

- International Sports Shooting Federation (ISSF) / European Shooting Confederation (ESC): two Olympic disciplines (Olympic Skeet and Olympic Trench) and one non-Olympic discipline (Double-trap)
- FITASC (Organisation #036): seven non-Olympic disciplines: Sporting, Compak Sporting, Universal Trench, Helices, Trap1, Universal Skeet, Combined Game shooting

(FITASC, 2023; ISSF, 2023) rules require the use of smooth bored shotguns not greater than 12 bore. Cartridges must be loaded with *“lead pellets, lead alloy or of any other ISSF approved material”*; however, FITASC stipulate the use of lead exclusively. In effect, this means only lead or coated lead materials (e.g., copper coated lead shot). ISSF rules stipulate the weight of the pellet load must not exceed 24.5 g per cartridge (for FITASC the maximum is 28 g of lead); the diameter of each pellet must not exceed 2.6 mm. Guns and cartridges are subject to official checks during the shooting program.

Most respondents to the EU call for evidence indicated that in practice lead is most frequently used. Based on the demand from hunters and sports shooters, soft iron shots have also been developed for competition purposes, e.g., Rottweil Competition Line Steel Trap (ECHA, (2022b)).

The suitability of alternatives has been discussed by Thomas and Guitart (2013) who highlight that shot made from steel is not approved by the ISSF. In reaction to this Thomas and Guitart (2013) argue that steel would be a suitable alternative because of:

1. the volume of cartridges fired by competitors,
2. the parity with prices for lead cartridges,
3. the suitability of steel shot to be used in trap and skeet events,
4. and the ease of substitution for lead shot in conventional 12 and 20 gauge shotgun cartridges

According to Thomas (2015), there would be no impact on the guns from the use of steel shot cartridges for sports shooting. Both the shot loads and the shot size of cartridges suited for Olympic shooting would allow steel shot through any choke constriction. Skeet shooting uses the smallest barrel choke constriction of any event, so the concern regarding damage to the choke of barrels does not exist. Trap shooting requires choke constrictions, and small steel shot of diameter 2.5–2.6 mm can be used in existing guns. Modern competitive trap shotguns are designed with removable choke tubes of different choke constrictions, allowing competitors to select the choke constriction that gives them the optimal shot pattern at the requisite distance. Coated steel shot can also be retrieved easily from the fallout zones of shooting ranges using portable magnetic machinery (ECHA, (2022b)).

ECHA (2022b) states that the possibilities to substitute lead exist but would require approval of the ISSF and other federations to allow the use of non-lead shot for competition. According to Thomas (2015) the lower density of steel shot compared with lead shot necessitates the use of larger diameter shot and an increase in shot velocity, to achieve the same ballistic efficiency and effective range. Thus a shot diameter of 2.6 mm might be advisable for Olympic trap shooting, in which targets may be broken at a longer distance than in skeet shooting. The ISSF regulations would, already, allow pellets of this diameter to be used.

FITASC (Organisation #036; FITASC, (2020); and, FITASC and ISSF/ESC, (2021a)) challenge these assertions, refuting the conclusion that *"the use of lead shot in sports shooting is not limited by technical barriers but rather by organisational barriers"*, suggesting the EU REACH restriction dossier submitter provided erroneous ballistic performance data. The organisations emphasise that ballistics are the priority for clay target shooting, and argue that no suitable replacement is currently available. FITASC, (2020) published a comparative analysis between lead and steel shot assessing ejection velocities, the ballistic trajectory characteristics of lead and steel pellets in lateral wind speeds of 0 km/h and 30 km/h, and pellet diameter. The analysis concludes that when shot under the same conditions, the reach of a steel pellet is significantly shorter, reaches a significantly lower maximum altitude and loses energy significantly faster than that of a lead pellet. Furthermore, the steel pellet was more significantly affected by wind than lead (Audibert, 2020; FITASC, 2020). The report also discussed the supply constraints for tungsten or bismuth alternatives in quantities required for sports shooting.

FITASC (Organisation #036; FITASC, (2020); and, FITASC, (2020); and, FITASC and ISSF/ESC, (2021a)) highlighted the potential for increased ricochet, increased noise, increased recoil associated with steel cartridge loads, formation of steel pellet agglomeration (caused by oxidation within the cartridge) and the negative impacts for shooters and shooting clubs/grounds, e.g., increased recoil and noise nuisance leading to potential closure.

According to ECHA (2022b), recoil is a function of powder type, load and velocity and is in principle, independent of shot material. However, as non-lead shot is normally accelerated to a higher velocity there is a general tendency that alternative gunshot may cause a more pronounced recoil, though lighter loads and improved powder composition can compensate for this. This is likely to be observed in lighter shotguns not constructed to deal with heavy recoil, but would equally apply to heavy load lead shot cartridges. In contrast FITASC (Organisation #036; FITASC, (2020); and, FITASC and ISSF/ESC, (2021a)), contends that steel cartridges will result in significant recoil compared with lead loads and will be potentially harmful to shooters health, particularly in the competition setting, where thousands of cartridges may be fired annually by an individual.

FITASC (Organisation #036) provided a comparative study on the levels of noise generated by both lead and steel shot. It argued that steel shot cartridges generate higher pressure (approximately 11.5% increase) compared with lead cartridges. This would be associated with higher noise levels of such a degree that they would be no longer compliant with (French) regulatory limits, i.e., an increase of approximately + 6 to +9 db at 100 m distance using steel shot cartridges. This equates to an increase of 3.98 to 7.94 times the acoustic intensity (power level), equating to between one and a half (1.51x) to approaching twice (1.86x) the level of loudness (calculation undertaken by the Agency). The submission does not indicate to what extent this noise impact would occur at all shooting ranges, so its representativeness is not known.

ECHA (2022b) recognises that noise may be an issue with the use of steel shot, but also highlights that without contextual information (population living around shooting ranges) this point is difficult to assess further. Correspondence with a Danish EPA expert confirmed that Denmark has recently undertaken new tests concerning noise from steel shots in shooting ranges. The previous tests were undertaken in 1995 prior to the national ban of lead shot. The results are not uniform and indicate that some steel shots are quieter whereas others are louder than lead shot. There are ongoing discussions about the consequences for potential restrictions of the shooting ranges but as yet there are no clear conclusions on the topic [Danish EPA; Private communication February 2023].

FITASC and ISSF/ESC (2021a), discussed differences in ballistic performance between lead and steel shot. Calculations were provided for steel pellets with varying diameters (2.4 mm to 3.0 mm) and muzzle velocities (390 m/s to 600 m/s) intended as a replacement for trap shooting at ranges of 30 m, 40 m and 50 m. The addendum concluded that replacement of 2.4 mm lead pellets (muzzle velocity of 400 m/s) with 2.6 mm steel pellets (muzzle velocity of 390 m/s) would lead to a decrease in performance (energy) of 44 %, 50 % and 55 % at 30 m, 40 m and 50 m, respectively. Similarly, replacement of a regular lead-pellet cartridge by a high-performance steel-pellet cartridge would lead to a decrease in performance (energy) of 34 %, 41 % and 47 % at 30 m, 40 m and 50 m, respectively. There are two specific shooting conditions where the steel pellet performs approximately (within a +/- 5 % range) the same as the lead pellet, i.e., where the pellet diameter is 2.9 mm or 3.0 mm with a muzzle velocity of 425 m/s (FITASC and ISSF/ESC, (2021a)).

For skeet shooting, a similar set of calculations were produced for pellet diameters of 2.4 mm to 3.0 mm and muzzle velocities ranging from 390 m/s to 600 m/s at 30 m. The results showed that replacement of 2.4 mm lead pellets (muzzle velocity of 400 m/s) with 2.6 mm steel pellets (muzzle velocity of 390 m/s) alternatives would lead to a decrease in performance (energy) of 46% (or 36% with High Performance Steel). Additionally, the behaviour of four types of sport shotgun ammunition fired both horizontally and at a 40° angle were calculated in a simulation. This concluded that the reach of steel pellets is 17 % less and the energy is almost half than that of lead FITASC and ISSF/ESC, (2021a).

In response to a number of questions raised by FITASC, ECHA commissioned a review by an independent ballistic expert (Kneubuehl, 2022). The report concluded that if steel shot of same or very similar cross-sectional density (CSD) to 2.4 mm lead shot are selected, the ballistic trajectory characteristics remain practically the same; velocity, flight time and wind sensitivity are similar; and the energy at the target increases. In order to meet the equivalent CSD of 2.4 mm lead shot, steel shot of diameter ≥ 3 mm are required (ideally ≥ 3.25 mm); below 3 mm there is less energy and less precision with steel shot. In order to maintain shot pattern, the load (the number of pellets) can be increased, but the resulting recoil (increase) would need to be managed by reducing the muzzle velocity at the same time.

FITASC (Organisation #036) states that the use of steel shot for Olympic and non-Olympic shooting activities would require a complete redesign of trajectories and a complete reorganization of shooting ranges thus representing an unbearable cost for many shooting ranges. FITASC (Organisation #036) also emphasise that there would be inequality in sporting competitions between countries whose sporting shooters are required to use non-lead ammunition versus those that are allowed to, as they would be forced to train with ammunition with different ballistic qualities.

When asked about the effect of the national restriction, the Danish EPA confirmed that competition shooters require a permit to purchase lead shots for sports shooting. Currently some shooting ranges are approved for the use of lead shots. However, it stated that most training is done with steel shots, which work just as well [Danish EPA; Private communication February 2023].

The CPSA (Organisation #101) view is that an outright ban of lead shot would be the end of GB (Olympic) sporting medals as transitioning from shooting with steel for training to shooting with lead at competition would not be possible because of different ballistic characteristics and "*at Olympic standard so much of the sport is a mental game*" (EA/CPSA stakeholder meeting January 2023). CPSA (Organisation #101) has concerns regarding limitations to performance levels of alternatives such as steel shot and risks such as ricochet. It emphasises that GB international competitors, Commonwealth and Olympic athletes must not be disadvantaged when competing on a global stage. As with all other sports, success at elite level requires a very broad-based pyramid of competition and given that international competition requires use of lead shot, competitors at all levels need to compete with the same ammunition.

The governing body for competitive muzzle loading in GB is the Muzzle Loaders' Association of Great Britain ((MLAGB); Organisation #121). GB has an active and successful international muzzle loading team. The MLAGB is responsible for selecting team members and supports these team members during events. International muzzle loading events are run by the Muzzle Loaders Associations International Committee (MLAIC, the world governing body for muzzle loading shooting) and not by the ISSF. There are around 50 people in the current National squad. International rules for muzzle loading competitions stipulate the use of lead shot (BSSC, Organisation #100; Anglian Muzzle Loaders, Organisation #63). It is noteworthy that the MLAIC rules actually stipulate:

- *5.11 Loads: b.) Lead (or non-toxic lead substitutes of single metals only) shot size may have a maximum diameter of 2.6 mm. The use of cups to hold steel shot is not permitted.*

This suggests that non-toxic lead shot substitutes are potentially allowed (although steel shot is effectively excluded, because of the prohibition of cup use), (MLAIC, 2020).

In the 2021 GB Call for Evidence, the HBSA (Organisation, #094) provided a response which stated that whilst bismuth shot may be used in some shotguns it is expensive compared with lead shot and thus not practical for competition shooting (and training) where a large number of shots may be fired.

Practical or Dynamic shotgun shooting

Practical or Dynamic shooting is undertaken principally with Section 1 shotguns (i.e., semi-automatic shotguns capable of firing more than 3 shots) of 12 or 20 bore and takes place in shooting bays measuring from 10 m x 10 m to 30 m x 30 m. The bays are usually surrounded by earthen banks. Shooting at steel or paper targets is undertaken either with ‘bird shot’, i.e., 28 g loads of no. 7 (2.4 mm), ‘buckshot’, i.e., a 30 g load of SG (“Small Goose”, .332 inch / 8.4 mm) shot or with solid slugs at ranges from as little as 5 m at targets on the ground. Under International Practical Shooting Confederation (IPSC) rules, any shooting under 40 m at a steel target must be conducted with bird shot to avoid the risk of ricochet. All shooting is undertaken with lead ammunition in compliance with IPSC regulations. Lead ammunition will deform and fall safely to the ground after striking a steel target, whereas non-lead ammunition could pose a serious ricochet hazard (BSSC, Organisation #100).

Numerous respondents to the Public Consultation have highlighted the increased potential of harder non-lead alternative shot (particularly steel shot) to ricochet from steel target plates, effectively making it unsuitable for use in Practical Shotgun Shooting and threatening the continuance of the sport (including individuals #078, #147, #154, #162, #252, #397, #421, #424, #936, #1025, #1275, #1494, #1826, #2136,#2246, #2250, #2584).

2.2.3.8 *Summary of alternatives to lead shot*

It is apparent that development of non-lead shot for live quarry, primarily steel shot, has accelerated in recent years and demand from shooters has increased, with an increasing proportion of shooters using non-lead alternatives for at least some of their live quarry shooting in GB. Non-lead alternatives of comparable accuracy and lethality exist for the majority of situations. Based on experience in other countries, it is possible crippling rate could increase initially post-transition (as was observed in the USA) until shooters learn to adapt their behaviour (i.e., shoot within their capability and the range of their gun and ammunition), but this adaption could be encouraged with concerted educational campaigns by shooting organisations. The significant factors in a successful shot are shot pattern density, hunter behaviour, cartridge and shot size selection, judgement of shot selection, and wind conditions. Notwithstanding, there are certain calibres (e.g., .203 (AAA), .410 or 28 bore) or types of firearms (e.g., older Damascus barrelled or smaller chambered shotguns) where effective non-lead alternatives either do not exist yet, or are technically challenging to develop (see Section 2.2.3.1).

It is likely that there is an increased potential for ricochet with harder non-lead alternative shot and this should be factored into the shooter's behaviour (i.e., not selecting risky shots towards inappropriate backstops and wearing protective eyewear). There may be implications in terms of availability of non-lead alternatives and potential ricochet risk for effective pest control around farm buildings as some of the smaller calibres (e.g., 28 bore and .410) are also used for this purpose, larger calibres being unsuitable (see Sections 2.2.3.1 and 2.2.3.2). Similarly, Forestry England has confirmed that whilst it has successfully transitioned to non-lead shot for most live quarry applications it has not found a suitable alternative to the larger .203 (AAA) shot, although it considers this due to market demand rather than technical development issues.

The current options and availability of non-lead shot alternatives appear more limited for shotgun clay pigeon / target shooting sports. Development of alternatives for lead shot to date has primarily involved steel shot cartridges for live quarry shooting. The constraints specified by sports governing bodies has meant uptake by shooters in GB and therefore demand has been limited. Notwithstanding, it is apparent that effective non-lead shot alternatives for target sports do exist (as they are in use by at least some shooters in GB) and are being developed (e.g., Rottweil Competition Line Steel Trap). ECHA (2022b) argues that substitution of lead is possible but would require approval of the sports governing bodies. However, based on the comments received during the GB Public Consultation, it is unlikely that the sports governing bodies will change their opinion, in the short term, as they cite scientific evidence around lower performance levels, risks such as ricochet, recoil, noise nuisance and potential acidification of ground by deposition steel shot resulting in the mobilisation of lead. There may be potentially negative implications for GB athletes competing at international level for target shooting. Non-lead alternatives may not be practical in all circumstances either, for example because of unacceptable safety constraints (i.e., ricochet) in the case of Practical Shotgun shooting; or in certain antique / historic / heritage shotguns due to cost increases (i.e., significant cost implications for using large quantities of more expensive bismuth shot required for competition shooting) or the potential for barrel wear. Additionally, it has been argued that use of non-lead alternative ammunition does not allow for preservation of heritage, where in order to preserve original performance the original ammunition for which the firearm was designed should be used (see Section 2.2.3.1).

Consideration of producers' development and supply chain timescales necessary to affect sufficient capacity to meet demand will need to be factored into any required transition period.

2.2.4 Bullets

2.2.4.1 *Suitability of non-lead bullets*

Non-lead bullets are of a typically monolithic design, retain their weight upon impact with a target, fragment less and are less toxic than lead bullets. For larger calibres, non-lead bullets (typically 100 % copper, or gilding metal construction with around 90 % copper) have been demonstrated to exhibit high accuracy, penetration and consistent rapid expansion, comparing favourably with lead bullets (ECHA, 2022b; Knott et al., 2010; Spicher, 2008). Since initial development in the 1980s, factory assembled non-lead ammunition has been developed and made available by major manufacturers, and non-lead ammunition is also available for home reloaders.

In a rifle, the helical engraving on the inside of the barrel (the 'rifling') imparts spin to an elongated projectile generating the gyroscopic righting moments that stabilise the projectile in flight. The stability of a projectile in flight is determined by its spin rate. The required stabilising spin rate is dependent on the twist rate of the rifling in the barrel; mass, length and velocity of the bullet; and for any given calibre of rifle there will be rifling designs that match the normal range of bullet types for that calibre Barrel twist rates offered by different manufacturers may make specific bullet weight/length/calibre combinations inappropriate. To solve this issue may require an individual to re-barrel a firearm or buy an alternative (GTA, Organisation #132).

The shift from lead bullets to less dense non-lead materials results in a change to the projectile's weight/volume ratio. Within a given calibre, maintaining weight is achieved only by increasing the length of the projectile, by a factor corresponding to the ratio between the density of the lead-containing and lead-free projectile. Increasing bullet length affects its passage through the rifle barrel, increasing contact and generating greater friction, which can result in an increase in pressure (impacting safety and wear on the barrel and rifling). The contact surface between the bullet and the rifle barrel may be reduced with provision of radial cuttings (usually 1-3), which also counteract material deposits in the barrel, but this also results in weight loss requiring further redesign of bullet length and shape to offset. Increased bullet length can also result in loss of stabilization, affecting ballistics and accuracy, i.e., longer bullets may react differently, depending on the twist rate provided by the gun barrel. For some calibres the increased length may mean the bullet will not fit the rifle chamber without modification (ECHA, 2022b; Kanstrup and Haugaard, 2020a).

Zeroing is the process by which a firearm's sights are aligned such that at a given distance the point of aim and the point of the bullet's impact are the same. The process is important for both live quarry shooting and target shooting; however, if as previously described, the bullets are not consistent from shot to shot, no sight alignment will be possible. For live quarry shooting, zeroing is necessary to enable the shooter to deliver effective and humane dispatch of the target quarry without wounding (i.e., from a misplaced shot). Any change either to the rifle or to the ammunition used will change the impact point of the bullet and necessitate re-zeroing. Those managing wildlife must be allowed to zero their equipment (Home Office, 2022). Significant numbers of shooters hold firearms certificates that specify conditions by which they may zero their firearms to maintain competency on private land (often agricultural). Concern has been raised in the Public Consultation (individual #395), that many of such shooters may not have access to shooting ranges or may be forced to zero with different ammunition than that used to shoot the live quarry. It may not be possible to practice as freely or as safely due to the increased financial cost and increased ricochet hazard from non-lead bullets. The Agency would expect shooters to undertake sufficient zeroing to maintain competency regardless of increased cost and to do so in safe environments to prevent ricochet (i.e., appropriate backstops) if on private land. It is the Agency's intention that zeroing of a firearm to be used for live quarry shooting would fall within the definition of live quarry shooting use, rather than target shooting use in the event of any restrictions.

In comparison to lead, the lower density of non-lead bullets means that the smaller the diameter of the bullet, the more the bullet length must be increased to maintain mass (GTA, Organisation #132). The effect is relatively larger for small calibres than for large ones. Conversely, reduction in weight for smaller calibres requires increased velocity, which may mean that in some jurisdictions (for example Scotland) the requirements for bullet weight and/or energy cannot be complied with (ECHA, 2022b).

Ammunition must fall within the CIP-criteria set for the gun in the Tables of Dimensions of Cartridges and Chambers (TDCC). Reduced bullet weight equates to less energy at all shooting distances, which can be compensated for by increasing the velocity, which is achieved by adjusting the propellant. However, increased velocity has implications for stabilization of the bullet in the rifle barrel and thus accuracy, as well as safety (pressure) and wear (ECHA, 2022b).

The increased friction down the barrel resulting from firing a longer bullet using the same amount of power will mean the pressure will increase. The pressure will have to be adjusted to the bullet configuration to ensure it stays within the CIP pressure limit for that type of ammunition. However, pressure is only one of the considerations. If the alternative bullet is too ‘hard’, the wear on the barrel might be significant and might *“shoot out the barrel”*, which is a loss of the barrel rifling. This usually occurs at the commencement of rifling at the front of the breach where the bullet engages, and where it tends to wear first because that is the location of the hottest gases and the greatest inertia of the bullet. It could be possible to “shoot out the barrel” very quickly with a bullet that is safe but is hard to push up the barrel. So the fact that a copper (or alternative) bullet is harder and less ductile than lead will have an effect (The Agency / Lead in ammunition case team meeting with GTA, January 2023; (ECHA, 2020c)).

Copper fouling of the rifle barrel occurs via the deposition of copper with every copper/copper jacketed bullet that is fired. If not removed, it may interfere with bullet placement accuracy and pressure. It is reported by some shooters that copper fouling is more prevalent with non-lead bullets than with copper jacketed lead bullets. There is variation in the material used to make the non-lead bullets among ammunition producers, including pure copper, annealed copper, gilding metal (copper-zinc alloys), and brass. In theory, the copper surface of non-lead bullets and that of copper-jacketed lead-core bullets should leave the same amount of fouling in a given barrel. However, longer bullets and thus increased contact, softer material (e.g., annealed copper) and higher velocities may be potential contributing factors. The issue may be expected to be more significant for range practice/target shooting rather than hunting, given the greater number of bullets being fired in any given period (ECHA, 2022b; Gremse et al., 2014).

CIP have highlighted that transition to non-lead bullets, and in particular increasing length may mean that many bullets do not fit into magazines and/or chambers (TDCC) of many calibres, or have to be seated so deep in the cartridge case that there are pressure and safety implications. ECHA (2022b) considers that there is reportedly no viable alternative to lead or lead core bullets currently available which does not damage barrels of historic / heritage/ vintage firearms. Later vintage rifles have a rifling twist that is designed for lead-filled, jacketed bullets, of a certain density range. They will not be accurate when firing bullets under this density range and harder, more abrasive metals would cause excessive wear to the barrels. There are consequently no practical alternatives to pure lead, or jacketed lead, for use in these vintage firearms.

Harder, modern non-lead bullets may cause unsafe pressures, greater and quicker barrel wear, and in some examples have caused irreparable damage to the barrels of historic rifles. Once any damage is caused, the firearm is irrevocably degraded as a working historic item. Even if repair is possible, it will not be in its original state and therefore its value as a heritage item is lost. Additionally, use of non-lead ammunition does not allow proper research and study which requires original ammunition to replicate original performance. The preservation and maintenance of heritage of these firearms requires that they should continue to be used with the lead ammunition for which they were designed and built (HBSA, Organisation #94; BSSC, Organisation, #100; Trans Continental Rifle Association, Organisation #11).

2.2.4.2 *Ricochet*

In consideration of the allegedly unpredictable behaviour of ricocheting non-lead bullets for live quarry shooting, several studies have been undertaken (Kneubuehl, 2011; LAG, 2015c). The studies conclude that there are no significant differences evident in deflection characteristics between lead and non-lead ammunition. A 2010 report to the BASC (ECHA, 2022b; Harriman, 2010; LAG, 2015a) confirmed:

> - *Any bullet of any type or construction will ricochet if the circumstances are correct.*
> - *Ricochets from high velocity rifle bullets are rare.*
> - *Copper alloy rifle bullets do not appear to be any more likely to ricochet than conventional jacketed bullets.*
> - *Ricochets are only likely to be dangerous in the immediate vicinity of the impact i.e., in a situation that would be an inherently unsafe shot.*
> - *Ricochets are not an issue if a shot is taken with the target animal in front of a safe backstop.*

ECHA (2022b) reports that studies have been published in Germany by the Federal Ministry for Food and Agriculture in a project on "*Deflection of projectiles in hunting ammunition 2009–2011*". These concluded that there are no significant differences evident in ricochet characteristics between ammunition using lead and non-lead bullets.

Notwithstanding, several responses received during the Public Consultation (including #034, #078, #159, #206, #223, #327, #395, #405, #591, #741, #763, #1375, #1697, #2456, #2729) highlighted concerns that in live quarry situations harder non-lead alternative bullets had a greater potential for ricochet from hard surfaces or the ground, or to penetrate through the quarry target and continue.

In response to the 2022 HSE Lead Ammunition Public Consultation, stakeholders responsible for Red Squirrel conservation in the UK (individual #2372) stated that when using .22 Long Rifle (.22LR) rimfire rifles to shoot towards bait / feeder backstop locations, the non-lead alternatives endanger the shooter due to 'bounce back' and are not considered safe. They further state: "*where non-lead ammunition has been available in the USA for .22LR calibre, notably California, the same problems have been experienced by users regarding lack of accuracy, increased ricochets and bounce back, similar to our experience with regard to the use of non-lead ammunition in air rifles, but to a much greater extent in respect of safety due to the increased power and weight of the projectile with this calibre*."

The National Rifle Association (NRA; Organisation # 127) response states that lead-free bullets are not used in small or large calibre sports shooting and muzzle loading; their use is prohibited on civilian and (civilian use of) military ranges due to safety concerns associated with ricochet and penetration characteristics. Some 135 NRA affiliated civilian clubs shoot on military ranges, where they are prohibited from using lead-free projectiles. In their accredited stakeholder response to the March 2023 RISEP challenge meeting, NRA further clarified "*we have no evidence that non-lead bullets are unsafe; however we have been unable to find any research that confirms these bullets are safe to use on civilian ranges. The precautionary principle thus applies.*" However, the NRA is trialling lead-free expanding bullets for deer stalkers under controlled conditions at the National Shooting Centre ("NSC") at Bisley. The majority of private target shooting rifle ranges are affiliated with national governing bodies such as the NRA (Organisation #127) and the National Small-bore Rifle Association (NSRA; Organisation #123), and are designed to Defence Safety Authority (DSA) Ordnance, Munitions and Explosives (OME) Pt3 (previously Defence ranges safety (JSP 403)) specifications, which set out range design, operation and maintenance standards primarily for Ministry of Defence (MoD) ranges. The NRA provides guidance in their Range Design and Range Safety Handbook to assist civilian range operators in applying best practice to the operation of civilian rifle ranges. The handbook is based on the ballistic safety principles contained in DSA OME Pt3 where that is the best information available on ballistic properties of materials, ricochet, penetration and backsplash.

2.2.4.3 *Alternatives and wildfires*

In the US, outdoor target shooting has been suspected as the source of numerous wildfires, where the suspected process involves bullet fragmentation and transference of kinetic energy into thermal energy. Fragments can ignite organic matter in certain conditions i.e., very dry, fine particulate organic material, close to the impact site (Finney et al., 2013). In response to the Public Consultation, one individual (#310) did flag that non-lead alternatives "*have the potential to start wildfires, lead does not spark when it hits something like rock.*" However, Forestry England (Organisation #111) which has transitioned to non-lead ammunition for most wildlife management since 2014, did not flag this as an issue. Hard surfaces likely to cause ‘hot’ fragments are not suitable backstops, so the organisation would minimise those types of shots. The organisation was not aware of any wildfires associated with bullet fragments from our wildlife management activities [Personal Communication May 2023].

Finney et al. (2013) demonstrated that under test conditions ammunition containing steel components (core or jacket) and those made of solid copper *“could reliably cause ignitions”* after impacting a hard surface. Bullets were fired at a steel plate that deflected fragments downward into a collection box containing oven-dried peat moss. However, the report found that *“moisture content of the organic material will be an important factor in ignition. Peat moisture contents of 3-5 %, air temperatures of 34-49 °C (98 - 120 °F), and relative humidity of 7 -16 % were necessary to reliably observe ignitions in the experiments.”* Peat moisture contents above this did not produce ignitions. Conditions matching the experimental range imply summer-time temperatures, solar heating of the ground surface and organic matter to produce a drier and warmer microclimate where bullet fragments are deposited. On review of this report ECHA (2022b) concluded that it is *“highly unlikely that when the European hunting season opens these conditions will be met regularly.”* It would seem similarly unlikely that the required conditions would be met regularly in GB, both in terms of climatic conditions - although global warming has led to warmer conditions in general, but especially in summer; and also target shooting range design (i.e., most outdoor target shooting is towards appropriate bullet stop butts).

2.2.4.4 *Availability of non-lead rifle ammunition*

Alternatives for the most popular cartridges are available on both the EU and US market. The 37 leading ammunition manufacturers produce a wide range of 35 non-lead bullet calibres that cover a wide variety of hunting types (Thomas, (2013)). Thomas et al. (2016) concludes that major companies list calibres suitable for hunting every European game species and for every commonly used rifle and conclude from this that the product availability (i.e., that which is manufactured, as opposed to what is commonly available at the retail level) of non-lead rifle ammunition is not a limiting factor in Europe in the further growth in the use of non-lead bullets. ECHA carried out an independent investigation into the availability of non-lead alternatives for some of the common calibre types used in the EU, which are also relevant to GB. Of all the examined calibres only two, the .222 Remington (.222 REM) and .17 Hornady Magnum Rimfire (.17HMR), were found to have fewer than five non-lead alternative brands available, whereas the remaining calibres had in excess of five, or sometimes even ten, different brands available in a multitude of weights depending on specific hunting needs and preferences (ECHA, (2022b)).

However, others report that equally effective non-lead options do not yet exist for all types of firearms used in live quarry shooting, including one of the most common cartridges: the rimfire .22, used for small game hunting (ECHA, 2022b; EPPS, 2014).

Other firearms for which non-lead options are very limited or unavailable include some modern hunting rifles chambered for less common cartridges (ECHA, (2022b)). LAG (2015a) concluded that the available variety of non-lead rifle ammunition is more restricted than currently available for lead, so optimum loads may not yet exist for all circumstances.

In a study undertaken by BASC (Organisation #83), a search of non-lead rimfire loadings offered on manufacturer websites indicated the following options (available number of brands in parentheses): .22 Short (0), .22LR (5), .22 Winchester Magnum Rimfire (.22WMR) (1), .17 HMR (2), and .17 Winchester Super Magnum (.17WSM) (1). Of these only .22LR (3) and .17HMR(1) were held in stock by UK retailers. BASC further stated that there are currently no subsonic (i.e., having a velocity below the speed of sound, and avoiding the supersonic shockwave and associated loud ‘crack’ of a supersonic bullet) lead-free .22 rimfire alternatives on the market. As supersonic ammunition is significantly noisier, this will impact its usefulness for pest control where quarry will be scared away as well as potentially causing noise nuisance issues.

Similarly, stakeholders involved in Red Squirrel conservation (individual #2372) asserted that there are currently five types of non-lead .22 rimfire ammunition available in the UK: RWS HV Green, Norma Eco Speed, Norma Eco Power, CCI 21 g HP and Winchester Varmint. These comprise copper plated zinc core or compressed copper/polymer bullets. None of the available types are subsonic.

The GTA confirmed the larger calibres are effective for live quarry and most of the rifle-hunting community are willing to use non-lead, although there is currently a supply issue in the UK, exacerbated by world events such as Brexit and the ongoing war in Ukraine (The Agency / GTA Stakeholder Meeting September 2022).

Forestry England (Organisation #111) assert that UK manufacturers exist for larger rifle calibres that have the capability for full-scale production and are already producing lead-free ammunition at scale. However, for the smaller calibres the organisation asserts that the Ukraine war has slowed down much of the lead-free research and development. Components and raw materials have become harder to source and production is geared towards the war effort. The organisation is confident that small calibre lead-free bullets can be designed and manufactured to successfully replace lead projectiles. However, it is unaware of a single manufacturer of small calibre lead-free bullets in GB with the capability to complete the whole bullet manufacture / cartridge loading process currently, and suggests a collaborative approach (between different manufacturers) may be required.

Another concern raised during the EU Call for Evidence relates to the availability of ammunition for military and police uses in the event of a switch to non-lead, as they source from same market/production lines. As 70 - 90% of the market is civilian there may not be a business case to maintain lead bullet production lines, or it could result in lower production and higher cost (ECHA (2022b).

2.2.4.5 *Alternatives to lead bullets for live quarry shooting*

Live quarry shooting laws in GB define the minimum weight and momentum that bullets must have to achieve efficient and humane killing of game. In GB, legislation requires the use of soft nosed or expanding ammunition for shooting deer ((Home Office, 2022); see Section 1.3.5.3 Hunting Regulations)).

There is the concern that any restriction banning the use of lead rifle ammunition solely for live quarry shooting could result in lead ammunition otherwise legally held for target shooting, if so derogated, being used for hunting instead. This could potentially impact effective enforcement efforts. However, the "Guide on firearms licencing law" (Home Office, 2022) states in Paragraph 12.8 that ammunition should have sufficient muzzle energy to assure a *"clean humane dispatch of any quarry concerned"* and Paragraph 12.19 refers to the control of vermin with rimfire and small centrefire cartridges where "*Expanding ammunition may be granted for shooting vermin with a rifle."* Whilst the guidance is written as advice for Police FLDs and is not law, the expectation is that in areas where it makes recommendations a shooter is expected to follow them.

Among factors such as an uncomfortable firing position, hurried shot, distant target, concealed or moving target or an unfamiliar stalking area, Aebischer et al. (2014) identified that a bullet weight below 75 grains was associated with a higher rate of wounding of deer. Transition away from lead generally requires that lighter non-lead bullets are used. As in GB, hunting laws in several EU Member States define minimum weight and momentum bullets must have to achieve efficient and humane taking of game. Where such requirements might exclude use of lighter non-lead alternative bullets, ECHA (2022b) concludes that a change in legislation reflecting the state of knowledge in science that bases projectile and ammunition selection on measured terminal ballistic performance should generally be considered. This approach would aid decision-making processes in regard of reducing lead in game meat and is also likely to influence the transition period.

Recently the Finnish government hunting laws have been adapted to accommodate the use of non-lead ammunition and that *"similar processes either on-going or have been finalised in Norway, Denmark, Sweden and Finland*" (ECHA, 2022b; Kanstrup and Haugaard, 2020b); EA/GTA/BASC Stakeholder meetings September 2022). The requirement in Scotland for a bullet weight of not less than 100 grains for shooting deer other than Roe (see Section 1.3.5.3) has had implications for non-lead bullets and in particular .243 calibre (6.17 mm). Many of the existing non-lead options for .243 calibre rifles do not comply with minimum bullet weight requirements in Scottish legislation and some do not comply with legal minimum muzzle energy requirements in England, Wales and Scotland. A potential future solution might be for the Scottish

Government to change legislation to reduce the weight requirement and allow an 80 grain bullet. A well designed 80 grain non-lead alternative .243 bullet might be effective (EA/GTA Stakeholder meetings September 2022).

A review of the minimum bullet weight for the lawful culling of all deer species in Scotland by NatureScot (Lamont et al., 2022) concluded that consideration could be given to amending The Deer (Firearms etc.) (Scotland) Order 1985 with an addition of a minimum calibre stipulation of .240 along with a reduction in bullet weight from 100 gr to 80 gr for the culling of all species of deer. Alternately the bullet weight requirement could be removed and the legislation could require a minimum calibre of .240 and minimum muzzle energy of 1700 ft/lbs - as per legislation in England and Wales. Such stipulations would remove any opportunity for .22 centrefire calibres to be used to shoot larger deer species in Scotland.

Centrefire bullets

Numerous tests have been undertaken comparing the performance of lead and non-lead centrefire bullets of differing calibres (Gremse et al., 2014; M. Grund et al., 2010; Hackländer et al., 2015; Kanstrup et al., 2016; Martin et al., 2017; McCann et al., 2016; Spicher, 2008; Stokke et al., 2019; Trinogga et al., 2013). ECHA (2022b) provides an overview of the studies describing the main outcomes as well as the calibres used. ECHA (2022b) concluded that from the available studies it appears that the suitability of centrefire ammunition from 5.56 mm and up (smallest calibre tested: .222 and .223 which is equivalent to 5.56 mm) is well established and that this would imply that for hunting Roe Deer and heavier game species, suitable alternatives exist.

The British Deer Society (BDS; Organisation #95) expressed concern that some calibres currently permitted under existing legislation may not perform as efficiently with lighter non-lead projectiles. This presents potential welfare issues for the humane killing of deer. To ensure that a deer is killed humanely, any bullet used should not only be stable in flight to ensure accuracy but also expand predictably on impact and impart suitable levels of terminal energy. The ballistic properties of lead enable smaller bullets to be stabilised more efficiently in flight while ensuring desirable terminal ballistic properties. A greater volume of less dense material is required to construct a non-lead bullet with a similar weight to a lead-based one. In smaller calibres with bores of more restricted diameters, such a bullet might potentially be too long to be ballistically viable and/or physically fit into a rifle chamber or magazine. The BDS have highlighted the Police Firearms Licensing Departments' (FLD) tendency to restrict the selection of calibres allowed to the smallest appropriate calibres from the listed cartridges in the Guide on Firearms Licensing Law rather than allowing larger more effective (with non-lead) calibres. Many FLDs have traditionally encouraged .243 (6.17 mm) (or similar) as an appropriate 'entry level' calibre for deer managers for shooting all deer species.

While such small calibres may indeed be suitable with lead-cored bullets, the situation has changed with the move away from lead and the BDS suggests that allowing only smaller calibres to deer stalkers is no longer appropriate and firearm certificate applicants should be permitted greater freedom to select a calibre suitable to their circumstances from within the range recommended in the Home Office Guide on Firearms Licensing Law (Home Office, 2022).

In their response, Forestry England (Organisation #111), responsible for managing publicly owned forests in England, state that they "*are the largest single users of non-lead ammunition for deer and feral wild boar control England and have considerable experience of non-lead ammunition and its research and development*". The organisation has successfully migrated over to lead-free for all its deer management and is generally satisfied with the range of 'lead free' ammunition available in .308 calibre.

LAG (2015a) observed that anecdotal information indicates that copper bullets work very well for larger deer species, but that there was a lack of suitable non-lead ammunition for killing smaller game with rifle calibres less than .243. This was considered by LAG to be a problem for shooting foxes and rabbits (for example with .22 calibres, both centrefire and rimfire). In its more recent Public Consultation response, LAG (Organisation #125) asserts that lead-free small calibre .22 centrefire bullets for shooting e.g., small deer, foxes and rabbits are available but they are supersonic. Subsonic rounds for shooting have yet to be developed and are more ballistically challenging.

A recently conducted BASC (Organisation #83) survey shows that 27 % of respondents are using lead-free centrefire ammunition for at least some of their hunting; 8 % of respondents were exclusively using lead-free centrefire ammunition for hunting.

In the UK it is estimated that 15 % of full-bore rifles (i.e., 47,000) are chambered in calibres <6.5 mm (primarily .243 calibre) and are thus potentially unsuited to copper bullets. It is likely that many of these would have to be replaced or re-barreled (BSSC, Organisation #100). While it is clear that the transition to non-lead expanding ammunition is already successfully taking place in the larger rifle calibres used for the hunting of large game, technical difficulties remain in those centrefire calibres below 6.5 mm. The lower specific gravity of copper bullets (8.95 g/cm^3 as against 11.34 g/cm^3 for lead) means that in centrefire calibres below 6.5 mm it is difficult to achieve bullet weights of more than 90 grains which will conform with CIP design specifications, and which possess sufficient accuracy and lethality. Longer, lighter bullets are also more difficult to stabilise in flight and may thus require a higher barrel twist rate to achieve the necessary degree of accuracy over normal deer stalking ranges. This in turn means that rifles have either to be re-barrelled or replaced (BSSC, Organisation #100).

The GTA (Organisation #132) provided a technical overview of issues relating to small calibre non-lead ammunition use, recommending that the definition for small calibre is raised from 5.6 mm to 6.5 mm. There is a practical limit to what can be achieved by way of stabilising the bullet and providing it with sufficient energy to perform at target. Heavier bullets (which mean longer bullets in non-lead materials) will carry sufficient energy to target but not stabilise. Shorter stabilised bullets will be lighter but not have sufficient energy. The boundary for this challenge in standard twist rate barrels designed for lead ammunition types is at about 6.5 mm. For rifles over 6.5 mm (.255 in) the bore diameter is sufficiently large to accommodate longer bullets which can remain stabilised and continue to deliver the required energy at the target. For lead-free ammunition, depending on barrel twist rate, calibres below 6.5 mm could require re-barrelling to stabilise longer heavier bullets and maintain effective target effect. Re-barrelling is an expensive operation as it includes the new tighter twist barrel itself and careful re-fitting to maintain the safety critical headspace in the breech. Therefore, the GTA recommends the criteria used in regulatory definitions refers to 6.5 mm, rather than 5.6 mm.

A ballistics study undertaken by NatureScot (Lamont et al., 2022), comprising testing of seven types of commercial non-lead .243 (6.17 mm) bullets of 80, 85 and 90 grain in a rifle with a 1 in 10 barrel twist rate, at 100 m shooting into ballistic gelatine. The review demonstrated that with the exception of bullet weight, six of the seven tested non lead .243 bullets were sufficiently effective to deliver a humane kill in line with requirements of paragraph 3a of The Deer (firearms etc) (Scotland) Order 1985, i.e., *"with a muzzle velocity of not less than 2,450 feet per second (746.76 metres per second) and a muzzle energy of not less than 1,750 foot pounds (2,373 joules)."* The review also found that copper bullets are more likely to exit the carcass, but produce a cleaner carcass. Only seven factory types of non-lead .243 ammunition were able to be sourced, none of which were 100 gr, the minimum deer legal bullet weight for larger deer species in Scotland.

BASC (Organisation #83) undertook accuracy and penetration tests to review the suitability of a range of non-lead alternatives for .243 calibre (6.17 mm). In GB, the calibre is popular for being versatile for use on both deer and for vermin control (and therefore only having to own one gun) with an estimated 60,500 licensed rifles, which comprise some 14 to 21 % of the total number of centrefire rifles held on firearms licences in England and Wales. The results demonstrated that five of the six (at 100 m) and three of the five (at 200 m) non-lead brands/rifle combinations were sufficiently accurate to allow for the humane shooting of deer. BASC concluded that currently available expanding copper bullets do not universally stabilise in all rifles to achieve <100 mm groups. Tested lead-free alternatives produced smaller or marginally smaller permanent wound channels in ballistic soap when compared to the tested lead option at 100 m and 200 m. One of the six tested non-lead options would not comply with legal minimum muzzle energy requirements in England, Wales and Scotland and only one of the six tested non-lead options would be lawful for shooting of all deer species in Scotland. BASC (Organisation #83) consider that based on their findings, the large use of .243 calibre rifles means that the limitations of current non-lead ammunition options will be a significant problem for the sector if lead ammunition is restricted. Significant developments are required to bring a variety of suitable products to the market at a scale of supply that will meet market demand. BASC recommends raising the boundary for defining large calibre ammunition to calibres of 6.5 mm or larger. This would ensure that smaller calibre centrefires, including .243 calibre, benefit from a longer transition period (currently proposed as five years), to allow for development and scaling of supply of suitable non-lead alternatives.

In contrast, WWT (Organisation #134) does not support redefinition of large calibre from 5.6 mm to 6.5 mm to allow a longer transition period for every calibre below 6.5 mm as it considers this it would allow another 3.5 years of unnecessary risk. It adds: "*ECHA is not considering this necessary and Denmark can transition to non-toxic rifle ammunition by 2024*." Similarly, WWT does not support the proposed 5-year transition period for small calibre bullets, and claims it will provide no incentive to industry and hinder research, development and innovation. It considers that there are already non-toxic small calibre products on the market, which have been proven to be effective (e.g., (McTee and Ramsey, 2022)). The BVZS (Organisation #90) states that transition times to non-lead bullets should be as short as possible, based on their observation that *"even a simple internet search (available to all hunters) finds multiple products on the market for both non-lead gunshot and bullets."*

Forestry England (Organisation #111) confirmed that currently no suitable non-lead alternatives exist for solid slugs fired from a shotgun, which is a *"significant operational challenge*." The organisation uses solid slugs to control its wild pig (boar) populations. The organisation explained that wild pigs can be aggressive and follow up of injured pigs can be dangerous for staff; and, that a low velocity shot from a repeating firearm is relatively safe and extremely effective way of killing animals [Forestry England, Personal communication; May, 2023].

Rimfire bullets

The rimfire design comprises a low pressure system (the .22LR maximum pressure is 170 MPa, compared with 300 Mpa for .22 Hornet centrefire), where the barrel and chamber are similar diameters. The projectiles therefore depend on having a malleable flanged base that can engrave in the rifling to achieve forward obturation (gas seal between bullet and barrel). In comparison to lead, the density and malleability of lead-free materials restrict the ability of non-lead bullets to provide consistent engagement with the rifling of the barrel and match accuracy levels of lead bullets. The same gyroscopic stabilisation factors apply for rimfire as for centre-fire systems. Stabilisation is achieved in lead-free ammunition by retaining the profile of the lead round. The bullets are therefore much lighter (24 grains compared to 40 grains for lead), but to provide downrange energy the velocities have to be increased. The construction of .22 rimfire rifles allows the non-lead ammunition to exceed the normal lead ammunition pressures within CIP specification; however, there is a resulting increase in the noise produced when firing (GTA; Organisation #132).

A recently conducted BASC (Organisation #83) survey shows that 8 % of respondents are using lead-free rimfire ammunition for at least some of their hunting; 4 % of respondents were exclusively using lead-free rimfire ammunition for hunting.

ECHA (2022b) highlights the scarcity of available data from substantive testing of these calibres in literature, but summarises some additional studies. Rimfire cartridges (.22 LR) were tested by both Hampton et al. (2020) and McTee et al. (2017), using the same brand and model rifle (CCI .22 LR). McTee et al. (2017) found that non-lead and lead bullets incapacitated the small quarry (Columbian Ground Squirrels) equally effectively. Whereas, Hampton et al. (2020) indicated the only commercially available lead-free .22LR rimfire bullets in Australia at the time of the study produced substantially poorer animal welfare outcomes, but also recognised the limitations of the test for example small sample size, single quarry species, using a single rifle, using a single type of lead-based and lead-free bullet. McTee and Ramsay, (2022) found that the lead-free .22LR variant could offer suitable precision for some live quarry and pest control applications, but also concluded that this did not imply it would incapacitate animals as effectively as lead-based bullets.

Forestry England (Organisation #111) confirmed that significant further development is required to develop rimfire ammunition (particularly subsonic) to a point where it is as safe and as effective as lead, stating *“this is possible but requires further investment.”* The organisation has also encountered stability issues with longer bullets required for non-lead alternatives as some firearms have barrels with twist rates that cannot stabilize the longer bullet heads, particularly with .223 calibre. However, they state *“through development of these projectiles it is possible to overcome this problem.”*

Correspondence with a Danish EPA expert confirmed that rimfire ammunition would not be covered by the lead ban for hunting, but only because the market currently does not have suitable substitutes [Danish EPA; Private communication February 2023].

BASC (Organisation #83) has conducted testing of non-lead .22 calibre rimfire ammunition, comparing two non-lead brands with a subsonic expanding lead bullet used for shooting small game. From an accuracy perspective, the non-lead alternatives would likely prove effective to 60 m, but beyond that would not be accurate enough to dispatch small game humanely. Penetration testing indicated that the lead bullet generated significantly larger permanent wound channels than the non-lead equivalents. BASC concluded that given the limitations of accuracy and penetration the current non-lead alternatives are unlikely to be suitable for the humane shooting of small game beyond 60 m, whereas the lead bullet would be effective up to at least 75 m. Additionally, it concluded that there is currently insufficient availability of lead-free rimfire ammunition to meet demand in the event of any restriction on use of lead ammunition for live quarry shooting. BASC recommends that *“any restriction and transition period for rimfire ammunition is reviewed before implementation, and that such does not enter into force until such a time that the suitability, variety, and supply of non-lead rimfire ammunition can be guaranteed.”*

BASC (Organisation #83) raised a further concern about the high velocity of the non-lead alternatives and the resulting significant increase in noise. There are currently no subsonic lead-free alternatives on the market, and the increase in noise and associated disturbance during live quarry shooting / pest control would potentially lead to a decrease in the effectiveness of wildlife management / pest control measures. Several respondents to the Public Consultation (including individuals #108, #565, #1093, #1290, #1403) highlighted that the supersonic ‘crack’ associated with firing non-lead alternative .22 rimfire bullets cannot be effectively suppressed even with the use of a sound moderator. LAG (Organisation #125) recognises that subsonic (rimfire) bullets have yet to be developed and are more ballistically challenging. LAG cite a grey literature article from the Rifle Shooter magazine (Austen, 2022) that provides an assessment of the currently available non-lead .22LR rimfire ammunition. The article again highlights the technical challenges of lighter, higher velocity non-lead .22 bullets and their supersonic characteristics *“the muzzle crack was severe, so a sound moderator only really served to deaden the muzzle blast, but the supersonic crack was very loud.”*

BSSC (Organisation #100) asserts that rimfire rifles for hunting or pest control require acceptable levels of accuracy over ranges out to 150 m and sufficient downrange bullet energy to ensure a humane kill. This may be achieved with a .22 hollow point lead bullet weighing 38 grains (2.46 g) travelling at around 375 m/s or by a .17 calibre copper jacketed and polycarbonate tipped lead bullet weighing 17 grains (1.1 g) and travelling at a significantly faster 610 m/s. BSSC asserts that currently available non-lead bullets are unable to deliver comparable performance.

Stakeholders involved in Red Squirrel conservation (individual #2372) commented regarding use of rimfire rifles in the calibres of .22LR and .17HMR in the control of Grey Squirrels. Non-lead 17HMR calibre ammunition is readily available and widely used for delivering humane kill shots on squirrels at longer distances on the ground. However, it has limitations with regard to noise as it is supersonic and cannot be fully moderated (silenced), so would not normally be used in proximity of residential accommodation or livestock. Currently the types of non-lead .22 rimfire ammunition available in the UK comprise copper plated zinc core or compressed copper/polymer bullets which travel at between 1700 fps to 1850 fps; to be subsonic they need to be under 1130 fps. It is impossible to silence / moderate any of the bullets currently available and this effectively rules them out for Grey Squirrel control. They make the following points: currently available .22 rimfire non-lead bullets do not ensure a consistent humane kill shot as they are not accurate enough and due to their hardness can penetrate through the animal with no expansion resulting in more wounded quarry.

2.2.4.6 *Alternatives to lead bullets in target shooting*

The basic calibres used in many of the ISSF and International Biathlon Union (IBU) events are .22LR and .30 - .38 (firearms) which are the existing standard as well for all sports / target shooting activities leading to these events (ECHA, 2022b). Examples of smallbore shooting disciplines include Target Rifle, Target Pistol, Rapid Fire Pistol, Biathlon, Benchrest, Practical Pistol, Mini Rifle and Running Target. Examples of ammunition developed to achieve the necessary level of precision within the ballistic specification of the disciplines include 0.22LR Precision Rifle, 0.22LR Precision Pistol, 0.22LR Rifle, 0.22LR Pistol, 0.22LR Biathlon, 0.22LR High Velocity and 0.22LR Heavy Weight. Examples of full-bore shooting disciplines include Target Pistol, Target Rifle, Practical Pistol and Practical Rifle. Again, popular examples of ammunition developed with requisite specification include 7.62 / .308, 6 mm BR, 6 mm XC, 6.5 x 55 mm, 7.5 x 55, 6 mm x 47, 9mm, 38 Super, 45 ACP, 10 mm, 40 CAL and 223 Rifle (ECHA, 2020c). ISSF regulations state that .22 rifle and pistol disciplines requires bullets made of lead or other soft material. For full-bore the stipulation is ammunition of any description that may be fired without danger to the athletes or range personnel (ISSF, 2023).

Target shooting (both indoor and outdoor) is likely to be by far the greatest use of .22 rimfire ammunition in GB (see Section 1.4.3). Very limited quantities of .22LR ammunition loaded with copper projectiles are available. Independent testing with this copper ammunition shows the 5 shot grouping diameters at 45.7 m (50 yards) to be on average 35.6 mm. This would not be considered acceptable for even entry level target shooting (ECHA, 2020c; ISSF, 2023). In 2020, at the ECHA workshop on lead in hunting and sports shooting, Eley gave a presentation entitled "*A Viewpoint from Competitive Target Shooting*." Eley emphasised that no current alternative materials (such as copper, tin and tungsten impregnated polymers) have successfully demonstrated the necessary combination of physical and mechanical properties required for competitive shooting. The deficiencies of currently available non-lead projectiles include: 1) lower densities resulting in supersonic projectiles with significantly higher noise levels; 2) higher hardness which restricts the deformation of the projectile within the firearm barrel, reducing the effectiveness of the seal to the pressurized gases which drive it, and also increases the risk of ricochet and splinter of the projectile which may require redesign of projectile capture and management on existing shooting ranges; and 3) lower ductility (the degree to which a material can sustain plastic deformation under tensile stress before failure) which also restricts deformation of the projectile within the firearm barrel and increases the potential for projectile cracking and splintering. Eley conclude that "*a change of projectile material will require redesign and development of all aspects of the firearm*", (ECHA, 2022b, 2020c).

The general feedback in the EU call for evidence was that here are no viable alternatives for the bullet calibres used in sports shooting. ISSF supplied information in response to the EU call for evidence which highlights the requirement of a high level of accuracy particularly for international athletes in competitions, and stated that only lead bullets are capable of this (ECHA, 2022b).

In response to the GB Public Consultation, BASC (Organisation #83) provided comments from a recently completed survey. No information regarding the scope of the survey was provided to the Agency, so there is uncertainty about its representativeness. The survey shows that 17 % of respondents were using lead-free centrefire ammunition for at least some of their target shooting and 6 % of respondents were exclusively using lead-free centrefire ammunition for target shooting. The same survey indicated 7 % of respondents were using lead-free rimfire ammunition for at least some of their target shooting and 3 % of respondents were exclusively using lead-free rimfire ammunition for target shooting. As MoD, NRA and NSRA ranges do not allow non-lead alternatives on their affiliated ranges (see Section 2.2.4.2 Ricochet) this suggests this shooting is being undertaken elsewhere and is informal / non-competition.

The NSRA (Organisation #123) conducted tests examining the accuracy of 5 different .22 rimfire bullets (2 lead and 3 lead-free). The two types of lead bullets used were Eley Tenex which represents the high-end product and Eley Club which represents a cheaper, reasonable standard; both would be found in competitions and training at top level and within local clubs. The non-lead alternatives tested were what were *"currently available internationally from high quality manufacturers."* Anschutz Match 54 action rifles were used representing a reasonably accurate rifle (but not highest-end) that is used by the largest number of shooters in GB. The rifles were fired in a 50 m indoor shooting range where there were no variables due to wind and other climatic conditions, using a fixed test rig to hold the rifle in a static position. The test showed the accuracy of the lead-free bullets (grouping 48.9 mm to 76.2 mm) was lower than that of the lead bullets (grouping 18.9 mm to 27.1 mm). Comparing the results from this test with the general standard of scores found in competition showed the standard lead ammunition supports the score levels of both postal and shoulder-to-shoulder competition across the various skill levels. However, the results demonstrated that even under ideal conditions, the lead-free ammunition was incapable of delivering the accuracy required even for the lowest level of competitor in either the postal or shoulder-to-shoulder competitions. The report also concluded that inferior ballistic coefficients of the non-lead bullets would result in significantly greater wind deflections in outdoor environments when compared with lead bullets. The NRSA concluded *“the effect of changing to lead-free ammunition would be to turn competitions into a lottery where the vagaries of the ammunition would dominate the results, independent of skill level.”* As such skill development would not be possible and there would be a loss of talent and training opportunities for Commonwealth, Olympic and Paralympic events. BSSC (Organisation #100) state “*when currently available non-lead ammunition is used, a rimfire rifle, even when clamped, shoots a random group which is significantly worse than can be achieved by an elite shooter using lead ammunition. Thus genuine competition is no longer possible, as the winner of a competition is no longer the best shot, but merely the luckiest.*”

The NSRA (Organisation #123) report also highlighted significant noise increase associated with non-lead .22 rimfire ammunition compared with subsonic lead .22 rimfire ammunition, citing testing that showed an “*increase of 8.4 dB(A) which, due to the logarithmic scale used, represents an increase of 6.9 times the acoustic intensity (power level) or approaching twice (1.79x) the level of loudness*.” This has implications for outdoor ranges as noise nuisance must be kept to a minimum and since many ranges are situated in residential areas could result in their closure or severe restrictions to use. Additionally, there could be significant cost increases associated with the transition to non-lead ammunition as it would potentially mean that clubs would have to revisit the construction of their ranges to ensure compliance. Current specifications for ranges (e.g., DSA 03.OME and The Design Construction and Maintenance of Target Shooting Ranges) are based on the use of lead ammunition.

Wilmslow Rifle Club (Organisation #112) asserts that no manufacturer has yet come up with a lead-free .22 rimfire alternative that is as accurate and consistent as even low-grade lead bullets. The accuracy deficit of currently available non-lead .22 rimfire ammunition is such that “*many people would simply leave the sport, frustrated at having to re-learn much of what they have been doing for many years. New shooters won’t be able to “get the bug” – that obsession with millimetre levels of accuracy and precision that characterises target shooting.”*

The National Rifle Association (NRA; Organisation #127) response states the supply and availability of lead-free bullets for sports shooting is very limited, and of uncertain performance. Police and military firearms training and competition account for 20 - 24 % of total range use at the NSC Bisley, and they are significant users of other regional civilian ranges. Police and military users will continue to use lead projectiles on outdoor ranges for the foreseeable future including on the NSC and other regional ranges.

BSSC (Organisation #100) also emphasises that there is considerable crossover in range use between civilian and military, police and emergency services shooters. Many civilian rifle clubs shoot over MoD ranges, and civilian target shooters are prohibited from using non-lead ammunition on military ranges. The expectation is that civilian use of MoD ranges will continue, but will be governed by the requirements of any restriction. Additionally, military, cadet, police and other emergency services personnel conduct firearms training and compete at civilian ranges. Discussion with MoD stakeholders confirmed that currently military training on civilian ranges is rare and only where there is a specific requirement that could not be met on an MoD range. Civilian shooting clubs do use MoD ranges, but are limited to ranges with No Danger Area or Limited Danger Area where lead capture and recovery is in place (The Agency / MoD Stakeholder meeting, 1st March 2023).

Discussion with MoD stakeholders confirmed that on MoD ranges civilian shooters are only allowed to use copper or steel jacketed lead core or solid lead bullets. The major concerns were uncertainties regarding stop butt attrition and damage to range infrastructure rather than just health and safety. There are currently no data regarding behaviour of non-lead alternatives for these issues and current small arms range design (originally JSP 403, now replaced by DSA 03.OME) is based on lead and lead core bullets. Accordingly, it is reasonable for civilian ranges that are constructed on these specifications to have the same moratorium for non-lead ammunition in place. Essentially departing from this guidance would be at the civilian range operator's 'own risk'. In the event that the military obtain relevant data and update range design they will share specifications in due course (The Agency /MoD Stakeholder meeting, 1st March 2023). It is worth noting that the US military and UK military have developed effective non-lead alternative 5.56 mm bulleted ammunition (either steel tipped copper alloy core (M855A1) or gilding metal jacketed steel core (L31A1)) for current rifles in service (The Register, 2016; US Army, 2011).

Rustington & District Home Guard Rifle Club Incorporating Hangleton Rifle Club (Organisation #135) operates from an open-air target shooting range that was constructed in and is wholly contained by a disused quarry. The organisation confirms that only lead bullets can be used for safety reasons and that the terms of use of their particular range prohibits all members from shooting jacketed ammunition. To comply with the ballistic limitations imposed on the range, and as suitable ammunition (i.e., lead bullet only) is not commercially available, it is necessary that the required ammunition be hand loaded. Therefore, members are required to cast their own lead bullets to suit their requirements. The choice with regard to bullet material has no current and practical alternatives.

International rules for muzzle loading competitions stipulate the use of lead bullets (BSSC, Organisation #100). MLAIC, rules actually stipulate:

- *7.6 Firearms and Ammunition: b.) iii) Bullets shall be of a contemporary style and may be lead or lead alloy, greased or paper patched. Gas checks are not permitted.*

One respondent (individual #1238) highlighted that there are no technically viable alternatives to lead for muzzle loaders and particularly for historic black powder revolvers where the soft lead projectile must be swaged into the chamber. The use of lead is an important safety factor to provide a gas-tight seal and avoid ‘front end-initiated chain fire’ to the other loads in the cylinder.

Correspondence with a Danish EPA expert confirmed that the upcoming ban of all lead ammunition for hunting does not extend to target shooting ranges and shooting ranges. The Danish EPA is discussing possible ways to remove/collect lead from shooting ranges with the military and the police [Danish EPA; Private communication February 2023].

2.2.4.7 *Summary of alternatives to lead bullets*

There has been significant development of non-lead alternative centrefire bullets for live quarry hunting, in part driven by the demand from game dealers and the food industry. Depending on the quarry and calibre, effective and accurate non-lead alternatives are available. However, not every rifle / bullet combination delivers the required accuracy or lethality, and much will depend on the calibre, rifle twist rate, quarry type, shot distance, hunter behaviour and the physical and ballistic properties of the non-lead alternative. There are important animal welfare issues around accuracy and efficacy of non-lead bullets and the ability to deliver humane dispatch of live quarry without causing additional suffering. Additionally, some legislative requirements prohibit certain bullet weights, effectively excluding non-lead alternatives in those calibres. ECHA and NatureScot both contend that a change in legislation could be considered regarding ammunition selection based on measured terminal ballistic performance. Such an approach may influence regulatory decision-making processes for reduction of lead in game meat and is likely to influence any proposed transition period.

There are concerns in the shooting community with regard to current supply issues, given the ongoing war in Ukraine. Shooting organisations have requested revision of the small calibre/large calibre demarcation from 5.6 mm to 6.5 mm to allow longer transition (to five years) for development of effective alternatives or re-barrelling or gun replacement and to meet scale of supply; this has been highlighted as being of particular concern for .243 calibre and its importance for control of UK deer populations. With regard to small calibre bullets, as the calibre and size of the bullet decreases, material and ballistic properties become more significant which impact bullet stabilisation, accuracy and lethal range. The increased velocities of the lighter non-lead bullets can result in unacceptable noise increase, limiting their usefulness for pest control. In relation to rimfire bullets (e.g., .22LR) currently there are no subsonic alternatives available and availability of non-lead alternatives with acceptable accuracy and lethality is limited.

For target shooting, non-lead bullet alternatives for competition would need to be accepted by sports governing bodies up to international level. Non-lead alternative bullets that are sufficiently accurate to be suitable for smallbore (i.e., .22LR) competition standard do not currently exist. The supply and availability of lead-free bullets for full-bore sports shooting is limited, although industry development is ongoing. Currently lead-free bullets for full-bore sports shooting are of uncertain performance. Additionally, the majority of shooting ranges affiliated to the sports governing bodies (e.g., NRA, NSRA) do not allow use of any ammunition other than copper or steel jacketed lead core or solid lead bullets. This is due in part to uncertainty over ballistic performance, potential for ricochet, and range infrastructure attrition and damage. Similarly, civilian shooters on MoD ranges are only allowed to use copper or steel jacketed lead core or solid lead bullets.

Non-lead alternatives may not be practical in all circumstances, for example because of unacceptable safety constraints (i.e., historic black powder revolvers), or in certain antique / historic / heritage firearms due the potential for barrel wear. Additionally, it has been argued that use of non-lead alternative ammunition does not allow for preservation of heritage, where in order to preserve original performance the original ammunition for which the firearm was designed should be used.

2.2.5 Non-lead alternatives for airguns

2.2.5.1 *Suitability and availability of non-lead alternatives for airguns*

In England and Wales, “legal limit” airguns do not require a licence. This is an air rifle producing a muzzle energy not in excess of 12 ft/lb or an air pistol producing a muzzle energy not in excess of 6 ft/lb. Above these muzzle energies, the airgun must have a firearms certificate to be held legally. Lead airgun ammunition is not covered by existing licensing regimes in England, Wales or Scotland. In England and Wales, an owner must be 18 or over to buy or possess a legal limit airgun or ammunition for an airgun; however, a person 14 years old or above may also possess a legal limit airgun or ammunition for an airgun on private premises with the consent of the occupier. The Agency does not consider that there are any reliable estimates of the number of airguns in circulation in GB; estimates have been provided of >6 million to >9 million in England and Wales ((BASC, 2022); BSSC, Organisation #100). Licensing of airguns was introduced in Scotland in 2015 and an Air Weapon Certificate or a visitor permit to use, possess, purchase or acquire an air weapon is required. In Scotland, there were 30,374 Air Weapon Certificates on issue as at 31 March 2021 (Police Scotland, 2021). Airgun shooting is relatively cheap, and the licencing regime and less physical nature of the sport means that it is the easy access to all forms of target shooting, particularly for youth (e.g., schools, uniformed groups (Scouts, Guides, Cadets etc.) and other youth organisations) and disabled shooters (NSRA; Organisation #123).

Lead airgun ammunition typically comprises waisted ‘diabolo’ style pellets (a solid head containing the centre-mass and thin-walled skirt), spherical ‘BB’ style or cylindro-conoidal slugs (comprising a cone like nose containing the centre-mass with a thin-walled rear cavity – see diagram in *Table 1.6*). Lead is historically used as the projectile material due to its combination of properties (density, hardness, ductility, low melting temperature) meaning that it grips the rifling and deforms into the barrel dimensions to provide a gastight seal, stabilise the projectile and has enough weight for continued momentum. Airgun projectiles are generally lighter than bullets, travel at a much lower velocity, and consequently do not fragment to the same extent as bullets.

Non-lead alternatives include tin-zinc alloys, copper, copper core with plastic jacket or skirt, steel core with plastic jacket or skirt and other plastic jacketed/skirted proprietary non-lead alloy cores. Any plastic component will potentially provide another plastic exposure pathway to the environment, unless constructed from bio-degradable material. The non-lead market share is extremely small as the ballistic performance is not sufficient for target shooting (ECHA, 2022b).

WWT (Organisation #134) observed that a UK-based online supplier had around 38 non-lead air rifle pellet products available and claimed extensive availability of non-lead alternatives from the wider Internet. Product reviews on their use for hunting on an online purchasing forum would suggest that the accuracy of air rifles for hobby shooting (which would cover a fair share of their use) is adequate. However, these tests and or reviews are not conclusive enough to come to a firm decision on product suitability (ECHA, 2022b).

BASC (Organisation #83) conducted a review of availability of individual types of pellets in each calibre in the GB. Three of the five popular calibres (0.20, .25, .30) had no lead-free options available for purchase, with .177 and .22 having a total of just six product options available for each calibre to purchase from major retailers. The Agency considers that the availability reflects the demand for and therefore usage of the different calibres, with .177 and .22 being more widely used.

BASC (Organisation #83) highlighted that increasing the muzzle energy of lighter lead-free airgun pellets would require an increase in the volume and pressure of air driving the pellet down the barrel. This would require a modification to the airgun’s propulsion mechanism, usually requiring assistance of a competent gunsmith. Therefore, ‘easy’ regulation of the level of propulsion according to the type of pellet being used is not possible. Such changes could produce energies >11 ft/lbs with lighter lead-free airgun pellets and render them suitable for the shooting of small game and vermin. However, it is then likely that muzzle energies >12 ft/lbs would be produced with heavier lead pellets, breaking current legal muzzle energy limits for unlicensed airguns. Such guns would have to be held as a Section 1 firearm requiring a firearms certificate.

Daystate (Organisation #058) – a long-established company manufacturing airguns in the UK – confirms that current non-lead airgun ammunition is unacceptable. This is mainly due to the density of available materials and the limited energy available to an airgun. It asserts that an alternative material will require substantial development, shape redesign, and purchase and design of new equipment. Special barrels will be required capable of firing the new ammunition at a greater velocity. Daystate explains that it would only start development of new ammunition and subsequently the necessary new designs for air weapons once the regulations are clarified and in effect and that transition will take time. It also highlights a current post-Covid lead ammunition supply issue, meaning that production of lead-free alternatives has been significantly reduced as manufacturers concentrate on fulfilling lead pellet backorders.

Correspondence with a Danish EPA expert confirmed that currently there are no substitutes for lead pellets for airguns and therefore they are not part of the ban for ammunition used for hunting with rifles [Danish EPA; Private communication February 2023].

2.2.5.2 *Ricochet*

Stakeholders responsible for Red Squirrel conservation in the UK explained the recognised method of shooting Grey Squirrels with air rifles is shooting towards static feeder locations in areas with safe back stops or metal feeder stations, at a known distance from the shooter's position, so that very accurate humane kill shots can be delivered (individual #2372). Deformation on impact is the normal process whereby the energy of the lead projectile is dissipated, but harder non-lead projectiles do not deform on impact and the stakeholders have experienced ricochet of non-lead ammunition from the steel plates of the feeders. They state, "*it is our opinion that the use of non-lead air rifle ammunition creates a strong possibility of serious personal injury to both the shooter and anyone else in proximity of the shooting station, way above the risks normally associated with the use of lead-based ammunition in air rifles*."

Several respondents highlighted that the increased potential for ricochet from hard surfaces makes use of harder non-lead alternatives an unacceptable safety risk in both sports shooting and pest control particularly where airguns are often used in and around buildings.

The British Field Target Association (BFTA, Organisation #41) expressed its concern that there may be a potential increased risk of ricochet from shooting non-lead airgun pellets towards metal targets / metal pellet catchers.

Given that experienced shooters can sometimes get a shot 'wrong' resulting in a ricochet, the Agency considers that there will be potential for increased risk of ricochet associated with non-lead alternative airgun ammunition from shots taken by less experienced or less mature / junior shooters.

2.2.5.3 *Alternative airgun ammunition for hunting*

Hunting (shooting live quarry, including pest control) activities are normally undertaken on farmland or woodland, but can include areas with pest issues, like golf clubs or recycling centres. The BASC code of practice (BASC, 2022) recommends live quarry shooting with legal limit air rifles should be conducted at ranges of less than 30 metres, with a power level greater than 11 ft lb (15 J). It recommends practicing to consistently hit the point of aim that will ensure a clean kill; usually the head, which normally has a maximum diameter of about 30 mm. Air pistols are not used for hunting, given their low muzzle energy. A survey (187 responses) of a popular online airgun forum on the use of lead ammunition by airgun enthusiasts in Britain (individual #2168) suggests that some 57 % undertook hunting/pest control. Of these respondents 64 % reported taking some quarry "for the pot", which may raise concerns about lead contamination of food. However, 55 % of hunters reported taking their quarry exclusively with head shots, and another 21 % of hunters taking 90 % of their quarry with head shots. *"The mean body / headshot split was 14 / 84% with both median and mode being 100% headshots."* As the head is normally part of an animal that is discarded, this suggests that the potential of lead contamination in food shot with airguns is relatively low. The report highlights that *"there is evidence that current lead-free airgun pellets do not have the same accuracy as lead pellets, and though differences in accuracy may seem inconsequential, the targets of airgun hunters can be small and at distance, and small differences in accuracy can be important".*

In response to the GB Public Consultation, BASC (Organisation #83) provided comments from a recently completed survey. No information regarding the scope of the survey was provided to the Agency, so there is uncertainty about its representativeness. The survey shows that 9 % of respondents were using lead-free airgun ammunition for at least some of their hunting and 4 % of respondents were exclusively using lead-free airgun ammunition for hunting.

There are no known studies or peer reviewed comparative test comparing the performance of lead and non- lead (often tin) based air rifle pellets for live quarry shooting (ECHA, 2022b).

WWT (Organisation #134) quotes a positive review of a non-lead airgun pellet available from an airgun website, which demonstrated groupings of 18.8 mm and 7.9 mm centre-to-centre, respectively and muzzle energy of 11.04 ft/lbs using lubricated pellets and a high quality legal limit pre-charged pneumatic (PCP) air rifle in .22 calibre in the Airgun Shooter magazine (Morton, 2021).

BASC (Organisation #83) conducted tests comparing non-lead airgun pellets in .177 (4 varieties) and .22 (1 variety) against lead airgun pellets in .177 (4 varieties) and

.22 (2 varieties). Pellets were fired through seven different makes / models of legal limit air rifles in .177 calibre (two spring powered and five PCP) and, three different makes / models of air rifles in .22 calibre (two spring powered and one PCP). The tests concluded that at 25 metres existing lead-free options "*could produce groups equivalent to or better than lead options in .177 calibre"* suggesting that the tested pellet / air rifle combinations are sufficiently accurate and consistent at 25 metres for shooting of small game and vermin. However, none of the .177 calibre lead-free options exceeded the 11 ft/lbs threshold in the tested airguns, making them unsuited to live quarry shooting. In contrast, four of the seven tested .177 lead pellet / air rifle combinations did not achieve the desired muzzle energy of 11 ft/lbs (range 9.76 to 10.87 ft/lbs). The tested non-lead .22 calibre / air rifle combinations did achieve the required muzzle energy for live quarry shooting, but did not have the desired accuracy and consistency. At 50 m the lead-free options were significantly less accurate than the lead options, although at this distance neither the lead nor lead-free options grouped below 30 mm.

One respondent to the Public Consultation (individual #1946) produced three ballistic modelling reports comparing lead and tin slugs, lead and zinc pellets of identical design and lead and tin pellets of identical design. It should be noted that it has not been possible to have the accuracy of these reports verified by an independent scientific expert. The reports concluded that for comparative accuracy zinc slugs will require either changing the barrel of the gun to a higher twist rate or using lighter and shorter slugs, which may necessitate reduction of the muzzle energy of the gun to avoid supersonic speed. For the identical pellets, tin and zinc are predicted to generally give larger groups sizes, lose energy more quickly, be more effected by crosswinds and to be more sensitive to defects and barrel fit than the lead equivalents. The degradation in accuracy of lead-free pellets and lead-free airgun slugs will give significantly increased group sizes, which *"will result in more animals being injured rather than cleanly killed in legitimate pest control."*

Stakeholders involved in Red Squirrel conservation in the UK (individual #2372) stated that when air rifles (both sub-12 ft/lb air rifles and firearms certificate air rifles) are used for Grey Squirrel control, humane dispatch requires head shots. Their experience of a variety of available brands of lead-free air rifle ammunition has not found any that provide consistently accurate humane shots out to 15 – 20 m and in many instances insufficient accuracy was achieved at even closer ranges of 10 metres or less. In their opinion this renders the use of non-lead ammunition impractical for undertaking humane control (with a lethal 'head shot') of Grey Squirrels by shooting with air rifles. The stakeholders state *"many of the new non-lead projectiles specifically say that the ammunition is designed for use in Pre-charged Pneumatic "PCP" air rifles. Each of us use PCP air rifles but many others use the traditional "Springer" type rifles. Some of us have tried the non-lead ammunition in "Springer" air rifles and have found them to be utterly useless. This* *would mean "Springer" air rifles should never be used for shooting live quarry with non-lead ammunition.*"

Forestry England (Organisation #111) provided limited data from air rifle trials. They indicated that non-lead .177 and .22 BSA Greenstar grouped as well as the lead pellet control; .177 was tested in three different rifles and grouped well in all out to 25 yds. In a small internal trial both the .22 and .177 non-lead ammunition killed rats as humanely and effectively as the lead pellets. No information was provided as to the trial conditions or the type of air rifle used (e.g., firearms certificate / legal-limit, spring loaded or PCP).

2.2.5.4 *Alternative airgun ammunition for target shooting*

Airguns are used for formal and informal target / sports shooting competitions. Around 80 % of shots are fired on indoor ranges. Airguns are also used at outdoor field target competitions at which metal knock-down targets are shot at (BSSC; Organisation #100). ISSF regulations state that 10 m, .177 air rifle and air pistol disciplines require projectiles of any shape made of lead or other soft material permitted (ISSF, 2023a). In 2020, at the ECHA workshop on lead in hunting and sports shooting, Eley gave a presentation entitled "A Viewpoint from Competitive Target Shooting" (ECHA, 2020c). Typical airgun disciplines include Target Air Rifle, Target Air Pistol, Target Sprint and Running Target. Popular examples of ammunition developed to achieve the necessary level of precision within the ballistic specification of the disciplines include: 0.17 AIR (4.49 mm), 0.17 AIR (4.50 mm), 0.17 AIR (4.51 mm) and 0.22 AIR (5.6 mm). Eley highlighted the level of accuracy required for competition shooting achieved with lead pellets is an enclosing group circle diameter of 5.5 to 6.0 mm, firing 10 lead pellets (0.17 calibre) at 10 m in ideal conditions. In contrast, available tin pellets are unable to match this performance. *"The physical and mechanical properties of tin prevent the formation of pellets with the necessary profile, mechanical properties and specifications required to consistently achieve this level of performance. At 10 m typically 10 tin pellets can produce an enclosing group circle of 15 to 20 mm, potentially reducing the score in a 24 shot ISSF final by up to 12 points."* ((ECHA, 2022b, 2020c); GTA, Organisation #132).

Testing undertaken by BASC (Organisation #83) suggest that the tested lead-free options would not be suitable for 'sports shooting', particularly competition shooting (such as Hunter Field Target) given that demands of accuracy for this shooting are much more stringent than those for live quarry shooting.

The NSRA (Organisation #123) undertook tests at their Aldersley Range at Wolverhampton on the accuracy of lead and non-lead airgun pellets. A fixed test rig was used to fire two rifles, an Anschutz 9007 and Air Arms S400 each at a distance of 10 m and 25 yards respectively. The tests showed decreased accuracy for non-lead (grouping of 8.75 mm to 11 mm) compared with lead (grouping of 4.95 mm) at

10 m; and non-lead (grouping of 38.2 mm to 73.4 mm) compared with lead (grouping of 13.2 mm) at 25 yards. As a result, the NRSA have concerns that the inaccuracy of lead-free ammunition and its ballistic inefficiency would turn competitive shooting into a matter of chance rather than skill for air rifle shooting disciplines. The NRSA (Organisation #123) further reports that the cost of lead-free airgun pellets is considerably higher than their lead counterparts and this may potentially have a large impact since airgun shooting represents the easy access end of target shooting sports; the ranges are easier to build and access, and there is no requirement for a firearms certificate.

The British Field Target Association (BFTA, Organisation #41) carried out tests on currently available lead-free pellets and concluded that accuracy is very poor beyond 30 m and that in wind free conditions the groups obtained at 50 m proved to be significantly larger than lead pellets (typically, a 75 mm group compared to a 10 mm group with lead). Lower density and poorer ballistic coefficients make them more susceptible to the effects of wind. On close targets (10 m) lead free pellets tend to ricochet off the target.

In their response to the Public Consultation the BSSC (Organisation #100) confirmed that non-lead pellets are commercially available in low quantities and are generally made of tin-zinc alloy, or alternatively of pure tin or zinc, but at present only lead pellets are capable of achieving the necessary degree of precision for competitive shooting with the .177 air rifle or pistol at 10 metres. In accuracy tests comparing lead and tin pellets, three groups of 10 pellets were shot per batch using the same rifle and the same target in a consecutive test. Accuracy was calculated by measuring the distance between the target centre and the shot hole centre. The radial standard deviation for the lead pellet (0.742 mm) was half of that for the tin pellet (1.52 mm) and the average group size was smaller: 6.7 mm for lead versus 9 mm for tin.

In response to the GB Public Consultation, BASC (Organisation #83) provided comments from a recently completed survey. No information regarding the scope of the survey was provided to the Agency, so there is uncertainty about its representativeness. The survey shows 8 % of respondents were using lead-free airgun ammunition for at least some of their target shooting and 4 % of respondents were exclusively using lead-free airgun ammunition for target shooting.

A survey (187 responses) of a popular online airgun forum on the use of lead ammunition by airgun enthusiasts in Britain (individual #2168) indicated that some 54 % of sports shooters exclusively shoot in the outdoor environment, with only 8 % shooting exclusively indoors. Low rates of ricochets were reported, with 56 % of airgun target shooters using lead not expecting to experience any ricochets while sports shooting. This suggests a high confidence that any lead ammunition would be recoverable after being shot with the use of an appropriate backstop, and mechanical method of recovery (e.g., a pellet trap).

2.2.5.5 *Summary of non-lead airgun ammunition*

There has been limited uptake of non-lead alternatives for hunting with airguns by the GB shooting community. There are concerns regarding product availability, accuracy, lethality and unacceptable ricochet risk. While it is evident that non-lead alternatives are available and are in use by some shooters and can be used for humane dispatch of live quarry in some circumstances, the situation is further clouded by performance differences between legal limit and firearms certificate airguns, springer versus PCP and whether 'like-for-like' comparisons are being made. Modifying legal limit airguns to compensate for lighter non-lead alternatives has implications for firearms classification, and may result in a breach of the legal limit if a lead projectile is subsequently fired. Notwithstanding, a minority of respondents have reported positive experiences of non-lead alternatives for shooting live quarry.

Currently there is only very limited uptake of non-lead alternatives for target shooting with airguns in the UK and there are no viable alternatives for competition target shooting that would deliver the required level of accuracy. Non-lead alternatives for national and international competition would need to be accepted by sports governing bodies. Development of non-lead alternatives would potentially necessitate a change of legislation around the 12 ft/lb legal limit and would potentially require substantial development of new airgun designs. Notwithstanding, it is evident that some shooters are undertaking some target shooting with non-lead alternative airgun ammunition.

2.2.6 Non-lead alternatives for humane dispatch

2.2.6.1 *Suitability and availability of non-lead alternatives for humane dispatch*

According to the Humane Slaughter Association (2023), ammunition used for humane slaughter/dispatch of animals includes bullets and shotgun ammunition. In instances where animals/livestock require humane dispatch, the operator has legal and moral responsibilities with regard to animal welfare (i.e., not to cause any avoidable pain, suffering or distress) and human safety (e.g., ricochet avoidance, adequate safe backdrop). Humane dispatch may occur: on-farm; in transit; in markets, lairages or collection centres; or as a result of accidents on the public highway, at racecourses, shows or exhibitions. Operators undertaking humane dispatch may include veterinary surgeons, knackermen, slaughtermen, farm staff and police firearms officers.

LAG (Organisation #125) members have begun discussions about use of lead-free bullets for humane dispatch of livestock or other animals, and use of non-lead compressed metal powder projectiles for some settings.

Charles Diplock partnership (Organisation #004) requests a derogation for lead bullets and shot for humane dispatch use, as the alternatives that are available are not suitable and in many cases would be less safe for the operator. It highlights that none of the bullets used in the industry end up in the environment as such or in the food chain.

The Royal Society for the Prevention of Cruelty to Animals (RSPCA; individual #1660) requests consideration to a possible derogation regarding use of lead ammunition in slaughter pistols used for humane euthanasia as alternatives to lead could potentially be problematic. The RSPCA accept that more research is needed to determine if alternatives can be used in slaughter pistols without compromising their efficacy.

The Agency is seeking further clarification on this matter during the SEA public consultation.

If, following consultation, a restriction on live quarry shooting with bullets is not proposed, it may be that lead bullets can be used where lead shot is currently used, if it is the case that alternative shot types are unsuitable. It is also worth noting that the Humane Slaughter Association's website does mention the use of steel shot when discussing the humane killing of livestock using firearms, so it may be that alternatives to lead shot are suitable for this function (Humane Slaughter Association, 2023).

2.3 *Approach to the SEA*

The SEA primarily uses a cost-effectiveness framework. The Agency has provided monetised estimates of certain benefits of restricting the shot uses but has been unable to monetise all of the benefits relevant to this use, or the benefits of restricting the other uses. Cost-effectiveness analysis (CEA) is the Agency's preferred approach in this SEA, due to many complexities inherent to environment and human health benefits assessment. Here, the Agency uses the tonnage of lead emitted by a particular use as a proxy for risk and compares the social costs of restriction of a given use to the quantity of lead abated. Qualitative analysis has been undertaken where this is deemed beneficial in providing a holistic comparison of costs and benefits, or where impacts cannot be quantified.

The geographical scope of analysis is GB. As mentioned in section 1.3.5.1, Northern Ireland (NI) falls under EU REACH regulation and as such impacts to NI are not considered in this dossier. A 20-year temporal scope has been chosen, with 2024 assumed to be the first full year of entry into law. Transition periods of up to 5 years are proposed/modelled depending on the restriction in question, with justification provided during the analysis of each restriction option. The Agency selected a 20-

year temporal scope as it considers it to be the minimum time-period over which costs and benefits can reasonably be compared. The Agency considers an appraisal period shorter than this to give insufficient time for the benefits of restriction to reasonably materialise, due to several of the costs being up-front in nature, compared to benefits which will likely take longer to materialise. However, the longer the time-period studied the greater the uncertainty in most parameters. Important factors within an SEA such as markets and consumer behaviour change over time for a variety of reasons. Economic models that analyse impacts over a longer time-period are more vulnerable to the impacts of changes in their parameters. The Agency considers 20 years to be a measured balance between these two considerations.

Impacts are presented in present value terms, using the Green Book (2022) recommended discount rate of 3.5 % (and 1.5% for health impacts). Unless stated otherwise, all values presented within the SEA have a price base year of 2022, calculated using HM Treasury (2023) GDP deflators.

The Agency conducts sensitivity analysis within the CBA, where the main assumptions and parameters are tested and the result of doing so reported. Herein, an ‘optimistic’, 'central' and 'pessimistic’ scenario from the perspective of benefits of restriction is explored. This allows the Agency to gauge how the ratio of benefits to costs could realistically change based on changes in the assumed value of the model’s parameters.

The Agency has used conservative assumptions throughout this SEA to minimise the likelihood that costs (benefits) of restriction are underestimated (overestimated). This approach has been taken so that an impact assessment which demonstrates benefits exceeding costs despite conservative assumptions can be interpreted by policymakers with confidence in light of various areas of uncertainty.

2.4 Baseline

Baseline release estimates for all uses

As outlined in Section 1.4.3, the Agency estimates the following annual releases of lead from the uses in scope:

Table 2.3: Estimated annual releases of lead from each use

Use	Annual lead ammunition use estimate (GB)	Annual lead emissions (GB, t)
Live quarry shooting with shot	54.2m cartridges	1,601
Live quarry shooting with bullets	0.7m small calibre bullets	2 (small calibre)

	0.2m large calibre bullets	1 (large calibre)
Outdoor target shooting with shot	181.3m cartridges	5,359
Outdoor target shooting with bullets	13.0m small calibre bullets 7.3m large calibre bullets	38 (small calibre) 73 (large calibre)
Live quarry and outdoor target shooting with air pellets	>16.9m	>13
Total	**235.5m cartridges** **21.2m bullets** **>16.9m air pellets**	**7,089**

Notes: cartridge estimates rounded to nearest 100,000, tonnages rounded to nearest tonne. All figures rounded to the nearest tonne. Totals are calculated based on unrounded estimates and rounded to the nearest tonne, rather than summing individual rounded estimates.

Further information on how the Agency has arrived at these figures may be found in Section 1.4.3.

In 2020, nine of the major UK shooting organisations announced a 5-year voluntary transition away from lead ammunition in live quarry shooting with shotguns, along with 8 other major shooting organisations. Additionally, certain supermarkets have committed to sell game meat shot only with lead-free cartridges. The Agency also understands that certain deer culls also stipulate the use of lead-free bullets. This demonstrates a growing public awareness of the risks associated with ingestion of spent lead shot. However, some recent research shows that the voluntary measures have had little impact so far. As mentioned in section 1.6.3, Green et al (2023) found that 94.0 % of the 235 pheasants from which shotgun pellets were recovered in 2022/23 had been killed using lead ammunition, compared to 99.5% in 2021/22 and 99.4 % in the 2020/21 season. Despite this, the Agency does anticipate some transition away from lead shotgun cartridges and large calibre bullets to occur in the baseline. In the absence of a sophisticated forecast, the Agency will decrease baseline annual emissions of lead from live quarry shooting with shot and large calibre bullets by an arbitrary 10% across the 20 year-time horizon to account for some switch in demand to lead-free alternatives. The quantities in Table 2.3 do not include this 10% reduction in LQS with shot and LC bullets, because the Agency assumes them to take place from 2025 onwards. Once accounting for a 10% decrease from 2025 onwards, the estimated annual emissions from LQS with shot and LC bullets become 1,441t and 1t[3], respectively.

The Agency does not anticipate a switch away from lead ammunition to alternatives in the baseline for the other uses. The BASC voluntary phase out, whether successful or not, does not apply to target shooting, and the Agency considers there to be little appetite to use lead-free ammunition in target shooting unless mandated. For small calibre bullets and air pellets, the Agency considers alternatives to lead to be worse-performing and less available at the time of writing, and so does not anticipate a reduction in their use under the baseline.

In summary, the annual uses outlined in Table 2.4 are forecast over the 20-year time-period studied, with a 10% total reduction from 2025 onwards for live quarry shooting with shot and large-calibre bullets alone. Table 2.4 outlines total estimated baseline lead emissions over the 20-year time period studied (2024-2043).

Table 2.4: Total estimated baseline lead emissions (20 years)

Use	Total estimated lead emissions, 2024-2043 (GB, t)
Live quarry shooting with shot	29,000
Live quarry shooting with bullets	36 (small calibre) 25 (large calibre)
Outdoor target shooting with shot	107,200
Outdoor target shooting with bullets	770 (small calibre) 1,460 (large calibre)
Live Quarry and outdoor target shooting with air pellets	>260
Total	**139,000** (3 significant figures)

In addition to this, a relatively small amount of non-lead ammunition is already being used. For shot, based on Blake International (2022, Organisation #132) (Hurley, 2022) the Agency estimates that roughly 4% of shot currently used in the UK is non-lead, primarily steel. The Agency does not have data for bullets but is aware that some shooters already transitioned to lead-free alternative ammunition, notably in

[3] Due to rounding, this figure bullets appears to be the same as that prior to accounting for a 10% reduction in use from voluntary measures. Unrounded data is used in the Agency's analysis, with results presented in rounded form.

large calibres where the technical barriers faced by small calibres do not exist.

2.4.1 Impact of EU restriction on the domestic market

ECHA have recommended a restriction on lead in ammuntion under EU REACH (ECHA, 2022a). It is important to consider any impacts this restriction could have on GB and factor these into both the baseline and the intervention case.

For shotgun cartridges, (Blake International, 2022 Organisation #132) (Hurley, 2022) provide a breakdown of UK consumption and trade flows. Their data suggest that in 2021/22, UK manufacturers produced cartridges equating to 6,531t of lead. 896t of lead in cartridges was imported into the UK, with 610t exported. As such, domestic manufacture comprised an estimated 96% of domestic consumption (6,531/(6,531+896-610). From this, the Agency infers that there should be no discernible impact on the supply or the price of lead cartridges as a result of an EU REACH restriction, which would likely see EU manufacturing of lead shot cartridges cease. As a result, lead cartridge prices are forecast to remain the same relative to alternative cartridges in the baseline central scenario.

(Blake International, 2022 Organisation #132) (Hurley, 2022) also reports that UK manufacturers produced steel shotgun cartridges with 1,144t of shot in 2021/22. Of this, 1,031t was exported, primarily to continental Europe and Scandinavia. Only 4t was imported, leaving 117t domestically consumed, see *Table 1.10*. These figures signal that the UK has comparative advantage in the trade of steel shotgun cartridges compared to continental Europe. Such comparative advantage could suggest that, as a result of the EU REACH restriction, UK manufacturers may expand their steel shotgun cartridge production to meet the resulting demand. This has implications for the Agency's socio-economic modelling of a UK restriction because it would likely mean that some share of the costs to manufacturers that are attributed to a UK REACH restriction would have occurred anyway under the baseline. The Agency has estimated the costs to manufacturers of a full transition away from lead shot, assuming business as usual under the baseline, in the absence of evidence (rather than a logic-based presumption) that manufacturers plan to expand steel shot cartridge production to meet European demand. As such, this may be an overestimate of this impact of a GB restriction, but fits in line with the Agency's conservative approach to the SEA outlined in Section 2.2.

Based on ECHA's Annex XV dossier (ECHA, 2022a), the EU use roughly 7-8 times more lead shot than GB. A transition from lead to (predominantly) steel alternatives on this scale may see a short-term price increase while supply extends to meet demand. Due to the relative scale of the GB market to that of the EU, the Agency assumes that any short-term price increase in steel shot cartridges would have likely occurred anyway. Nonetheless, in the sensitivity analysis the Agency does test the impact of a relative price increase in steel cartridges compared to other materials based on a GB restriction alone.

For bullets, the Agency understands that centrefire ammunition is imported into the UK from abroad. Through personal communications with industry, the Agency undertands that several factors, including the Russian invasion of Ukraine, mean that supply more generally is currently limited. The impact of an EU restriction on top of these external factors may further limit the baseline supply of both lead and lead-free bullets to the UK. Rimfire bullets are both domestically produced and imported from abroad. UK manufacturers have separate supply lines for military and civilian use, and so the same supply concerns linked to the Russian invasion of Ukraine are likely to be less impactful than for centrefire imports where bullets are produced on the same production lines irrespective of use.

2.5 Options analysis

There are uncontrolled risks to the environment and human health arising from the use of lead ammunition (see Sections 1.4 and 1.5). The Agency has therefore produced a list of potential risk management options that may be appropriate to reduce these risks. Each of these options was included on a long list that was then subject to scrutiny and development (HSE, 2022). From this long list a short list was developed by selecting only those options that the Agency considered were the most feasible and impactful. In particular, the options included in the short list are only those that have the potential to reduce or eliminate the risks identified for both the environment and human health. In addition, fiscal measures which were identified as options in HSE (2022) but not fully assessed were included in the short list. An analysis of each of the options on the short list was undertaken for each use, underpinned by information on uses, releases and availability of alternatives. The options considered potentially viable were then taken forward for assessment of the socio-economic impacts.

The short-listed options were assessed qualitatively against the criteria outlined in Annex 15 of UK REACH for assessing the appropriateness of a UK REACH restriction: effectiveness, practicality, monitorability and enforceability.

- Effectiveness: The restriction must be targeted to the effects or exposures that cause the risks identified, capable of reducing these risks to an acceptable level within a reasonable period of time and proportional to the risk (also with regards to the costs). For an option to be considered effective it must significantly reduce the risks to human health and/or the environment. If there is a lower reduction, or a reduction in only environmental or human health risk it will be concluded to be only partially effective and if there is little to no reduction then it will be concluded to be not effective. For the purposes of this assessment a reduction in exposure is considered to be equivalent to a reduction in risk. An assessment of the proportionality of the each shortlisted option is considered later in the impact assessment as part of the socio-economic analysis.

- Practicality: the restriction must be implementable, the technologies and alternatives must be available and economically feasible, the options should be understandable, and the means of implementation should be clear. It also includes considerations on the transition time required to implement the proposed restriction option. For an option to be considered practicable there must be feasible risk management measures, either management systems or installation of abatement measures which would significantly reduce the risks. If the installation of abatement or management measures would have a lower reduction, or a reduction in only environmental or human health exposure it will be concluded to be only partially practicable. If there is little to no reduction, then it will be concluded to not be practicable.

- Monitorability: the authority must identify methods to monitor the result of the implementation of the proposed restriction. For an option to be considered monitorable it must be possible to set up a clear mechanism to monitor the effectiveness of the option. If the option only allows a lower amount of monitoring it will be concluded to be only partially monitorable and if there is little to no monitoring possible then it will be concluded to be not monitorable.

- Enforceability: for each option to be considered enforceable the enforcing authorities must be able to ensure compliance by a clear and efficient supervision mechanism and have the required resources to do so. If the option does not have a clear mechanism, or there are potential loopholes, it would be concluded to be only partially enforceable. If there is no possible mechanism for ensuring compliance the option is concluded not to be enforceable.

Following the completion of the analysis of all the identified risk management options, the options that the Agency concluded would be effective and either fully or partially practicable, monitorable and enforceable were taken forward for further assessment in the impact assessment. This includes a consideration of the costs and benefits of the options.

The analyses for each of the use scenarios detailed in Table 1.4. have been completed below.

2.5.1 Lead in live quarry shooting

2.5.1.1 *Shot (Use #1)*

In this section the Agency reviews the options to mitigate the risks posed by lead shot when shooting live quarry:

The long list of options considered are:

RO1: Voluntary measures (as there is a voluntary scheme in place this is equivalent to a ‘do nothing’ option)

RO2: Fiscal measures

RO3: Require specific design / construction of lead shot

RO4: Ban on the placing on the market of game meat containing lead shot

RO5: Introduce a maximum level of lead in game meat

RO6: Advice to cut away meat when handling game killed by lead shot

RO7: Training programmes for hunters and pest control operators

RO8: Mandatory labelling of cartridge boxes and cartridges

RO9: Buy-back scheme for lead shot cartridges

RO10: Ban on placing on the market and use of lead shot for live quarry shooting

The options identified in the long list were assessed by the Agency in HSE (2022), with **RO1**, **RO2**, and **RO10** taken forward for the shortlist. These were the options that the Agency felt were the most feasible and impactful, and that had the potential to reduce or eliminate the risks to both human health and the environment.

The other options on the initial long list were not considered to be effective at reducing the risk for both the environment and human health. Although several of the options may reduce, though not eliminate, the risk of human exposure (such as RO4, RO5 and RO6), releases to the environment would not be reduced and so environmental risks would not be addressed.

2.5.1.1.1 RO1: Voluntary measures (do nothing)

Effectiveness

In February 2020, nine of the UK shooting and rural organisations produced a joint statement (BASC, 2020) which commits to using alternatives to lead ammunition for the shooting of live quarry by 2025. The signatories to the agreement are: Game and Wildlife Conservation Trust, British Game Alliance, British Association of Shooting and Conservation, Countryside Alliance, Country Land and Business Association, Moorland Association, National Gamekeepers Association, Scottish Lands and Estates and the UK-wide Shooting and Countryside Sports Advocacy. A voluntary move away from lead to non-lead alternative shot would eliminate future risks to the environment, and the risk to human health via game meat consumption would be removed immediately, if it was 100% successful.

While voluntary agreements are to be encouraged, they only work when all organisations and individuals who carry out the activity sign up to the voluntary measures and are committed to making the necessary changes. Those who disagree with voluntary measures may ignore them, for example, the Scottish Gamekeepers Association voiced their opposition when the announcement was made (Shooting UK, 2021). Concern was also raised by the four main manufacturers of steel shot in the UK who issued a joint statement highlighting the difficulty of transitioning to lead-free cartridges at the same time also moving away from plastic wads within the prescribed 5 years without additional support (The Field, (2020)), see also Section 2.2.3.4. In addition, some individuals who participate in shooting activities will not be members of a club or organised group and therefore would not be covered by this voluntary agreement. (Green et al., 2023) report that of the pheasants sampled that contained shot, 94% were lead shot. This indicates that there has been little progress so far in the voluntary initiative. The Agency anticipates the existing voluntary commitment to have reduced the use of lead shot for live quarry shooting by a marginal extent only by its target date of 2025. As mentioned in section 2.4, the Agency has assumed a 10% transition away from lead shot in 2025 under the baseline.

Regulations banning the use of lead shot for shooting over wetlands and certain bird species were introduced across GB between 1999 and 2004. Studies indicate that breaches of the Regulations are still high, with the proportion of ducks killed illegally with lead shot increasing from 68 to 77 % over surveys and analyses carried out from 2001 to 2013 (Cromie et al., 2015) and 87 % in the 2018/19 shooting season (Cromie et al., 2022). As the compliance with the existing legislative ban is low, voluntary measures are considered unlikely to be fully effective by themselves.

Practicality

The Agency assumes that a voluntary phase out is practical since the shooting organisations would not otherwise have announced their commitment to it. The use of lead shot is already banned over wetlands in GB, so non-lead alternatives are already available on the market and in use. In addition, Denmark banned the use of lead shot for live quarry shooting in 1992 (Kanstrup (2018), showing that live quarry shooting with alternatives is feasible and not detrimental to this use. Some of the shooting organisations have been holding shooting days where they invite shooters to try the lead-free alternative cartridges, therefore encouraging the switch to lead-free ammunition (BASC, 2023a). However, feedback received during the consultation by several shooting organisations report it to be unlikely that sufficient alternative cartridges will be available by 2025 for all those undertaking live quarry shooting.

Monitorability

Monitoring whether the voluntary measures are taken up might include checking what awareness raising each organisation is doing and what checks the voluntary schemes are making, for example whether they are present at shoots, looking at cartridges used etc. The success of this option is potentially monitorable as the carcasses of shot game can be sampled to ensure they do not contain any lead shot or fragments, where those carcasses enter the food chain or are available for sampling. However, not all carcasses are retrieved, some hunters keep the quarry they shoot for their own consumption and shot pests are commonly not collected so sampling in this case would not be possible. Cartridges are labelled for sale for target or live quarry shooting, as the shot pattern and load required is different for each type, however, there is some overlap between the uses. There is the potential for retailers of shot cartridges to monitor the sales of different types of cartridges to monitor whether there is a reduction in sales. This option is considered partially monitorable, particularly if there is co-ordination between the manufacturers, retailers and shooting organisations to monitor compliance.

Enforceability

Voluntary agreements are not underpinned by regulation and so cannot be enforced by regulatory bodies. It is possible that shooting organisations could perform spot checks during events or set up their own administrative compliance mechanisms, but these would need to be developed and are unlikely to cover all those who shoot live quarry. This option is not considered enforceable by the Agency, however compliance could be monitored by the shooting organisations and the progress reported to the Agency.

2.5.1.1.2 RO2: Fiscal measures

The introduction of a (Pigouvian) tax on the sale of lead shot could be used to influence the choices made by individual shooters.

By increasing the price of lead shot cartridges relative to alternatives, the tax would create an incentive to switch to alternatives. Any revenue raised could theoretically be used to support a consumer awareness programme, or fund projects to mitigate the environmental impact of lead pollution.

Effectiveness

The extent to which a Pigouvian tax would reduce the demand for lead shot depends on the cross-price elasticity of demand of alternative shot (XED). The Agency does not have data on the XED of alternative shot, but anticipates it to be price inelastic, meaning that a given percentage increase in lead shot price would yield a smaller increase in alternative shot demand. For instance, steel shot is already cheaper than lead shot, and can be used effectively in the majority of shotguns in current use. Despite this, its use in GB is currently very limited. This is indicative of inelastic XED and suggests that a given tax rate would correspond to a smaller percentage decrease in lead shot use. On this basis, the Agency concludes that fiscal measures would likely be ineffective at controlling the risk from this use.

Practicality

Such a tax may be costly and resource intensive to establish and maintain. Additionally, a tax burden could incentivise shooters to stockpile lead shot in advance or cast lead shot for home loading of cartridges to avoid paying tax. These potential issues lead the Agency to conclude that fiscal measures are not a practical option for controlling risk.

Monitorability

The impact of fiscal measures on the use of lead shot could likely be monitored via any sales data that are established during the process of implementing the tax, and any tax revenues raised. It could also be estimated based on sampling animal carcasses that were killed with shot; however, this would require introduction of a comprehensive program of sampling and analysis, which would require significant resource to undertake.

Enforceability

Domestically, the tax could be enforced by checking that suppliers of lead shot comply with the regulation. However, this would likely be challenging for lead shot that was imported into GB directly by consumers. As such, overall enforceability of this option may be limited.

2.5.1.1.3 R1O: Ban on placing on the market and use of lead shot for live quarry shooting

Effectiveness

A full ban on the placing on the market and use of lead shot for live quarry shooting would result in a 100 % reduction in the release of lead shot compared to the baseline and would therefore be effective in reducing future risks to the environment. Human exposure via game meat consumption would also be prevented as soon as the ban comes into force. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Practicality

Alternative ammunition is readily available. As discussed for option RO1, the main UK organisations representing shooting interests have acknowledged that a switch is feasible, alternatives perform effectively and have implemented a voluntary phaseout of lead shot for this use. As the use of lead shot over wetlands is already banned throughout GB this demonstrates that alternatives already exist and are in use now. Information provided during the public consultation indicates that 117 tonnes of steel cartridges are used per year, see *Table 1.10*. The Danish experience also shows that live quarry shooting with alternatives is not detrimental to this use. There is no indication that a lack of suitable alternative shot types, shot sizes, or other potential drawbacks of the shift from lead to non-lead shot in Denmark has changed the cost of live quarry shooting, the number of shooters, or their harvest (Kanstrup, 2015). Defining a transition time that allows sufficient volumes of non-lead alternative shot ammunition to be available on the market will be key to ensuring this option is practical.

Monitorability

Cartridges are labelled for sale for target or live quarry shooting, as the shot pattern and load required are different for each type. A ban on the placing on the market of shot cartridges for live quarry shooting is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly. A monitorable ban on sales alone should be sufficient to determine the effectiveness of this option. It could also be estimated based on sampling animal carcasses that were killed with shot; however, this would require introduction of a comprehensive program of sampling and analysis, which would require significant resource to undertake

Enforceability

This option is enforceable by regulatory authorities (for example the Environment Agency in England) as it involves control at the point of sale and compliance can be monitored remotely. Compliance visits could be carried out at relevant premises, either those identified as potentially non-compliant or on a random basis.

Enforcement in the field would not be practical in GB, and so the enforceability of this option relies on control at the point of sale. The available information indicates that compliance with the existing partial restriction of lead shot for live quarry shooting over wetlands is low. Introducing a full ban on supply and use of lead shot for all live quarry shooting over all terrains is easier to enforce and should result in high compliance.

The Agency understands that different cartridges are used for live quarry shooting and target shooting. As such, the Agency does not anticipate live quarry shooters using target shooting cartridges as these would be less effective than the non-lead alternatives but cannot rule out the possibility that some individuals may continue to use lead shot designed for target shooting in the pursuit of live quarry. This would be avoided if lead shot was also restricted for use in target shooting.

2.5.1.1.4 Summary of risk management options for live quarry shooting with lead shot

Table 2.5 Restriction options for *live quarry shooting* with lead shot

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
1	Voluntary measures (do nothing)	No	Yes	Partially	No
2	Fiscal measures	No	No	Yes	Partially
10	Ban on placing on the market	Yes	Yes	Yes	Yes

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
	and use of lead shot for live quarry shooting				

The only option to reduce risks to both the environment and human health that would be fully effective, practical, monitorable, and enforceable is a ban on the placing on the market and use of lead shot for live quarry shooting (RO10). The same conclusion was drawn by LAG (2015a) and ECHA (2021b). This has also been the experience in Denmark where lead shot was banned in 1992 for live quarry shooting.

The Agency estimates that this option would avoid the release of roughly 21,600t lead over a 20-year time period, for more detail see section 2.6.1.1.5. This analysis is based on a 5-year transition period for lead shot cartridges to allow the manufacturers sufficient time to be able to produce the quantity of predominantly steel shot cartridges required.

The costs and benefits of the preferred option, and whether this is deemed proportionate by the Agency, are assessed in Sections 2.6 and 2.8.

2.5.1.2 *Bullets (Use #2)*

In this section the Agency reviews the options to mitigate the risks posed by lead-containing bullets when shooting live quarry.

The long list of options considered are:

RO1: Voluntary measures (do nothing)

RO2: Fiscal measures

RO3: Require specific design / construction of lead bullets

RO4: Ban on the placing on the market of meat collected with lead bullets

RO5: Introduce a maximum level of lead in game meat

RO6: Advice to cut away meat when handling game killed with lead bullets

RO7: Training programmes for hunters and pest control operators

RO8: Mandatory labelling of packaging

RO9: Buy back scheme for lead bullets

RO10a: Ban of small calibre lead bullets for live quarry shooting

RO10b: Ban of large calibre lead bullets for live quarry shooting

The options identified in the long list were assessed by the Agency in HSE (2022), with **RO1**, **RO2** and **RO10** taken forward for the shortlist. These were the options that the Agency felt were the most feasible and impactful, and that had the potential to reduce or eliminate the risks to both human health and the environment. RO10 has been expanded to include a ban on the marketing of bullets for live quarry shooting, as well as their use.

The other options on the initial long list were not considered to be effective at reducing the risk for both the environment and human health. Although several of the options may reduce, though not eliminate, the risk of human exposure (such as RO4, RO5 and RO6) releases to the environment would not be reduced, so the resulting environmental risks would not be addressed.

2.5.1.2.1 RO1: Voluntary measures (do nothing)

Effectiveness

The voluntary phase out announced by the shooting industry in 2020 only covers the use of lead shot in live quarry shooting and therefore would not be effective in the mitigation of risks from lead bullets. The Agency does not know whether shooting organisations would be prepared to extend their voluntary measures to include bullets.

According to ECHA (2017a), Forestry England (formerly Forest Enterprise England) required their staff to use non-lead ammunition for deer and boar culling in 2016, based on concerns for the health of consumers of game meat, and to protect this organisation’s marketing position. Other organisations could in theory follow a similar path, however, the Agency does not consider it likely that a full switch away from lead bullets will happen under the baseline scenario of do nothing. As such, this option is not considered effective in controlling the risk from lead bullets.

Practicality

The availability of suitable alternatives varies depending on the size of bullet. For large calibre bullets, the Agency considers current alternatives to be of similar effectiveness (in terms of accuracy and lethality) to lead bullets and so a voluntary transition away from lead would be practical. There has been a move away from lead bullets for the hunting of deer. For example, some of the Approved Game Handling Establishments announced that from August 2021 they would no longer buy venison shot with lead (British Deer Society, 2021) and the National Game Dealers

Association committed that its members will no longer be accepting game shot with lead ammunition from July 2022 (National Game Dealers Association, 2021).

The Agency considers current small calibre (and particularly rimfire) alternatives to perform less well in general than lead bullets, which would limit the practicality of a voluntary transition until further development has taken place.

Monitorability

Monitoring whether voluntary measures are taken up might include checking what awareness raising each organisation is doing and what checks the voluntary schemes are making, for example whether they are present at shoots, looking at bullets used etc. The success of this option is potentially partially monitorable as the carcasses of shot game can be sampled to ensure they do not contain any lead bullets or fragments. However, if shooters choose not to retrieve carcasses in some circumstances, sampling would not be possible. Such monitoring may also be resource-intensive to undertake.

Enforceability

Voluntary agreements are not underpinned by regulation and so cannot be enforced by regulatory bodies. As such, this option is not enforceable.

2.5.1.2.2 RO2: Fiscal measures

The introduction of a (Pigouvian) tax on the sale of lead bullets could be used to influence the choices made by individual shooters.

By increasing the price of lead bullets relative to alternatives, the tax would create an incentive to switch to alternatives. Any revenue raised could theoretically be used to support a consumer awareness programme, or fund projects to mitigate the environmental impact of lead pollution.

Effectiveness

The extent to which a Pigouvian tax reduce would reduce the demand for lead bullets depends on the cross-price elasticity of demand of alternative bullets (XED). The Agency does not have data on the XED of alternatives bullets, but anticipates it to be price inelastic, meaning that a given percentage increase in the price of lead bullets would yield a smaller increase in alternative bullet demand. The Agency also anticipates XED to be more inelastic for small calibre bullets as the alternatives for small calibre bullets perform relatively less well compared to lead than is the case for large calibre bullets. On the basis of this assumed inelastic XED, the Agency concludes that fiscal measures would likely be ineffective at controlling the risk from this use.

Practicality

Such a tax may be costly and resource intensive to establish and maintain. Additionally, a tax burden could incentivise shooters to stockpile lead bullets in advance (up to the limit allowable under their firearms certificate) or cast unjacketed small calibre lead bullets for home reloading to avoid paying tax. These potential issues lead the Agency to conclude that fiscal measures are not a practical option for controlling risk.

Monitorability

The impact of fiscal measures on the use of lead bullets could likely be monitored via any sales data that are established during the process of implementing the tax, and any tax revenues raised. It could also be estimated based on sampling animal carcasses that were killed with bullets; however, this would require introduction of a comprehensive program of sampling and analysis, which would require resource to undertake.

Enforceability

Domestically, the tax could be enforced by checking that suppliers of lead bullets comply with the regulation. However, this would likely be challenging for lead bullets that are imported into GB directly by consumers. As such, overall enforceability of this option may be limited.

2.5.1.2.3 RO10a: Ban of the placing on the market and use of small calibre lead bullets for live quarry shooting

Effectiveness

A ban on the placing on the market and use of small calibre lead bullets (<6.5 mm centrefire and rimfire in general) would be effective in removing both the environmental and human health risks. This ban would result in a 100% reduction in releases (roughly 3 tonnes per year). Secondary poisoning of wildlife and human exposure via game meat consumption would be prevented as soon as the ban comes into force. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Individual hunters would be limited in building up stocks of ammunition before a ban comes into effect based on the quantities allowable under their firearms certificate.

Practicality

The Agency does not generally consider there to be well performing small calibre alternatives currently available, given regulatory constraints around bullet weights for specific quarry, product availability and supply, and limitations of accuracy, energy transfer and noise moderation (particularly for .22 rimfire). The Danish experience is that currently the market does not have suitable substitutes for rimfire ammunition and therefore it is not covered by the Danish lead ban for hunting. As such, the Agency does not currently consider this option to be practical, though the Agency anticipates that if this option were selected it would incentivise further research and development which may induce progress in quality and availability of alternatives. This, in turn, would increase the practicality of this option. The proposed ECHA restriction may also have a similar impact.

Monitorability

A ban on the placing on the market of expanding small calibre bullets for live quarry shooting is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly. A monitorable ban on sales alone should be sufficient to determine the effectiveness of this option. It could also be estimated based on sampling animal carcasses that were killed with lead bullets; however, this would require introduction of a comprehensive program of sampling and analysis, which would require significant resource to undertake.

Enforceability

The Agency understands that different bullet types are typically used for live quarry shooting and target shooting disciplines. This is due to the need for bullets used to shoot live quarry to expand upon impact. However, the Agency understands that this is only a legal requirement for bullets used to pursue deer. It is currently unclear if there are situations where non-expanding bullets (of sufficient velocity) would be used to pursue smaller quarry. Since bullets for indoor target shooting must remain available for sale, the Agency considers there may be challenges in the control of lead bullets for live quarry shooting at the point of sale. Enforcement in the field would not be practical in GB, so the enforceability of this option relies on control at the point of sale.

2.5.1.2.4 RO10b: Ban of the placing on the market and use of large calibre lead bullets for live quarry shooting

Effectiveness

A ban on the placing on the market and use of large calibre lead bullets (≥ 6.5 mm) for live quarry shooting would result in a 100% reduction in releases (roughly 1 tonne per year), and in turn be an effective measure to remove both the human health and environmental risks of this use. Secondary poisoning of wildlife and human exposure via game meat consumption would be prevented as soon as the ban comes into force. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Individual hunters would be limited in building up stocks of ammunition before a ban comes into effect based on the quantities allowable under their Fire Arms Certificate.

Practicality

The Agency considers there to be a range of well-performing lead-free alternatives to large calibre lead bullets currently available. Therefore, the Agency considers this option to be practical.

Monitorability

A ban on the placing on the market of expanding large calibre bullets for live quarry shooting is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly. A monitorable ban on sales alone should be sufficient to determine the effectiveness of this option. It could also be estimated based on sampling animal carcasses that were killed with lead bullets; however, this would require introduction of a comprehensive program of sampling and analysis, which would require significant resource to undertake.

Enforceability

The Agency understands that different bullets are typically used for the live quarry shooting and target shooting disciplines due to the need for bullets used to shoot quarry to expand upon impact. For example, the Deer Act 1991 already makes it illegal to use non-expanding (i.e. target shooting) ammunition to shoot deer. Furthermore, the non-expanding nature of the bullets means they may not transfer sufficient energy or cause enough damage to vital organs to be lethal in the short term, resulting in wounding rather than killing outright and risking the quarry escaping. Nonetheless, it is currently unclear if there are situations where non-expanding bullets (of sufficient velocity) would be used to pursue quarry for which the use of expanding bullets is not mandated. It also remains unclear whether there are valid, necessary uses for expanding ammunition outside of live quarry shooting. Since bullets for indoor target shooting must remain available for sale, the Agency considers there may be challenges in the control of lead bullets for live quarry shooting at the point of sale. Enforcement in the field would not be practical in GB, so the enforceability of this option relies on control at the point of sale.

2.5.1.2.5 Summary of risk management options for live quarry shooting with bullets

Table 2.6 Restriction options for live quarry shooting with lead bullets

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
1	Voluntary measures	No	Partially	Partially	No
2	Fiscal measures	No	No	Yes	Partially
10a	Ban on the placing on the market and use of small calibre lead bullets for live quarry shooting	Yes	No	Yes	No
10b	Ban on the placing on the market and use of large calibre lead bullets for live quarry shooting	Yes	Yes	Yes	No

The only option the Agency identified that is likely to be effective in reducing risks to both the environment and human health is a ban on the placing on the market and use of lead bullets for shooting live quarry (RO10a and RO10b). For larger calibre bullets this is considered practical due to the availability of suitable non-lead alternatives on the GB market. However, this is currently impractical for small calibres as the alternatives are in an earlier stage of development and testing than for larger calibre bullets. If a restriction was put in place across all calibres, a longer transition period may be granted to smaller calibre bullets to allow for sufficient time to develop more suitable alternatives.

A lack of precise information on the varied use scenarios for expanding or non-expanding bullets leads to uncertainties around enforcement. At this stage, the Agency is unable to determine whether and to what extent lead bullets that remain available for target shooting would continue to be purchased for target shooting but actually used for live quarry shooting (which would be unlawful in the event that a restriction is implemented). Such an outcome would undermine the effectiveness of a restriction on the placing on the market of lead bullets for live quarry shooting. Work is continuing to attempt to resolve some of the above uncertainties, and the Agency will consider any further information received during the second public consultation on these matters.

A 5-year transition period may be a proportionate transition period for small calibre bullets if a restriction is undertaken. In the event of restriction on large calibre bullets, the Agency has not identified similar challenges to those of small calibre that warrant a transition period of equal length. As such, a shorter transition away from lead, perhaps of 3 years, may be more appropriate.

The Agency estimates that a restriction on the placing on the market and use of small and large calibre lead bullets would avoid the releases of 27t and 21t lead, respectively, over a 20-year time-period. This analysis is based on a 5-year transition period for small calibre bullets and a 3-year transition period for large calibre bullets.

The costs and benefits of such a restriction, and whether this is deemed proportionate by the Agency, are assessed in Sections 2.7 and 2.8.

2.5.1.3 *Airgun ammunition (Use #3)*

In this section the Agency reviews the options to mitigate the risks posed by lead airgun ammunition when shooting live quarry. This use was incorporated in the assessment of live quarry shooting with small calibre bullets in HSE (2022) as the Agency did not have sufficient information available to assess this use separately. Following the provision of additional information during the public consultation, the Agency has assessed the options. Of all the options considered for live quarry shooting with small calibre bullets, only a ban on the placing on the market and use was considered to be effective at reducing the risks to the environment and human health. Therefore, this option has also been considered for airgun ammunition.

Airgun ammunition typically comprises waisted 'diabolo' style (a solid head containing the centre-mass and thin-walled skirt), 'BB' style or cylindro-conoidal slug style. Airgun ammunition is used for live quarry shooting, outdoor target shooting and indoor target shooting. The same ammunition is shot for all uses (except for BB's which are generally used for target shooting/plinking) and therefore a ban on the placing on the market of lead airgun ammunition cannot be considered as this would prevent sales for the indoor uses that are out of scope. The Agency has therefore considered a ban on the use of lead airgun ammunition for live quarry shooting.

2.5.1.3.1 RO1: Ban on the use of lead airgun ammunition for live quarry shooting

Effectiveness

A ban on the use of lead airgun ammunition for live quarry shooting would result in a 100 % reduction in release of lead and would therefore be effective in reducing future risks to the environment. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Practicality

Although non-lead alternatives are available, significant concerns remain regarding product availability, accuracy, lethality and unacceptable ricochet risk, particularly for legal limit (sub-12 ft/lbs) and 'springer-type' airguns. Current non-lead alternatives are generally unacceptable for the majority of airguns. This is mainly due to the density of available materials and the limited energy available to an airgun. In Denmark, lead airgun projectiles are currently excluded from the ban for ammunition used for hunting with rifles as there are *"no substitutes"*. Public consultation responses indicate that there has been limited uptake of non-lead alternatives for live quarry shooting, with a minority of respondents reporting positive experiences of non-lead alternatives. The Agency considers a ban on the use is impractical.

Monitorability

A ban on use for live quarry shooting would not be monitorable checking carcasses in a monitoring scheme as many of the quarry killed using airguns do not enter the food chain.

Enforceability

The Agency does not have a reliable estimate of how many people own and shoot airguns. In England and Wales legal limit airguns (air rifle producing a muzzle energy ≤ 12 ft/lb or an air pistol producing a muzzle energy ≤ 6 ft/lb) do not require a Fire Arms Certificate, and the only restriction is age (i.e., minimum of 18 years to buy or possess a legal limit airgun or ammunition, or minimum of 14 years on private premises with the consent of the occupier). In Scotland licensing of airguns was introduced in 2015, however, possession of airgun ammunition is not covered by the Act. Estimates from industry stakeholders suggest between 4 million and 9 million airgun owners

Lead airgun ammunition is not covered by existing licensing regimes in England, Wales or Scotland. Therefore the sale of lead airgun ammunition is much wider and not limited to ammunition retailers, but is also available through online retail, sporting shops, country/farm supplies, hardware shops and garden centres etc. Indoor use at target shooting ranges, which constitutes 80% of the total airgun ammunition use in GB (BBSC, Organisation #100) is out of scope of this restriction, so ammunition would still be available on the GB market even if a ban on live quarry shooting came into force.

A ban on the use of lead airgun ammunition would further be difficult to enforce, given that most of the live quarry use is often informal (i.e., not an organised/commercial shoot), on private land and practised alone.

The Agency considers that this option is unenforceable, due to the continued legal sales for indoor target shooting use, uncontrolled supply and impracticality of enforcing in the field.

2.5.1.3.2 Summary of risk management options for live quarry shooting with airgun ammunition

Table 2.7 Restriction options for live quarry shooting with airgun ammunition

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
1	Ban on the use of lead airgun ammunition for live quarry shooting	Yes	No	No	No

The only option that could reduce risks to the environment would be a ban on the use of lead airgun ammunition for live quarry shooting. However, there are no viable alternatives for many airguns and ammunition will still be available for sale for indoor use so a ban on use would not be practical, monitorable, or enforceable. The Agency was unable to identify a risk management option to be taken forward to the SEA for this use.

2.5.2 Lead in target shooting

2.5.2.1 *Shot (Use #4)*

In this Section the Agency reviews the options to mitigate the risks posed by lead shot used for target shooting.

The long list of options considered are:

RO1: Voluntary measures

RO2: Fiscal measures

RO3: Require specific design / construction of lead shot

RO4: Mandatory labelling of cartridge boxes and cartridges

RO5: Buy-back scheme for lead shot cartridges

RO6: Ban on placing on the market and use of lead shot for target shooting

RO7: Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and athletes

RO8: Ban on use of lead shot for target shooting with a derogation for licensed sites with risk management measures

RO9: Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and licensed athletes at specific sites

The options identified in the long list were assessed by the Agency in HSE (2022). The options taken forward for the short list were **RO2**, **RO6**, **RO7, RO8** and **RO9**:

The other options on the initial long list were not considered to be effective at reducing the risk to the environment. RO1 has not been shortlisted, as was the case for live quarry shooting with shot. This is because the voluntary phase out announced by the shooting industry (BASC, 2020) only covers the use of lead shot in live quarry hunting and therefore would not be effective in the mitigation of risks from target shooting. Although a similar voluntary phase out could be feasible, comments received during the call for evidence suggest there is currently little appetite for such an approach within GB. Effectiveness is therefore likely to be low for this option.

2.5.2.1.1 RO2: Fiscal measures

The introduction of a (Pigouvian) tax on the sale of lead shot could be used to influence the choices made by individual shooters.

By increasing the price of lead shot relative to alternatives, the tax would create an incentive to switch to alternatives. by increasing their costs and thereby making alternatives more attractive. Any revenue raised could theoretically be used to support a consumer awareness programme, or fund projects to mitigate the environmental impact of lead pollution.

Effectiveness

The extent to which a Pigouvian tax reduce would reduce the demand for lead shot depends on the cross-price elasticity of demand of alternative shot (XED). The Agency does not have data on the XED of alternatives shot, but anticipates it to be price inelastic, meaning that a given percentage increase in lead shot price would yield a smaller increase in alternative shot demand. For instance, steel shot is already cheaper than lead shot, and can be used effectively in the majority of shotguns in current use. Despite this, its use is currently very limited. This is indicative of inelastic XED and suggests that a given tax rate would correspond to a smaller percentage decrease in lead shot use. On this basis, the Agency concludes that fiscal measures would likely be ineffective at controlling the risk from this use.

Practicality

Such a tax may be costly and resource intensive to establish and maintain. Additionally, a tax burden could incentivise shooters to stockpile lead shot in advance or cast lead shot for home loading of cartridges to avoid paying tax. These potential issues lead the Agency to conclude that fiscal measures are not a practical option for controlling risk.

Monitorability

The impact of fiscal measures on the use of lead shot could likely be monitored via any sales data that is established during the process of implementing the tax. It could also be estimated based on sampling animal carcasses that were killed with shot.

Enforceability

Domestically, the tax could be enforced by checking that suppliers of lead shot comply with the regulation. However, this would likely be challenging for lead shot that was imported into GB directly by consumers. As such, overall enforceability of this option may be limited.

2.5.2.1.2 RO6: Ban on placing on the market and use of lead shot for target shooting

Effectiveness

A full ban on the use of lead shot for target shooting would result in a 100% reduction in release of lead shot and would therefore be effective in reducing the risks to the environment. Under this option, an estimated 80,400t of lead emissions would be avoided over a 20-year period. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Additional steps may also be necessary to minimise the risk of individual shooters building up large stocks of lead shot before a sales ban comes into effect.

Practicality

Alternative non-lead ammunition that performs efficiently is readily available. However, for GB athletes competing at an international level this option is not practical, for example ISSF rules dictate that lead shot must be used in international shotgun sports competition (such as the Olympic Games). As such, although this option would be relatively practical to implement, it would have significant practical implications for how international athletes trained for their sport, with feedback received during the consultation period indicating that this would be detrimental for the prospects of those shooters.

Monitorability

Cartridges are labelled for sale for target or live quarry shooting, as the shot pattern and load required are different for each type. A ban on the placing on the market of lead shot cartridges for target shooting is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly. A monitorable ban on sales alone should be sufficient to determine the effectiveness of this option. However, as target shooting generally takes place on an organised basis involving either fixed or mobile locations, the operators on these ranges could check the shooters are not using lead shot cartridges.

Enforceability

This option is enforceable by regulatory authorities (for example the Environment Agency in England) as it involves control at the point of sale and compliance can be monitored remotely. Compliance visits could be carried out at relevant premises, either those identified as potentially non-compliant or on a random basis.. Compliance visits could also be made at ranges to ensure that they have the appropriate measures in place to ensure no lead shot is being used on site.

2.5.2.1.3 RO7: Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and athletes

Effectiveness

This option is a ban on the placing on the market and use of lead shot for target shooting but with a derogation for licensed suppliers to sell and licensed individuals to use lead shot. This would allow athletes subject to international sporting requirements to train and compete in sports where lead shot is still required by the relevant governing bodies, as mentioned in Section 1.1.2.1.2. Recreational target shooters who are not required to use lead shot would be required to use alternatives (as in RO6). These sites would not be required to implement specific RMMs for all risks, due to the practicality concerns outlined in RO8.

CPSA, in a meeting on 6/3/2023, estimated that there are 30 people in the British Shooting Olympic academy, who are actively training for the next or subsequent Olympic Games and 170 people in the British Shooting development programme. These numbers are similar to the numbers submitted by the NRA (organisation #127) during the public consultation. In their consultation response, the NRA estimated there to be 200 ‘elite’ GB athletes, 60 of whom are ‘top athletes’ and 140 of whom are ‘pathway athletes’, citing British Shooting as their source for the figures, these descriptions, however, were not defined in the response. Through further engagement with representatives from key shooting organisations, including the Clay Pigeon Shooting Association and the British Sports Shooting Council, the Agency believes that a reasonable derogation could license up to 50 athletes at one time, with the athletes in question updated over time. The decision maker may decide to derogate more or fewer athletes than this, but the Agency will later present impacts under the assumption that the top 50 athletes are allowed to continue using lead ammunition.

The NRA also estimates that the top 60 athletes use, on average, 20,000-30,000 lead shot cartridges each per year. The Agency takes the mid-point of this estimate, 25,000, as the average annual cartridge use per top 60 athlete.

Using manufacturer sales data provided by Blake International, 2022 (Organisation #132) to derive the average weight of lead used per target shooting cartridge, the Agency estimates that a derogation for 50 athletes would result in annual emissions of 37t lead once in place, compared to 5,360t per year under the baseline (and 0 under RO6). Totalled across a 20-year period, this option would avoid the emissions of an estimated 79,800t of lead compared to the baseline. Once in place, this constitutes an annual emissions reduction in this use of >99% compared to the baseline.

Although this option would reduce >99% of the annual emissions of lead from this use, an estimated 37t of lead would still be emitted per year due to the continued use of lead shot by athletes continuing under the derogation. Some risk to the environment would still remain from these emissions and as such, this option cannot be considered 100% effective in controlling risk. If this derogation was implemented, there should be no agricultural use (crops or grazing) within the site boundary at sites where the licensed athletes use lead shot to prevent risks to livestock. Nonetheless, it is a significant reduction compared to the baseline annual emissions of 5,360t.

Practicality

A regulatory system would need to be set up to implement this option which would identify the relevant authority(ies) responsible for granting licences to suppliers and individuals. Issues around which organisations would be responsible, and the exact logistics of this option could be worked through during the transition period proposed by the Agency. This option could impose administrative and cost burdens that may not be considered proportionate, in which case this option would resemble that of RO6 with no uptake of the derogation. However, if the supply of cartridges could be made directly from the manufacturers to the athletes then this option does become more practicable. This option is being explored by the Agency and British Shooting.

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual athletes and their suppliers, which could involve annual reporting of the number of suppliers licensed to sell lead shot (and the amounts involved) as well as the number of licensed individuals. However, this option would require records to be kept by both the retailer and potentially the athlete.

A supply chain could also be set up directly from manufacturers to licensed individuals and in turn monitored and therefore there is no need to issue licences to retailers. This option is being explored by the Agency and British Shooting. If the supply directly from manufacturers to athletes can be introduced this option is simpler than a licencing scheme for retailers as there would be no legal sale of lead cartridges for target shooting through any retailers as there would be fewer actors involved and less risk of non-licensed shooters being able to source lead shot.

Enforceability

On the basis that all sale of lead cartridges is banned, except the supply directly from the manufacturers to the designated athletes this option is enforceable. A ban on the sale is considered enforceable as the compliance can be monitored at the point of sale and compliance can be monitored remotely. Compliance visits could be carried out at relevant premises, either those identified as potentially non-compliant or on a random basis. It is not expected that those training for the Olympics would share their ammunition with other shooters due to the risk of them losing their licence. Records could be kept by the athletes to show how many cartridges they have received, from which manufacturer and where they have been shot, this would help to show compliance.

2.5.2.1.4 RO8: Ban on the use of lead shot for target shooting with a derogation for licensed sites with risk management measures

Effectiveness

This option is a ban on the use of lead shot with a derogation for shooting ranges that have adequate risk management measures (RMMs) in place to limit lead releases. This would likely not remove all the risks associated with this use, due to limitations in the effectiveness of RMMs, but would reduce them. This would allow the continued use of lead shot cartridges at specific locations, by all users at these sites, ensuring that athletes competing at international competition can continue to train with the lead ammunition as specified by international sports governing bodies, in addition to more casual shooters who do not wish to incur any costs that they would accrue under a switch to steel (such as replacing their shotgun if necessary). This option would not include a ban on the marketing of lead shot for target shooting.

Relevant RMM conditions would need to be specified. HSE (2022) considered the scenario where licensed sites would be required to reduce 90% of emissions via RMMs. Feedback during the consultation, and subsequent engagement with relevant parties, leads the Agency to conclude that such a recovery rate is neither technically nor economically feasible, and as such is also unlikely to be implemented voluntarily. This will be considered further under the category of ‘practicality’.

This option would reduce risk to a certain extent, depending on the conditions specified. Sites would implement RMMs to this standard on a judgement of economic and technical feasibility, and the proportion of sites implementing such RMMs, and number of shooters who use these sites to use lead ammunition, would dictate the extent to which emissions (and therefore risk) is reduced. The Agency cannot make further conclusions on effectiveness due to the uncertainty of how such a programme would practically operate, as discussed below.

Practicality

The CPSA (organisation 101) notes in their consultation response that the Nuthampstead Shooting Ground (considered more widely to be the most effective shotgun target shooting lead recovery programme currently in place in the UK), achieves an estimated recovery rate of 75%. The CPSA also note that this is a trap shooting site and that 70% of CPSA sites are sporting grounds where such reclamation would not be possible due to the topography and shot fallout on these grounds. For example, sporting grounds can be in wooded areas where reclamation would be highly impractical, or even forbidden in the case of the National Shooting Centre at Bisley due to its SSSI status. The recovery system in place at Nuthampstead, an earth berm 25m high and 300m long and covered in plastic, would require planning permission to be installed at other sites. The Agency understands that this differs from the experience in some countries in continental Europe, where the majority of sites are trap grounds meaning that reclamation is more feasible. However, even on trap grounds the Agency is doubtful of the technical and economic feasibility of such an approach.

Through engagement with industry, the Agency concludes that any recovery requirement similar to 90%, or even lower than this, would likely not be technically or economically feasible for the vast majority, if not all, sites. As such, the Agency does not consider RO8 to be a practical option.

Additionally, relevant authority(ies) would have to be responsible for granting licences to sites. Standards for verifying that a given level of recovery has been achieved would also need to be established. Some sites might not choose to use the derogation if such verification was costly or burdensome for them.

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual sites, which could involve annual reporting of the amount of lead shot used at each site. The site operators would need to demonstrate that the necessary operational conditions and RMMs were in place to ensure that the minimum recovery rate is met. This information could be made publicly available, either by the site operator or the relevant authority(ies).

Enforceability

This option is enforceable as checks could be made that site operators have the appropriate licences in place. Issues around which organisations would be responsible would require further consideration. However, unless the lead shot were only made available via the site operator, shooters could still buy lead shot from suppliers and use it at non-licensed sites (or for live quarry shooting) and this could be more difficult to check. Due to the use of lead shot to date, and as spent lead shot is not typically removed from these sites, it would be difficult to determine whether lead shot found at a non-licensed site demonstrated non-compliance or historical use.

2.5.2.1.5 RO9: Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and licensed athletes at specific sites.

Effectiveness

This option is similar to that of RO7, with the addition of specifying specific sites where licensed athletes are able to continue their use of lead shot. These sites would not be required to implement specific RMMs for all risks, due to the concerns around practicality outlined in RO8. However, if this derogation was implemented, there should be no agricultural use (crops or grazing) within the site boundary to prevent risks to livestock. The effectiveness of this option should in theory be no different to that of RO7, because the same athletes would be using the same quantity of lead shot, just at specific sites.

Practicality

The practicality of this option is the same as that of RO7, with the additional requirement of licencing of specific sites. This would add to any administrative burden and during the transition period thought would need to be given to where these sites would be located, and how many would be licensed at any given time. This decision could be based on several considerations, such as inherent environmental site risk (e.g. variables such proximity to surface and groundwater), proximity to the identified athletes, etc. Owners of certain sites may be very keen to be involved to allow the identified athletes to train, whereas others may not wish to be involved due to the administrative burden or other reasons (e.g. financial impact).

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual athletes, suppliers and shooting ranges, which could involve annual reporting of the number of licensed individuals as well as the amount of lead shot sold and shot used at each site.

Each site would also need to keep records showing that the only people allowed to shoot with lead shot are the professional athletes who hold a licence. This issue can be further developed during the transition period.

Enforceability

This option is partially enforceable as checks could be made on both individuals and site operators to ensure they have the appropriate licences in place. Due to the use of lead shot to date, and as spent lead shot is not typically removed from these sites, it would be difficult to determine whether lead shot found at a non-licensed site demonstrated non-compliance or historical use.

2.5.2.1.6 Summary of risk management options for lead shot for target shooting

Table 2.8 Restriction options for target shooting with lead shot

Risk Management Option		Effectiveness	Practicality	Monitorability	Enforceability
2	Fiscal measures	No	No	Yes	Partially
6	Ban on placing on the market and use of lead shot for target shooting	Yes	Partially	Yes	Yes
7	Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and athletes	Partially	Yes	Yes	Yes

Risk Management Option		Effectiveness	Practicality	Monitorability	Enforceability
8	Ban on use of lead shot for target shooting with a derogation for licensed sites with risk management measures	Partially	No	Yes	No
9	Ban on placing on the market and use of lead shot for target shooting with a derogation for licensed suppliers and licensed athletes at specific sites.	Partially	Partially	Yes	Partially

The only option that would be fully effective at eliminating risk, monitorable and enforceable in principle is a ban on the placing on the market and use of lead shot for target shooting.

However, this option is not fully practical as the use of lead shot cartridges is currently required by some sport's governing bodies (such as the IOC). A restriction with derogation would allow for individual athletes as identified by the appropriate sporting body to continue to train and compete with lead shot. The Agency considers the only derogation that would be realistically feasible is that of a select number of athletes, supplied directly by the manufacturer, being allowed to continue to use lead shot on any site. The implementation of this derogation would mean that the restriction would not be fully effective in reducing risks to the environment. However, the Agency estimates that less than 1% of emissions currently occurring under the baseline would continue under this option. As will be explored later in the SEA, the Agency considers this intervention to be the most cost-effective measure, and more desirable from a socio-economic perspective than a blanket restriction. This derogation could be indefinite or time-limited. If time-limited it could be paired with action to influence the international sports governing bodies to change their rules to allow for a full restriction of lead shot in target shooting without undesired impacts on British athletes.

If a restriction, or restriction plus derogation, was selected, a transition period of 5 years is proposed to give manufacturers sufficient time to increase production of alternatives, in addition to allowing sufficient time to establish the list of athletes possessing derogated use and the specifics of operating this. This is consistent with the 5-year transition period recommended if a live quarry shooting restriction is selected.

Once in place, the avoided lead release under a restriction plus derogated athlete use is estimated to be 5,323t per year compared to the baseline, summing to roughly 79,800t across a 20-year time-period. Compared to a blanket restriction, 37t of lead are estimated to be released per year. This release constitutes less than 1% of current annual emissions from target shooting with lead shot and would allow for the continued practice of British shooters with lead shot being able to compete in a variety of international competition, such as the Olympic Games where 46 Olympic medals have been won by team GB across the three shooting sports, one of which is the shotgun discipline (Team GB, 2023).

The costs and benefits of the preferred options are assessed in Sections 2.6 and 2.8.

2.5.2.2 *Bullets (Use #5*

In this section the Agency reviews the options to mitigate the risks posed by lead bullets used for target shooting. In general specific calibres are used for smallbore and full-bore target shooting. The basic calibres used in many of the ISSF and IBU events are .22LR (smallbore) and .30 - .38 (full-bore) (ECHA, 2022). ISSF regulations state that .22 rifle and pistol disciplines requires bullets made of lead or other soft material. For full-bore the stipulation is ammunition of any description that may be fired without danger to the athletes or range personnel (ISSF, 2023a).

The long list of options considered are:

RO1: Voluntary measures

RO2: Fiscal measures

RO3: Mandatory labelling of packaging

RO4: Buy-back scheme for lead bullets

RO5a: Ban of use of small calibre lead bullets for target shooting

RO5b: Ban of use of large calibre lead bullets for target shooting

RO6: Ban on placing on the market and use of lead bullets with a derogation for licensed suppliers and licensed athletes

RO7: Ban on use of lead bullets with a derogation for sites with appropriate risk management measures

The options identified in the long list were assessed by the Agency in HSE (2022). The options taken forward for the short list were **RO2**, **RO5a**, **RO5b**, and **RO7**.

The other options on the initial long list were not considered to be effective at reducing the risk for both the environment and human health. RO1 has not been shortlisted, as was the case for live quarry shooting with bullets. Although a similar voluntary phase out could be feasible for this use, comments received during the call for evidence suggest there is currently little appetite for such an approach within GB. Effectiveness is therefore likely to be low for this option.

2.5.2.2.1 RO2 Fiscal measures

The introduction of a (Pigouvian) tax on the sale of lead bullets could be used to influence the choices made by individual shooters.

By increasing the price of lead bullets relative to alternatives, the tax would create an incentive to switch to alternatives. Any revenue raised could theoretically be used to support a consumer awareness programme, or fund projects to mitigate the environmental impact of lead pollution.

Effectiveness

The extent to which a Pigouvian tax would reduce the demand for lead bullets depends on the cross-price elasticity of demand of alternative bullets (XED). The Agency does not have data on the XED of alternatives bullets, but anticipates it to be price inelastic, meaning that a given percentage increase in the price of lead bullets would yield a smaller increase in alternative bullet demand. The Agency also anticipates XED to be more inelastic for small calibre bullets than for large calibre bullets as the alternatives for small calibre bullets perform relatively less well compared to lead than is the case for large calibre bullets. On the basis of this assumed inelastic XED, the Agency concludes that fiscal measures would likely be ineffective at controlling the risk from this use.

Practicality

Such a tax may be costly and resource intensive to establish and maintain.

Additionally, a tax burden could incentivise shooters to stockpile lead bullets in advance (up to the limit allowable under their Fire Arms Certificate) or cast unjacketed small calibre lead bullets for home reloading to avoid paying tax. These potential issues lead the Agency to conclude that fiscal measures are not a practical option for controlling risk. Additionally, as the NRA and NSRA do not currently allow for non-lead bullets to be used on their ranges, it can be assumed that very little to no switch away from lead would occur in the absence of such stipulations being revised. This further limits the practicality of this option.

Monitorability

The impact of fiscal measures on the use of lead bullets could likely be monitored via any sales data that are established during the process of implementing the tax, and any tax revenues raised.

Enforceability

Domestically, the tax could be enforced by checking that suppliers of lead bullets comply with the regulation. However, this would likely be challenging for lead bullets that are imported into GB directly by consumers. As such, overall enforceability of this option may be limited.

2.5.2.2.2 RO5a: Ban on use of small calibre (<6.5mm) lead bullets for target shooting

Effectiveness

A use ban on the use of small calibre lead bullets (generally .22 rimfire) for target shooting would be effective in reducing environmental risks. A full ban on the use of lead bullets for sports shooting would result in a 100 % reduction in release of lead bullets (roughly 2 tonnes per year). A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Individual shooters would be limited in building up stocks of ammunition before a ban comes into effect based on the quantities allowable under their Fire Arms Certificate.

Practicality

The Agency considers that viable .22 rimfire bullets that deliver the necessary accuracy and precision to be suitable for smallbore competition standard do not currently exist. Non-lead alternatives for competition would need to be accepted by sports governing bodies up to international level. Additionally, the majority of shooting ranges affiliated to the sports governing bodies (e.g., NRA, NSRA) do not allow use of any ammunition other than jacketed lead core or solid lead bullets. This option may therefore have limited practicality for the time being. Currently, non-lead monolithic bullets are not permitted to be used on any range covered by the NRA or NSRA as discussed in Section 2.2.

Monitorability

The Agency considers that a ban on use of lead bullets for outdoor target shooting would be monitorable through compliance reports submitted by range operators. However, small calibre bullets would still be available on the market for indoor target shooting which would limit the ability to effectively monitor and interpret sales data from ammunition suppliers.

Enforceability

The enforceability of this option by regulatory authorities as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges which are outside the scope of this restriction. However, as target shooting is undertaken in formal settings (i.e., shooting ranges), compliance with range operator conditions would be required. Compliance reports could be submitted by the shooting industry.

2.5.2.2.3 RO5b: Ban on use of large calibre lead bullets for target shooting

Effectiveness

A ban on the use of large calibre (≥6.5 mm centrefire) lead bullets would be effective in reducing environmental risks. A ban on the use of lead bullets for sports shooting would result in a 100 % reduction in release of lead bullets (1 tonne per year). A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

Individual shooters would be limited in building up stocks of ammunition before a ban comes into effect based on the quantities allowable under their Fire Arms Certificate.

Practicality

The Agency considers supply and availability of lead-free bullets for full-bore target shooting is currently very limited, and of uncertain performance although industry development is ongoing. Non-lead alternatives for competition would need to be accepted by sports governing bodies up to international level. Additionally, the majority of shooting ranges affiliated to the sports governing bodies (e.g., NRA, NSRA) do not allow use of any ammunition other than jacketed lead core or solid lead bullets. Therefore, the Agency considers that this option is currently impractical.

Monitorability

The Agency considers that a ban on use of lead bullets for outdoor target shooting would be monitorable through compliance reports submitted by range operators. However, large calibre bullets would still be available on the market for indoor target shooting which would limit the ability to effectively monitor and interpret sales data from ammunition suppliers.

Enforceability

The enforceability of this option by regulatory authorities as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges. However, as target shooting is undertaken in formal settings (i.e., shooting ranges), compliance with range operator conditions would be required. Compliance reports could be submitted by the shooting industry.

2.5.2.2.4 RO7: Ban on use of lead bullets for target shooting with a derogation for sites with appropriate risk management measures

This option would be applicable to both large and small calibre bullets.

Effectiveness

This option is a ban on the use of lead bullets for target shooting with derogation for ranges that have adequate risk management measures to limit lead releases. Risks to soil, water and livestock are expected to occur if lead bullets are left uncollected over longer periods of time. It is therefore considered possible to mitigate against the identified risks by the implementation of appropriate risk management measures at shooting ranges. This option would allow the continued use of lead bullets at specific locations by all users of these sites, and therefore ensure that sportsmen and women can continue to train with the ammunition required by their governing bodies and military and police training can continue on civilian ranges.

Relevant conditions would need to be specified. As discussed in Section 1.3.4 the risks posed by lead bullets can be reduced by using bullet containment and recovery of lead bullets. The guidance on range design requires bullet capture for safety reasons and in many instances this is expected to be sufficient to control the risks.

Practicability

ECHA (2021c) states that in the '*CSR (2020) bullet containment is required*' and therefore this option is practicable. Responses to the GB call for evidence (Section 1.4.3.1) indicated that risk management measures achieving 90 % lead recovery are already in place at some shooting ranges in GB, indicating that this appears to be a practical option. As there are existing requirements for bullet capture on ranges for safety reasons it is expected that all ranges will have bullet capture and recovery.

This restriction option allows the continued use of lead bullets at sites that have demonstrated that appropriate management measures to reduce the environmental risk are in place by all users, ensuring that international competitors can continue to train with the required ammunition.

Monitorability

This restriction option is monitorable as the sites would have to apply to use lead on their sites and would need to demonstrate that the necessary operational conditions and risk management measures were in place.

Enforceability

This option is enforceable as checks could be made that site operators have the appropriate risk management measures in place to allow the continued use of lead bullets. Sites could be required to notify that they have the appropriate risk management measures in place, allowing the relevant enforcement authority to have a list of sites available. Compliance reports could be submitted by the shooting industry, sports governing bodies and range operators. Due to the use of lead bullets to date, it would be difficult to determine whether lead bullets found at sites that do not have the appropriate risk management measures in place demonstrate non-compliance or historical use.

2.5.2.2.5 Summary of risk management options for target shooting with lead bullets

Table 2.9 Restriction options for target shooting with lead bullets

Risk Management Option		Effectiveness	Practicability	Monitorability	Enforceability
2	Fiscal measures	No	No	Yes	Partially
5a	Ban of small calibre lead bullets for target shooting	Yes	No	Yes	Partially
5b	Ban of large calibre lead bullets for target shooting	Yes	No	Yes	Partially

Risk Management Option		Effectiveness	Practicability	Monitorability	Enforceability
7	Ban of lead bullets for target shooting with derogation for sites with appropriate risk management measures	Yes	Yes	Yes	Partially

RO7 is the only risk management option that the Agency considers effective, monitorable, practical and enforceable in principle. Due to the environmental risks identified and the range of risk mitigation measures available, the Agency considers that the risks from this use can be managed via the use of risk management measures at the shooting ranges. Therefore, a derogation allowing the use of lead-containing bullets at ranges where risks to the environment from this activity are reduced by the use of appropriate lead containment and recovery, is taken forward for further consideration within the SEA. A similar conclusion was drawn by ECHA (2021b).

Risk management measures are already recommended in the EU REACH registration dossier for metallic lead to ensure safe use, and the Agency anticipates that they will also be included in the full UK REACH registration dossier when it is submitted in due course. Further, as there are already requirements for bullet capture on GB ranges for safety reasons it is expected that all ranges will have bullet capture and recovery.

Target shooting ranges would need to demonstrate that the necessary operational conditions and risk management measures are in place to ensure recovery of deposited lead (e.g. using appropriate lead collection systems). Information provided during the call for evidence indicated that risk management measures achieving above 90 % lead recovery are already in place at some shooting ranges in GB.

The use of lead bullets is currently required by some sport’s governing bodies and so this derogation would allow athletes to continue to train and compete at shooting ranges that have the appropriate risk management measures in place.

Transition periods have been proposed to allow for the implementation of appropriate risk management measures at sites which do not already have these in place. A transition period of 2 years is proposed for the ban on the use of lead bullets for target shooting with a derogation for those sites with risk management measures, due to the expectation that shooting ranges may already have risk management measures in place sufficient to meet the proposed derogation or that these can be readily installed.

The avoided lead release from this option (RO7) are estimated at 93t over 20 years. The costs and benefits of the preferred option are assessed in Sections 2.7 and 2.8.

2.5.2.3 *Airgun ammunition (Use #6)*

In this section the Agency reviews the options to mitigate the risks posed by lead airgun ammunition when target shooting. Although identified as a separate use in HSE (2022) the Agency did not have sufficient information available in order to assess the options for this use. Instead, the options considered for target shooting with small calibre bullets were considered to be appropriate for this use. Following the provision of additional information during the public consultation, the Agency has re-assessed the options.

As discussed in more detail in Section 1.4.3.4 lead airgun ammunition is used for live quarry and indoor and outdoor target shooting and therefore a ban on the placing on the market of lead airgun ammunition cannot be considered as this would prevent sales for the indoor uses that are out of scope. Of all the options considered for target shooting with small calibre bullets, a ban on use with a derogation for licensed sites with appropriate risk management measures was considered to be appropriate to take forward into the socioeconomic analysis. Therefore, this option has also been considered for airgun ammunition.

2.5.2.3.1 RO1: Ban on the use of lead airgun ammunition for target shooting with a derogation for licensed sites

Effectiveness

This option is a ban on the use of lead airgun ammunition for outdoor target shooting with a derogation for ranges that have adequate RMMs to limit lead releases. Risks to soil, water and livestock are expected to occur if lead airgun ammunition is left uncollected over longer periods of time. It is therefore considered possible to mitigate against the identified risks by the implementation of appropriate risk management measures at shooting ranges. This option would allow the continued use of lead airgun ammunition at specific locations by all users of these sites.

Practicality

Although non-lead alternatives are available, significant concerns remain regarding product availability, accuracy and unacceptable ricochet risk, particularly for legal limit (sub-12 ft/lbs) and ‘springer-type’ airguns. Currently there are no viable alternatives for competition target shooting that would deliver the required level of accuracy and precision. For instance, according to BSSC (Organisation #100) '*target shooting at 10m requires extreme precision'* and the non-lead alternatives do not deliver this. Furthermore, national and international sports governing bodies, including the International Sports Shooting Federation (ISSF) and the Federation International des Armes de Chasse (FITASC) stipulate the use of lead ammunition for airgun competitions. Recovery of the lead at many ranges is possible as they have ammunition catchers, although this is generally not done at Practical Shooting sites as these are more dynamic sites where the targets are moved around frequently and the setup of these sites would be negatively affected by requiring pellet capture. This option is therefore not considered practical.

Monitorability

This restriction option is monitorable as the sites would have to apply for licences to use lead on their sites and would need to demonstrate that the necessary operational conditions and risk management measures were in place to ensure a minimum lead recovery and have no agricultural land within the shooting area. The volume of lead used on each of these sites would be reported to allow the GB authorities to ensure compliance. However, the use of lead airgun ammunition takes place not only in formal shooting settings, such as ranges or field target sites, but also informally taking place on private land, such as farmland and back gardens, so these would be impossible to monitor. The Agency considers monitorability of any ban on the use is impractical.

Enforceability

This option is enforceable as checks could be made that site operators have the appropriate risk management measures in place to allow the continued use of lead airgun ammunition. Issues around which organisations would be responsible would require further consideration, together with how the scheme would be operated. Compliance reports could be submitted by the shooting industry, sports governing bodies and range operators. Due to the use of lead airgun ammunition to date, it would be difficult to determine whether lead airgun ammunition found at sites that do not have the appropriate risk management measures in place demonstrate non-compliance or historical use.

The Agency does not have a reliable estimate of how many people own and shoot airguns. In England and Wales legal limit airguns (air rifle producing a muzzle energy ≤ 12 ft/lb or an air pistol producing a muzzle energy ≤ 6 ft/lb) do not require a Fire Arms Certificate, and the only restriction is age (i.e., minimum of 18 years to buy or possess a legal limit airgun or ammunition, or minimum of 14 years on private premises with the consent of the occupier). In Scotland licensing of airguns was introduced in 2015, however, possession of airgun ammunition is not covered by the Act. Estimates from industry stakeholders suggest between 4 million and 9 million airgun owners as discussed in Section 1.4.3.4.

Lead airgun ammunition is not covered by existing licensing regimes in England, Wales or Scotland. Therefore, the sale of lead airgun ammunition is much wider and not limited to ammunition retailers, but is also available through online retail, sporting shops, country/farm supplies, hardware shops and garden centres etc. While airgun target shooting represents approximately 90% of the outdoor uses, outdoor shooting only represents 20% of the total use (BSSC, Organisation #100).

A ban on the use of lead airgun ammunition in outdoor settings without risk management measures will be difficult to enforce, as it takes place not only in formal shooting settings, such as ranges or field target sites, but also informally taking place on private land, such as farm land and back gardens.

The Agency considers that this option is unenforceable, due to the continued legal sales for indoor target shooting use, uncontrolled supply and impracticality of enforcing in the field.

2.5.2.3.2 Summary of risk management options for target shooting with airgun ammunition

Table 2.10 Restriction options for outdoor target shooting with airgun ammunition

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
1	Ban on use for lead airgun ammunition for outdoor target shooting with derogation for licensed sites	Yes	No	No	No

The option considered would reduce risks to the environment. However, there are no viable alternatives for many airguns and the ammunition will still be available for sale for indoor use so a ban would not be practical, monitorable, or enforceable. The Agency was unable to identify a risk management option to be taken forward to the SEA for this use.

2.6 Economic analysis of options considered effective, practical, monitorable and enforceable

This section details the Agency's economic analysis of the options identified as effective, practical, monitorable and enforceable. Costs of the options are first presented, beginning with those of the shot uses, followed by the bullet uses. Benefits of the options are subsequently outlined.

A cost-effectiveness approach has been undertaken for each option, with supporting qualitative analysis wherever costs cannot be quantified. The cost-effectiveness framework uses tonnage release of lead as a proxy for risk. For the shot uses, a cost-benefit framework is also used as the Agency has been able to partially monetise the benefits of restrictions on these uses. This has not been possible for the bullet uses because no quantitative risk assessment has been undertaken here.

2.6.1 Costs of intervention-lead shot

Following the options analysis, this section will assess the costs of the restriction on the shot uses, including assessing the impact of the proposed derogation for individual athletes as identified by the appropriate sporting body level on certain sites.

When modelling the impacts, the Agency used the ratio of tonnage releases from LQS versus TS (23:77) to apportion impacts where relevant. For instance, where a restriction on the use of lead shot requires the purchase of new shotguns, the Agency assumes that 23% of the total cost of new shotguns to be attributable to a restriction on LQS, and 77% attributable to TS. This assumption is necessary to circumvent certain data gaps, such as the exact share of shotguns owned that are attributed to each use. As such, the Agency assumes that the share of shotguns owned for LQS and TS equal the share of total shot emissions that each use makes up.

The Agency does not anticipate research and development costs, nor familiarisation costs, to occur as a result of restricting this use. Suitable alternatives to lead shot are already widely available and as such this research and development is assumed to have already occurred. Familiarisation costs are not considered because the Agency believes that shooters are already familiar with the topic of lead-free alternatives and what it would mean for them. For instance, BASC have held several sustainable shooting days where shooters are able to try alternatives and learn what it means for their shotguns. Additionally, if shooters are not familiar with what a restriction would mean for them, they may find this out whilst partaking ordinarily in a shoot. The Agency doubts that such conversation amongst fellow practitioners would induce a welfare loss in shooters that could be classified as a familiarisation cost.

The total costs of a restriction are dictated by the responses taken by each shooter to restriction. Restriction imposes costs on the market for the shooting activities and in turn will lead to a new equilibrium. Shooters face several options in response to restriction. For instance, a shooter owning only one shotgun, which cannot shoot steel shot (including with modification) but can shoot bismuth shot, faces the following options following restriction:

1) Replace this shotgun with one suitable for shooting steel shot
2) Continue use of this shotgun but with bismuth shot
3) Cease shooting activities
4) Some combination of options, including option 1 or 2 plus reducing their activity. For instance, they could buy a new shotgun suitable for steel shot which they will predominantly use, occasionally using their existing shotgun with bismuth. Or, they may continue to use their existing shotgun with bismuth but reduce their overall activity due to the increased price of bismuth relative to lead.

Ultimately, each shooter's response to a restriction will depend on their preferences, which are in turn dictated by their personal circumstances. A shooter with 10 guns, 9 of which can shoot steel, and the remaining shotgun can only shoot bismuth, may retire the use of the 10th shotgun, and continue the use of the other 9 with steel shot. However, were this 10th shotgun to be the only shotgun owned by another shooter, they may retire it and replace it with a shotgun suited to steel or continue using it with bismuth shot. As such, the outcome of this individual shotgun varies from being retired, retired and replaced, or continually used with bismuth depending on who owns that shotgun. Equally, a shooter that only occasionally shoots but whose shotgun(s) is/are unsuitable for steel use may prefer to switch to bismuth rather than buy a new shotgun and use the cheaper alternative of steel.

One factor influencing shooter response is the distribution of shotguns owned among shooters. As at 31st March 2022, the average shotgun certificate holder in England and Wales owns 2.6 shotguns, with their being 522,627 shotgun certificate holders and 1,367,579 shotguns covered by these certificate (Home Office, 2021). However, the underlying distribution of this average will impact the costs of restriction. If, hypothetically, 522,626 shotgun certificate holders owned 1 shotgun, and 1 certificate holder owned 844,953 shotguns, the social welfare implications of a restriction would likely be different to if the underlying distribution were much more equal (for instance, no one owning more than 3 shotguns). But in either case, the mean number of shotguns held is 2.6. The Agency does not have access to the dataset underpinning this average, and so cannot investigate this further.

To account for the both the inherent complexity and uncertainty of estimating the new equilibrium under restriction, several key simplifying assumptions are made during the modelling of impacts. These will be explored in the relevant sections of this SEA. To account for the impacts of any uncertainty in these assumptions, the Agency undertakes sensitivity analysis, in addition to using conservative assumptions where possible. More information can be found in Section 2.7.

2.6.1.1 *Restriction on live quarry shooting with lead shot*

The Agency has identified and monetised the following costs that are likely to arise from restricting the use of lead shot in LQS:

- Shooter substitution costs
- Costs to manufacturers
- Climate impacts
- Enforcement costs

2.6.1.1.1 Shooter substitution costs

The Agency anticipates that, under a restriction on LQS with lead shot, a variety of costs would occur directly to shooters in substituting away from lead shot to alternative shot. These costs can be classified as either one-off or on-going costs.

In terms of one-off costs, shooters may face:

- The cost of purchasing a new shotgun in order to shoot alternatives to lead shot
- The cost of modifying their existing shotguns(s) in order to shoot alternatives to lead shot
- Any re-proof that may be required after such modifications.

In terms of on-going costs, shooters may face:

- Costs due to more expensive alternative ammunition.

As outlined at the beginning of section 2.5, the costs of restriction depend greatly on the actions taken by shooters in response to restriction. The following simplifying assumptions have been taken to model impacts of restriction:

1) The Agency assumes that 73% of shotguns in use can instantly switch to (standard) steel shot without modification or re-proof. This is based on the results of the GunsOnPegs & Lycetts 2022 census [personal communication Guns on Pegs], seen by the Agency, where they find that that 73% of game shooters surveyed ‘do not need to make any equipment changes in order to use steel shot’.

2) The Agency assumes that a further 5% of shotguns in use could use steel shot following modification. This is based on the BSSC consultation response (Organisation #100) where they estimate that 60% of 'traditional side-by-side shotguns' are 'older shotguns…which are not suited to most currently produced steel shot cartridges'. Using population estimates within ONS (2021), this equals an estimated 319,670 shotguns for GB, constituting 22% of the estimated total number of shotguns in GB. This implies that 78% of shotguns could use steel, and as such the Agency assumes that the difference between this figure and that of GunsOnPegs represents the number of shotguns that need to undergo modification (such as changes to choke) in order to shoot steel (5%). The Agency also assumes that all of these modifications will take the shotguns out of proof, and as such they will all need re-proof. This is a conservative assumption; minor modifications such as small changes to choke should not take a shotgun out of proof. Nonetheless, the Agency assumes all modified guns to be re-proofed due to uncertainty in exactly what share would be re-proofed in reality.

3) The Agency assumes that all shotguns in current use that can use steel shot do use it in the event of restriction. Steel shot has a significantly lower unit price than bismuth shot (and slightly lower than lead shot), in addition to performing similarly to lead. As such, the Agency does not see a rationale for a shooter choosing bismuth shot if they are able to use steel in their gun(s). Therefore, the Agency assumes that **78% of shotguns will use steel shot post-restriction**, with 5% of these requiring modification and re-proof. The Agency notes that this is a far more conservative estimate than that used in ECHA's Annex 15 dossier (ECHA, 2022a) where the dossier submitter assumed 85% of shotguns are assumed to use steel in the worst-case and central scenarios. SEAC noted that they consider this assumption to be 'overly conservative' and **recalculated the central scenario to equal 95%.** As such, the GB estimate is significantly more conservative than that used in the EU. If the Agency were to use a 95% estimate this would **significantly decrease the estimated costs of restriction**. The Agency does consider 78% to be a conservative assumption, however, has been informed during the public consultation that British shooters are fond of older shotguns (MLAGB); Organisation #121) which may mean that a lower percentage are able to shoot steel than those of the EU.

4) The Agency assumes that no shooters will leave their respective shooting discipline as a result of the restriction. It may be that if faced with, for example, replacing a new shotgun or using bismuth shot, some shooters will cease all shooting activity instead. However, the Agency does not

have information on the proportion of shooters that this may be relevant to.

5) Following on from assumption 4, where a shooter is unable to shoot steel shot in any of their guns (with or without modification), they are assumed to either replace this gun, or switch to bismuth and continue its use. In the central scenarios of analysis, they Agency has assigned an arbitrary 50:50 split in the absence of evidence on the likelihood of the average shooter deciding to replace their shotgun vs continue its use with bismuth. Impacts are explored in the sensitivity analysis within the range of 100% of affected shooters replacing their gun, to 100% of affected shooters switching to bismuth shot. As previously mentioned, some combination of responses is also possible. The Agency acknowledges that not every shooter who owns a gun unsuited to steel will replace this gun or continue its use with bismuth. Shooters who own multiple guns may just cease use of such shotguns. This does not, however, mean that they are not faced with a cost. Rather, it suggests that the shooter's welfare loss from:

   1) *purchasing a new gun and using this in combination with their other shotguns*

   is more significant than the welfare loss from:

   2) *retiring that gun from use and switching 100% of use to their other shotguns.*

   The Agency conducted desktop research of popular shotguns used in both live quarry and target shooting, calculating an average shotgun price of £2,232 and £2,096 respectively. This price data is used as a proxy to estimate the welfare loss resulting from shotguns that are no longer used: either a) replaced (in which case the Agency assumes that the utility from the replaced shotgun compensates the foregone utility of the retired shotgun, with the opportunity cost of purchasing the new shotgun (£2,232 or £2,096) constituting the welfare loss to the shooter) or b) not replaced. In reality, a shooter who retires a shotgun unsuited to steel may be willing to pay more, less, or equal to £2,232 or £2,096 for the ability to continue use of their particular affected shotgun. Nonetheless, in the absence of such data, the Agency uses the prices above as proxies of the welfare loss induced due to owning a shotgun that cannot use steel. The Agency notes that, all things equal, the greater the difference in welfare between states 1 and 2 above, the greater the probability that its owner will continue to use it with bismuth shot. This should reduce the risk that the proxy used by the Agency to estimate the welfare loss in those that do not retire their gun is unsuitable.

Following on from these assumptions, the Agency calculates the one-off substitution costs faced by shooters as follows:

1) Replacement cost of unsuited shotguns

The Agency assumes that these shotguns will be replaced uniformly across the 5-year transition period proposed. As such, 1/5th of the replaced shotguns (50% of unsuited shotguns in the central case) that can be attributed to a LQS restriction (on a tonnage ratio basis, 23%) are replaced on an annual basis across 5 years. This can be expressed as:

0.5 * 319,670 * 0.23 * 0.2 = 7,352.

Multiplying this estimated number of shotguns replaced per year by the assumed price of £2,232 gives an estimated annual replacement cost of £16,407,500. Totalled across the 5-year period, this equals **£82.0m** (undiscounted).

2) Modification costs

As outlined earlier in this subsection, the Agency assumes that 5% of shotguns will be modified in order to use steel shot. The Agency assumes these modifications to take place uniformly across the 5-year transition period proposed. As such, 1/5th of this 5% of shotguns that can be attributed to a LQS restriction (on a tonnage ratio basis, 23%) are modified on an annual basis across 5 years. This can be expressed as:

0.05 * 1,482,254 * 0.23 * 0.2 = 3,409.

The price of such modification will vary by the modification completed, in addition to other factors such as the shotgun being modified and geographical region of GB. The Agency assumes a modification cost of £225 based on one London-based gunsmith's price of an 'over & under service' (as at late-2022 (London Gun Company, 2022)). The Agency anticipates that the most common modification will be changes to choke, which are considered likely to cost less than £225 on average. Additionally, the Agency understands that some shooters will be able to modify their own choke, and as such will not accrue a gunsmith cost, only a time-foregone cost. Overall, the Agency considers £225 to be an overestimate of the average cost of the shotgun modifications assumed to occur in 5% of cases but takes it forward as a conservative assumption. As such, the estimated modification costs are £0.77m on an annual basis, summing to **£3.8m** over a 5-year period (undiscounted).

3) Proof costs

As previously mentioned in this subsection, the Agency assumes that all modified shotguns are re-proofed. As such, 3,409 additional shotguns are assumed to be proofed per year across 5 years as a result of restriction compared to the baseline. Using the data from the London Proof House (2022), the Agency assumes an average proof cost of £31.17 per shotgun. Using this cost, the estimated annual proof cost is £0.1m, summing to **£0.5m** across the 5-year period (undiscounted).

In terms of on-going costs, the Agency calculates the following impact:

1) Ammunition cost

Based on (Blake International, 2022 Organisation #132) (Hurley, 2022), the Agency estimates the following baseline number of cartridges to be used in GB per year for LQS:

Lead: 54,160,820

Steel: 1,716,895

Other metals (primarily bismuth): 258,071.

BASC (2022) estimate the following average prices per set of 250 cartridges:

Lead: £129

Steel: £112

Bismuth: £422.

Using these data, the Agency estimates the baseline expenditure on shotgun cartridges (including the assumption that the voluntary measures will lead to a 10% reduction in LQS lead shot use in 2025), to which a transition away from lead can be compared. The Agency applies the bismuth price to the ‘other metals’ category of shot, in the absence of up-to-date price data on other non-bismuth alternatives. In the sensitivity analysis, the Agency inflates the price of steel overtime to test the impact that relatively more expensive steel shot prices would have. This is done to challenge the assumption that switching to steel from lead represents a cost saving to shooters, which is currently the case.

Using the data above, in 2024, prior to the assumed impact of the voluntary transition away from lead shot, the Agency estimates £29.2m to be spent on shotgun cartridges by GB shooters under the baseline. On an annual basis from 2025 onwards, the Agency estimates a total baseline expenditure on shotgun cartridges for live quarry use of £29.7m. This is comprised of £25.2m on lead cartridges, £2.9m on steel cartridges, and £1.6m on other metals.

The Agency estimates that this figure will rise to £32.9m in the case of restriction, comprising a **£3.2m** annual increase in the expenditure on shot cartridges for LQS. This cost is a combination of transitioning to cheaper steel shot as well as more expensive bismuth shot, with the net result being a increased cost to shooters due to the significantly greater relative price of bismuth to lead than steel to lead. The Agency notes that to break even, a post-restriction ratio of steel:bismuth shot cartridges of ~95:5 would be required (beyond which a cost saving would occur). The Agency's central scenario sees a ratio of ~89:11.

Totalled across the 20-year appraisal period, this additional ammunition cost equals **£48.0m** (undiscounted).

The sum of the total estimated shooter substitution costs across the 20-year appraisal period is **£134.5m** in undiscounted terms, and **£112.9m** in PV terms. This is the sum of shotgun substitution costs, modification costs, re-proof costs and increased ammunition costs.

2.6.1.1.2 Costs to manufacturers

Blake International, (2022, Organisation #132) (Hurley, 2022) examine and audit the UK shotgun cartridge manufacturing industry to estimate the costs of a complete transition away from lead shot. They conclude that such a transition would cost manufacturers an estimated £20.89m over 5 years. Given that the Agency has assumed a 10% transition away from lead under the baseline, in addition to ECHA's proposed restriction on lead, it may be that some or much of these costs would have occurred under the baseline. This is strengthened by the discussion in section 2.4.1 which suggests that the UK has comparative advantage in the trade (export) of steel shot. Due to uncertainty in the extent to which this may be true, the Agency will make the conservative assumption that the entirety of these costs can be attributed to the restriction. It could be reasonable to assume that 10% of the share of this cost that can be attributed to a LQS restriction would have been incurred anyway under the baseline. However, the Agency deems much of this cost likely to only occur during a significant transition, rather than one of 10%.

This cost is broken down as follows:

1) Cartridge filling machinery

Due to steel shot being potentially sparking, abrasive and exhibiting different flow and fill characteristics, manufacturers sheath certain components of machinery when filling steel. This means that processing steel filled cartridges is slower than lead, with the report estimating this to reduce capacity by 40%. As a result, the report states that manufacturers believe they will need to expand production capacity by between 15 and 19 high output filling machines to transition away from lead, with an estimated capital cost of £6.675m.

2) Injection moulding machinery and tools

The report notes that a transition from lead to steel shot requires full cup cartridge wads. This in turn requires additional wad production capacity, meaning manufacturers will be required to invest in and/or lease injection moulding equipment to develop their own injection moulds. The report estimates this process to cost £1.865m in terms of injection moulding equipment and £2.98m in dies and tools.

3) Buildings and infrastructure

Filling machinery is typically located in block wall bays as a blast safety precaution. The report notes that most manufacturing sites will require additional storage areas and/or warehousing to accommodate new inventory, in addition to potentially requiring new buildings to house injection moulding equipment. The report estimates that this impact will cost manufacturers £2.95m.

4) Site decontamination

The report notes that transitioning away from lead shot production will require manufacturers to decontaminate production areas that were previously used for lead shot, estimated to cost £0.2m.

5) Working capital expansion

The report notes that a transition away from lead to steel will likely require an expansion in manufacturers' working capital. This is due to sourcing steel from China, where credit requirements will change, in addition to the need to maintain buffer stocks to mitigate supply chain shipping disruption risk. The report estimates that this will cost manufacturers £6.42m across the transition period.

In totality, (Blake International, 2022 Organisation #132) (Hurley, 2022) estimates additional costs to manufacturers of £20.89m across a 5-year transition period from lead to steel. The Agency accepts this analysis. Weighting this value by the share of lead shot attributable to LQS (23%) results in an estimated manufacturer cost from a restriction on LQS with shot of **£4.9m** in undiscounted terms and **£4.5m** in PV terms. The Agency assumes this cost to be accrue uniformly across the 5-year transition period, equalling £0.97m on an annual basis (undiscounted).

2.6.1.1.3 Climate impacts

The Agency uses emissions factors (EF) provided by the Bureau of International Recycling (BIR, 2008) to estimate the resulting change in greenhouse gas (GHG) emissions from a transition from lead shot to alternatives. Because the primary shot alternative in the case of restriction will be steel, the Agency compares the changes in GHG from a switch from lead shot to steel shot and assumes that the EF for bismuth equals that of lead, in the absence of a BIR EF for bismuth. In any case, bismuth shot would likely constitute a relatively small share of shot used post-restriction.

Various factors impact the EF of producing a given metal from its ore. For instance, a variety of different furnace methods can be used to produce steel, each with different GHG emissions. EFs also vary greatly depending on whether primary or secondary production is occurring.

BIR (2008) propose a primary production EF for lead of 1.63tCO2/t Pb (blast furnace). They estimate a secondary production EF of 0.015tCO2/t Pb.

For steel, they propose a primary production EF for steel of 1.67tCO2/t Steel (blast furnace-basic oxygen furnace). For secondary production, the EF is estimated to be 0.7tCO2/t steel (electric arc furnace).

(Blake International, 2022 Organisation #132) (Hurley, 2022) state that steel shot cannot be made from recycled steel due to it being contaminated with harder steel allows and having a low carbon specification. They note that replacing lead shot for steel will add ~1.65tCO2/t of shot, implying that 100% of lead shot is currently made from recycled lead. Additionally, they note that under a lead shot restriction, steel will be sourced from China to produce steel shot. They estimate that this will add 0.3tCO2/t to the BIR (2008) EF for steel. The Agency weights this for the share that is attributable to a LQS restriction (23%) to estimate an imported primary steel EF of 1.74tCO2/t.

The worst-case scenario in terms of climate impacts is one where lead shot, under the baseline, is domestically produced entirely from recycled lead, and under a restriction steel shot is produced from 100% primarily produced steel imported from afar (presumed to be China). The Agency cannot validate that this is the likely reality of a restriction but will use the scenario as a conservative assumption. The Agency also notes that even if lead were sourced domestically and not from China, this does not mean that it is free of transport emissions. Nonetheless, any transport emissions from domestically sourced lead are likely negligible when compared to metal shipped from China to the UK.

Under the baseline, the Agency estimates 1,601t of lead shot to be used on an annual basis for LQS (1,441t from 2025 onwards), in addition to 26t (152t) of steel shot and 4t (27t) of non-steel alternatives. Using the respective EFs outlined above, the Agency estimates the annual baseline GHG emissions[4] from producing shotgun

[4] It should be noted that the Agency is not here undertaking a thorough life-cycle assessment of shot

cartridges to be:

<u>2024</u>

Lead + non-steel alternatives: 0.015 * (1,601 + 5) = 24tCO2

Steel: 1.74 * 24 = 45tCO2

<u>2025 onwards</u>

Lead + non-steel alternatives: 0.015 * (1,441 + 27) = 22tCO2

Steel: 1.74 * 152 = 264tCO2

Under the Agency's central restriction scenario, it is estimated that 1,286t of steel shot will be used on an annual basis, in addition to 173t of bismuth shot. This total weight of metal used on shot is lower than under the baseline. This is due to steel being less dense than lead, meaning that an equal sized ball bearing made from lead will weigh more than that made of steel. To adjust the weight of steel used in the average shot cartridge, the Agency has used the quantity figures provided by (Blake International, 2022 Organisation #132) (Hurley, 2022). Dividing the number of lead cartridges sold on an annual basis by the weight of lead used in these cartridges gives an average shot weight of 0.028t. For steel, this is lower at 0.026t. The Agency adjusts the metal volumes accordingly. Using the respective EFs outlined above, the Agency estimates the annual restriction GHG emissions[5] from producing shotgun cartridges to be:

Bismuth: 0.015 * (173) = 3tCO2

Steel: 1.74 * 1,286 = 2,236tCO2

Based on this analysis, the Agency assumes that a restriction will result in 2,239tCO2/year compared to 286tCO2/year under the baseline (from 2025 onwards). This equals an annual addition of 1,953tCO2. Using the BEIS (2021) carbon values for the corresponding year, the climate impacts from restriction can be estimated at **£9.4m** across the 20-year appraisal period in undiscounted terms, and **£6.2m** in PV terms.

2.6.1.1.4 Enforcement and compliance-check costs

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cartridges. The estimates GHG emissions from the various types of shot are not complete as there are undoubtedly other sources from emissions when producing shot cartridges (such as production of the wad). Nonetheless, this approach allows for a relative comparison of lead shot to that of steel.

[5] It should be noted that the Agency is not undertaking a thorough life-cycle assessment of shot cartridges. The estimated GHG emissions from the various types of shot are not complete as there are undoubtedly other sources of emissions when producing shot cartridges (such as production of the wad). Nonetheless, this approach allows for a relative comparison of lead shot to that of steel.

Based on discussions with Environment Agency enforcement experts, the Agency estimate that the necessary compliance checks under a restriction would cost **£10,800** across the 20-year appraisal period in undiscounted terms, and **£7,200** in PV terms. This cost is based on the FTE requirements anticipated by the Agency to undertake the relevant compliance checks across GB. In the event of non-compliance, further action will likely be required which would see this cost rise. In any case, it is certainly not considered to be a significant cost relative to the others identified.

2.6.1.1.5 Totals and summary statistics

In line with the analysis presented above, the Agency estimates the societal costs of restriction on lead shot for LQS to be £148.7m across the 20-year appraisal period. This is **£123.7m** in PV terms, resulting in an average annual discounted cost of **£6.2m**. The Agency estimates that this restriction, with a 5-year transition period, would avoid the release of roughly 21,600t of lead across the same 20-year appraisal period. This results in a cost-effectiveness ratio of **£5,700/t** Pb avoided. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Birds (primary poisoning)
- Birds (secondary poisoning)
- Ruminants/Grazing animals
- Mammalian scavengers/companion animals
- Soil contamination
- Water contamination
- Neurodevelopmental impacts in children
- Chronic Kidney Disease impacts
- Cardiovascular impacts.

PACEC (2014) estimate that at least 600,000 people in the UK shoot live quarry, clay pigeons or targets. Based on the fact that three shooting activities fit within this figure, the Agency will assume that one third of these shooters (200,000) are live quarry shooters. In reality, the Agency anticipates there to be a high degree of interdisciplinarity within these three types of shooting.

Adjusting for GB population as a share of UK, this becomes 194,000. Dividing the average annual costs by this figure gives an estimated average annual cost per shooter of **£32**. If all (>)600,000 UK shooters practiced the three disciplines, this average annual cost per GB shooter would be estimated at £11.

GunsOnPegs (2022) report that the average game shooter's annual budget for the activity is £6,877, meaning that the average annual societal costs from this restriction would comprise **0.46%** of the average live quarry shooters annual budget for the activity.

The costs are summarised in Table 2.10.

Table 2.11: Summary of costs of LQS lead shot restriction

Description of cost	**PV cost (20yrs)**	**Group affected**	**Share of total costs in central scenario**
Shotgun replacement cost	£76.7m	Shooters	62.0%
Shotgun modification cost	£3.6m	Shooters	2.9%
Shotgun proof cost	£0.5m	Shooters	0.4%
Ammunition substitution cost	£32.1m	Shooters	26.0%
Manufacturer cost	£4.5m	Manufacturers in short term, shooters in longer term (assuming cost-pass through)	3.7%
Climate cost	£6.2m	Society	5.0%
Enforcement cost	£0.002m	State	0.006%
Total	**£123.7m**	-	100%

As shown in Table 2.7, 88% of the estimated costs of restriction are attributed to shooters replacing/foregoing shotguns unsuited to steel alternatives and the increased expenditure on alternative shot post-restriction (the combination of significantly more expensive bismuth shot relative to lead shot, and slightly less expensive steel shot relative to lead shot). Due to the significance of these two costs in constituting the total societal costs of restriction, the assumptions underpinning them are especially important. In particular, the assumed number of shotguns that are unsuitable for steel alternatives and the proportion of shooters who replace/retire a gun versus continue its use with bismuth shot can greatly impact the total estimated costs of restriction. As such, these will be given strong consideration in the sensitivity analysis later in the SEA.

2.6.1.2 *Restriction on target shooting with lead shot (without derogation)*

In the absence of a derogation for athletes participating in international competition, the Agency has identified and monetised the following costs that are likely to arise from restricting the use of lead shot in TS:

- Shooter substitution costs
- Costs to manufacturers
- Climate impacts
- Enforcement costs
- Loss of international sporting competitiveness.

Section 2.5.1.3 will explore how these costs change in the event of a restriction with derogation, which the Agency's analysis suggests to be a more economically efficient intervention and preferable to a blanket restriction.

2.6.1.2.1 Shooter substitution costs

The Agency anticipates that, under a restriction on TS with lead shot, a variety of costs would occur directly to shooters in substituting away from lead to alternatives. These costs can be classified as either one-off or on-going costs.

In terms of one-off costs, shooters may face:

- The cost of purchasing a new shotgun in order to shoot alternatives to lead
- The cost of modifying their existing shotguns(s) in order to shoot alternatives to lead
- Any re-proof that may be required after such modifications.

In terms of on-going costs, shooters may face:

- Costs due to more expensive alternative ammunition.

As outlined at the beginning of section 2.5, the costs of restriction depend greatly on the actions taken by shooters in response to restriction. The same simplifying assumptions outlined there also apply to the analysis of a target shooting restriction. Following on from these assumptions, the Agency calculates the one-off substitution costs faced by shooters as follows:

1) Replacement cost of unsuited shotguns

The Agency assumes that these shotguns will be replaced uniformly across the 5-year transition period proposed. As such, 1/5th of the replaced shotguns (50% of unsuited shotguns in the central case) that can be attributed to a TS restriction (on a tonnage ratio basis) are replaced on an annual basis across 5 years. This can be expressed as:

$$0.5 * 319{,}670 * 0.77 * 0.2 = 24{,}615.$$

Multiplying this estimated number of shotguns replaced per year by the assumed price of £2,096 gives an estimated annual replacement cost of £51,592,100. Totalled across the 5-year period, this equals **£258.0m** (undiscounted).

4) Modification costs

As outlined earlier in this subsection, the Agency assumes that 5% of shotguns will be modified in order to use steel shot. The Agency assumes these modifications to take place uniformly across the 5-year transition period proposed. As such, 1/5th of this 5% of shotguns that can be attributed to a TS restriction (on a tonnage ratio basis) are modified on an annual basis across 5 years. This can be expressed as:

$$0.05 * 1{,}482{,}254 * 0.77 * 0.2 = 11{,}413.$$

The price of such modification will vary by the modification completed, in addition to other factors such as the shotgun being modified and geographical region of GB. The Agency assumes a modification cost of £225 based on one London-based gunsmith’s price of an ‘over & under service’ (as at late-2022) (London Gun Company, 2022). This assumption is tested in the sensitivity analysis to account for uncertainty in relying on one gunsmith’s costs. The Agency anticipates that the most common modification will be changes to choke, which the Agency believes may in fact cost less than £225 on average. Additionally, the Agency understands that some shooters will be able to modify their own choke, and as such will not accrue a gunsmith cost, only a time-foregone cost. Overall, the Agency considers £225 to be an overestimate of the average cost of the shotgun modifications assumed to occur in 5% of cases but takes it forward as a conservative assumption. As such, the estimated modification costs are £2.57m on an annual basis, summing to **£12.8m** over a 5-year period (undiscounted).

5) Proof costs

As previously mentioned in this subsection, the Agency assumes that all modified shotguns are re-proofed. As such, 11,413 additional shotguns are assumed to be proofed per year across 5 years as a result of restriction compared to the baseline. Using the data from the London Proof House (2022), the Agency assumes an average proof cost of £31.17 per shotgun. Using this cost, the estimated annual proof cost is £0.4m, summing to **£1.8m** across the 5-year period (undiscounted).

In terms of on-going costs, the Agency calculates the following impact:

2) Ammunition cost

Based on (Blake International, 2022 Organisation #132), (Hurley, 2022), the Agency estimates the following baseline number of cartridges to be used in GB per year for TS:

Lead: 181,321,007

Steel: 5,747,866

Other metals (primarily bismuth): 863,977.

BASC (2022) estimate the following average prices per set of 250 cartridges:

Lead: £129

Steel: £112

Bismuth: £422.

Using these data, the Agency estimates the baseline expenditure on shotgun cartridges, to which a transition away from lead can be compared. The Agency applies the bismuth price to the 'other metals' category of shot, in the absence of up-to-date price data on other non-bismuth alternatives. In the sensitivity analysis, the Agency inflates the price of steel overtime to test the impact that relatively more expensive steel shot prices would have.

On an annual basis, using the data above, the Agency estimates a total baseline expenditure on shotgun cartridges for TS use of £97.6m. This is comprised of £93.6m on lead cartridges, £2.6m on steel cartridges, and £1.5m on other metals. The Agency estimates that this figure will rise to £109.5m in the case of restriction, comprising a **£11.9m** annual increase in the expenditure on shot cartridges for TS. This cost is a combination of transitioning to cheaper steel shot as well as more expensive bismuth shot, with the net result being a cost due to the significantly greater relative price of bismuth to lead than steel to lead. The Agency notes that to break even, a post-restriction ratio of steel:bismuth shot cartridges of ~95:5 would be required (beyond which a cost saving would occur). The Agency's central scenario sees a ratio of ~89:11.

Totalled across the 20-year appraisal period, this additional ammunition cost equals **£178.7m** (undiscounted).

The sum of the total estimated shooter substitution costs across the 20-year appraisal period is £451.3m in undiscounted, and **£374.3m** in PV terms.

2.6.1.2.2 Costs to manufacturers

The same costs to manufacturers outlined in section 2.5.1.1.2 apply here, with the Agency having scaled them on a tonnage basis across LQS and TS. In doing so, the Agency estimates that a TS restriction would cost manufacturers £16.2m in undiscounted terms and **£15.2m** in PV terms. The Agency assumes this cost to be accrue uniformly across the 5-year transition period, equalling £3.2m on an annual basis (undiscounted).

2.6.1.2.3 Climate impacts

The same climate impacts outlined in Section 2.5.1.1.3apply here, with the Agency having scaled them on a tonnage basis across LQS and TS. In doing so, the Agency estimates that a TS restriction would result in 8,213tCO2/annum compared to 247tCO2/annum under the baseline, under the worst-case scenario. This equals an annual addition of 7,967tCO2. Using the BEIS (2021) carbon values for the corresponding year, the climate impacts from restriction can be estimated at £38.1m across the 20-year appraisal period in undiscounted terms and **£25.3m** in PV terms.

2.6.1.2.4 Enforcement and compliance-check costs

Based on discussions with Environment Agency enforcement experts, the Agency estimate that the necessary compliance checks under a restriction would cost ~£65,800 across the 20-year appraisal period in undiscounted terms, and **£44,000** in PV terms. This cost is based on the FTE requirements anticipated by the Agency to undertake the relevant compliance checks across GB. In the event of non-compliance, further action will likely be required which would see this cost rise. In any case, it is certainly not considered to be a significant cost relative to the others identified.

2.6.1.2.5 Loss of international sporting competitiveness

As outlined during the options analysis in Section 2.5, shooting federations such as the ISSF stipulate that lead shot must be used during competitive shooting competitions. A blanket restriction on the use of lead shot in target shooting sports would mean that GB athletes would be required to train with lead alternatives in preparation for sporting competitions, such as the Olympic Games, and then use lead shot during the competition. Through engagement with the CPSA the Agency understands that this would be highly impractical and may significantly impact the competitiveness of GB athletes. Although steel shot is accurate and well-performing, the Agency understands that shooting steel shot cartridges is a different experience to those of lead due to inherent physical properties of the metals. At the very highest level of sport, this has the potential to affect performance in a relative sense much more significantly than for average shooters, many of whom should not see a tangible difference in their ability to target shoot accurately.

The Agency considers there to be two main plausible impacts that would result from losing high level sporting competitiveness:

- Foregoing any economic/fiscal benefits accrued from winning competitions (such as the Olympics)
- Loss in welfare experienced by athletes competing at a high level and those who aspire to/would have gone on to compete at a high level, those involved more widely in the sport such as coaches, and all enthusiasts/supporters.

It is challenging to gauge the magnitude of these impacts. Feedback received during the consultation period from stakeholders suggests that restriction would be the end of high-level competition for GB shooting. The inability to practice with lead shot could be totally detrimental to competition day performance, or it may only give GB athletes a slight disadvantage. In any case, the Agency accepts that training with an alternative ammunition metal to that which will be used on competition day could impact the physical and psychological performance of athletes.

In an attempt to quantify the impact of losing high level competitiveness in shotgun shooting sports, the Agency has used the funding allocated to the shooting disciplines by UK Sport for the 2024 Paris Olympics as a proxy for the value of such competition. As UK Sport is accountable to the Department for Culture, Media and Sport (UK Sport, 2023), the Agency assumes that the funding allocated to shooting for the Olympics is a sound lower bound estimate of the public value placed on this being able to happen.

UK Sport have provided £6,130,091 for shooting and £1,941,168 for para-shooting to facilitate athletes competing at the 2024 Olympic Games (UK Sport, 2020). Olympic para-shooting is limited to rifles and pistols and so is not relevant for this section of the impact assessment. Olympic shooting comprises three separate disciplines: shotgun, pistol and rifle. Inflating the UK Sport funding value to 2022 prices, dividing by 3 (assuming equal funding split across the 3 sports) and further dividing by 4 to turn the 4-year Olympic cycle into an annualised value gives an annual funding value of £533,354 for shotgun sports. Using this as the lower-bound value for the cost of losing high level competitiveness in shotgun sports gives a total value of £10.7m across the 20-year appraisal period in undiscounted terms and **£8.0m** in PV terms.

The Agency notes limitations to this approach. Firstly, it is not clear to what extent high-level competitiveness will be affected, with this methodology assuming a full loss in competitiveness. However, GB athletes may continue to have some, but potentially reduced, success when training purely with lead-free alternatives. Secondly, the approach taken to monetise a full loss in competitiveness is surely an underestimate of this impact, given that it ignores all the private funding put into shooting by shooters themselves, spectators, etc. Thirdly, it ignores any international competition beyond that of the Olympics. Consequently, the Agency expects a blanket ban on the use of lead shot in target shooting to have significant impacts on the performance of athletes training for and participating in international competition. The Agency notes that, in the event of a blanket UK REACH restriction, GB athletes could potentially re-locate to Northern Ireland to continue training with lead (as Northern Ireland falls within EU REACH jurisdiction, and ECHA (2023) have recommended a derogation such that athletes competing internationally would be able to continue to use lead shot to train at ranges with adequate RMMs), whilst maintaining the ability to participate as part of team GB. This would undoubtedly entail costs for the shooters without any reduction in the quantity of emissions occurring within the UK (emissions previously occurring in GB would then occur in Northern Ireland).

2.6.1.2.6 Totals and summary statistics

In line with the analysis presented above, the Agency estimates the societal costs of restriction on lead shot for TS to be £516.6m across the 20-year appraisal period. This is **£422.8m** in PV terms, resulting in an average annual discounted cost of **£21.1m**.

The Agency estimates that this restriction, with a 5-year transition period, would avoid the release of roughly 80,400t of lead across the same 20-year appraisal period. This results in a cost-effectiveness ratio of **£5,300/t** Pb avoided. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Birds (primary poisoning)
- Birds (secondary poisoning)
- Ruminants/Grazing animals
- Mammalian scavengers/companion animals
- Soil contamination
- Water contamination

PACEC (2014) estimate that at least 600,000 people in the UK shoot live quarry, clay pigeons or targets. Based on the fact that three shooting activities fit within this figure, the Agency will assume that one third of these shooters (200,000) are shotgun target shooters. In reality, the Agency anticipates there to be a high degree of interdisciplinarity within these three types of shooting.

Adjusting for GB population as a share of UK, this becomes 194,000. Dividing the average annual costs by this figure gives an estimated average annual cost per shooter of **£109**. If all (>)600,000 UK shooters practiced the three disciplines, this average annual cost per GB shooter would be estimated at £36.

GunsOnPegs (2022) report that the average game shooter's annual budget for the activity is £6,877. Assuming this budget extends to that of target shooters, the average annual societal costs from this restriction would comprise **1.58%** of the average live quarry shooters annual budget for the activity.

The costs are summarised in Table 2.12.

Table 2.12: Summary of costs of TS lead shot restriction

Description of cost	**PV cost (20yrs)**	**Group affected**	**Share of total costs in central scenario**
Shotgun replacement cost	£241.1m	Shooters	57.0%
Shotgun modification cost	£12.0m	Shooters	2.8%
Shotgun proof cost	£1.7m	Shooters	0.4%
Ammunition substitution cost	£119.6m	Shooters	28.3%
Manufacturer cost	£15.2m	Manufacturers in short term, shooters in longer term (assuming cost-pass through)	3.6%
Climate cost	£25.3m	Society	6.0%
Enforcement cost	£0.04m	State	0.01%
Loss of international	£8.0m	Society	1.9%

sporting competitiveness			
Total	**£422.8m**	-	100%

As shown in Table 2.8, ~85% of the estimated costs of restriction are attributed to shooters replacing/foregoing shotguns unsuited to steel alternatives and the increased expenditure on alternative shot post-restriction (the combination of significantly more expensive bismuth shot relative to lead shot, and slightly less expensive steel shot relative to lead shot). Due to the significance of these two costs in constituting the total societal costs of restriction, the assumptions underpinning them are significant. In particular, the assumed number of shotguns that are unsuitable for steel alternatives and the proportion of shooters who replace/retire a gun versus continue its use with bismuth shot can greatly impact the total estimated costs of restriction. As such, these will be given particular consideration in the sensitivity analysis later in the SEA.

2.6.1.3 *Restriction on target shooting with lead shot (with derogation)*

In the event of a derogation for use by athletes competing internationally, the impacts are similar to those outlined in Section 2.5.1.2 with some nuanced differences. These differences are explored below, with the Agency also noting where impacts are not anticipated to differ in the event of derogation.

2.6.1.3.1 Shooter substitution costs

As in Section 2.5.2.1, shooters are anticipated to face a variety of costs associated with transitioning away from lead shot to alternatives. These costs can be classified as either one-off or on-going costs.

In terms of one-off costs, shooters may face:

- The cost of purchasing a new shotgun in order to shoot alternatives to lead
- The cost of modifying their existing shotguns(s) in order to shoot alternatives to lead
- Any re-proof that may be required after such modifications.

In terms of on-going costs, shooters may face:

- Costs due to more expensive alternative ammunition.

As outlined at the beginning of Section 2.5, the costs of restriction depend greatly on the actions taken by shooters in response to restriction. The same simplifying assumptions outlined there also apply to the analysis of a target shooting restriction. Following on from these assumptions, the Agency calculates the one-off substitution costs faced by shooters as follows:

1) Replacement cost of unsuited shotguns

The Agency assumes that the same number of shotguns will be prematurely replaced with or without the derogation. This assumption has been made because the Agency anticipates derogated athletes to be shooting high-performance, modern shotguns, which will be capable of shooting at least standard steel shotgun cartridges. As such, the shotguns of all the athletes who would be derogated are assumed to fall within the 73% that are already capable of shooting steel shot. Thus, the estimated replacement cost of unsuited shotguns equals that of the blanket restriction case: **£258.0m** (undiscounted) over a 5-year period.

2) Modification costs

Following the reasoning above, the Agency assumes that the modification costs of a derogated restriction will not differ from those of a blanket restriction, because derogated athletes are assumed to own shotguns that will not require modification. As such, the estimated modification costs under a derogated restriction sum to **£12.8m** over a 5-year period (undiscounted).

3) Proof costs

The number of shotguns modified (and therefore assumed to need re-proof) does not differ in the case of derogated restriction compared to a blanket restriction. As such, the proof costs here remain unchanged from Section 2.5.1.2.1, summing to **£1.8m** across the 5-year period (undiscounted).

In terms of on-going costs, the Agency calculates the following impact:

1) Ammunition cost

Based on (Blake International, 2022 Organisation #132), (Hurley, 2022), the Agency estimates the following baseline number of cartridges to be used in GB per year for TS:

Lead: 181,321,007

Steel: 5,747,866

Other metals (primarily bismuth): 863,977.

BASC (2022) estimate the following average prices per set of 250 cartridges:

Lead: £129

Steel: £112

Bismuth: £422.

As outlined during section 2.5.2.1.3 the Agency estimates the top 50 British athletes for shotgun sports to use roughly 25,000 cartridges/year each, totalling to 1,250,000/year overall. Using (Blake International, 2022 Organisation #132) (Hurley, 2022) data on the number of lead cartridges sold and corresponding metal weight, the Agency estimates that this to equal 37t of lead.

The Agency adjusts the ammunition cost presented in Section 2.5.1.2.1 to account for the fact that under a derogated restriction, an estimated 1.25m lead cartridges will be sold annually, compared to 0 in the case of blanket restriction and 181.3m under the baseline. The Agency assumes that these 1.25m lead cartridges would have been steel under a blanket restriction, in line with assumption outlined previously in this subsection that athletes will possess shotguns that are already capable of shooting at least standard steel shot. The resulting additional ammunition cost of a derogated restriction compared to the baseline is estimated at **£180.0m** (undiscounted) across the 20-year appraisal period.

The sum of the total estimated shooter substitution costs across the 20-year appraisal period is **£452.6m** in undiscounted terms and **£375.2m** in PV terms.

2.6.1.3.2 Costs to manufacturers

The Agency assumes that the costs to manufacturers of a derogated restriction equal that of a blanket restriction, due to more or less the same transition occurring in either case. The Agency anticipates a possible creation of a supply chain direct from manufacturers to the governing body in charge of managing the operational aspects of the derogation. This, in theory, may impose a time/administrative cost upon manufacturers, but the Agency does not consider this to be significant in comparison to the other manufacturer costs that have been outlined. Additionally, slightly less than a full transition would occur due to the derogation, which may result in some minor cost savings for manufacturers.

Accordingly, the Agency estimates the costs to manufacturers under a derogated restriction on TS with lead shot to equal £16.2m in undiscounted terms and **£15.2m** in PV terms. The Agency assumes this cost to be accrue uniformly across the 5-year transition period, equalling £3.2m on an annual basis (undiscounted).

2.6.1.3.3 Climate impacts

The Agency has modified the climate impacts outlined in section 2.5.1.2.3 to account for the respective share of shot made up of each metal type where identified athletes continue to shoot lead shot. In doing so, the Agency estimates that a derogated TS restriction would result in 8,152tCO2/annum compared to 247tCO2/annum under the baseline, under the worst-case scenario. This is marginally less costly in terms of GHG emissions than a blanket restriction, due to less steel being used with its greater emissions factor than lead. This equals an annual addition of 7,905tCO2. Using the BEIS (2021) carbon values for the corresponding year, the climate impacts from restriction can be estimated at £37.8m across the 20-year appraisal period in undiscounted terms, and **£25.1m** in PV terms.

2.6.1.3.4 Enforcement and compliance-check costs

Based on discussions with Environment Agency enforcement experts, the Agency estimate that the necessary compliance checks under a blanket restriction would cost ~£65,800 across the 20-year appraisal period. The Agency does not anticipate a derogation to require significant additional resource in burden in terms of enforcement but will assume this impact to arbitrarily equal £100,000 (undiscounted) across the 20-year appraisal period to allow for additional resource that may be required. The Agency assumes this total to be annualised from 2029, when the proposed restriction would be implemented, equalling **£66,900** in PV terms.

2.6.1.3.5 Totals and summary statistics

In line with the analysis presented above, the Agency estimates the societal costs of a derogated restriction on lead shot for TS to be £506.7m across the 20-year appraisal period. This is **£415.5m** in PV terms, resulting in an average annual discounted cost of **£20.8m**.

The Agency estimates that this restriction, with a 5-year transition period, would avoid the release of circa 79,800t of lead across the same 20-year appraisal period. This results in a cost-effectiveness ratio of **£5,200/t** Pb avoided. This is a more favourable cost-effectiveness ratio when compared to that of a blanket restriction. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Birds (primary poisoning)
- Birds (secondary poisoning)
- Ruminants/Grazing animals
- Mammalian scavengers/companion animals
- Soil contamination
- Water contamination.

PACEC (2014) estimate that at least 600,000 people in the UK shoot live quarry, clay pigeons or targets. Based on the fact that three shooting activities fit within this figure, the Agency will assume that one third of these shooters (200,000) are shotgun target shooters. In reality, the Agency anticipates there to be a high degree of interdisciplinarity within these three types of shooting.

Adjusting for GB population as a share of UK, this becomes 194,000. Dividing the average annual costs by this figure gives an estimated average annual cost per shooter of **£107**. If all (>)600,000 UK shooters practiced the three disciplines, this average annual cost per GB shooter would be estimated at £36.

GunsOnPegs (2022) report that the average game shooter’s annual budget for the activity is £6,877. Assuming this budget extends to that of target shooters, the average annual societal costs from this derogated restriction would comprise **1.56%** of the average live quarry shooters annual budget for the activity.

The costs are summarised in Table 2.13.

Table 2.13: Summary of costs of TS lead shot restriction with derogation

Description of cost	PV cost (20yrs)	Group affected	Share of total costs in central scenario
Shotgun replacement cost	£241.1m	Shooters	58.0%
Shotgun modification cost	£12.0m	Shooters	2.9%
Shotgun proof cost	£1.7m	Shooters	0.4%
Ammunition substitution cost	£120.4m	Shooters	29.0%
Manufacturer cost	£15.2m	Manufacturers in short term, shooters in longer term (assuming cost-pass through)	3.7%
Climate cost	£25.1m	Society	6.0%
Enforcement cost	£0.07m	State	0.02%
Total	**£415.3m**	-	100%

As shown in Table 2.12, 87% of the estimated costs of restriction are attributed to shooters replacing/foregoing shotguns unsuited to steel alternatives and the increased expenditure on alternative shot post-restriction (the combination of significantly more expensive bismuth shot relative to lead shot, and slightly less expensive steel shot relative to lead shot). Due to the significance of these two costs in constituting the total societal costs of restriction, the assumptions underpinning them are significant. In particular, the assumed number of shotguns that are unsuitable for steel alternatives and the proportion of shooters who replace/retire a gun versus continue its use with bismuth shot can greatly impact the total estimated costs of restriction. As such, these will be given particular consideration in the sensitivity analysis later in the SEA.

2.6.2 Costs of intervention-lead bullets (including airgun pellets)

This section examines the costs of intervention on the various bullet uses, including airgun projectiles. The Agency considers the data generally available on these uses, in addition to that received in the consultation, to be considerably weaker than that for the shot uses. This is likely due to proportionality, whereby these uses comprise a smaller share of the total emissions within scope of this restriction proposal. As such, stakeholders have perhaps tailored their efforts accordingly. The Agency has sought to fill data gaps wherever possible, but despite this prefers to take a semi-quantitative approach to examining impacts. Simplifying assumptions are necessary within this analysis, as was the case in Section 2.5, and these are outlined throughout this sub-section.

2.6.3 Restriction on live quarry shooting with lead bullets

This sub-section will examine the costs of restriction on both large and small calibre lead bullets used for live quarry shooting.

2.6.3.1 *Restriction on live quarry shooting with large calibre lead bullets (≥6.5mm)*

The Agency has identified the following costs that may occur under a restriction on LQS with LC lead bullets:

- Ammunition substitution cost
- Enforcement cost

Based on engagement with the GTA, the Agency considers LC alternatives to be suitable for existing rifles in use without modification. This in turn means that new rifles should not need to be purchased to enable use of alternatives to lead. Similarly, according to the GTA, civilian centrefire is typically produced outside of the UK, meaning any manufacture costs of a LQS restriction with LC bullets should fall beyond the geographic scope of this restriction. Climate impacts have not been considered; alternative bullets are made from a variety of different metals such as tin, zinc and copper, each with their own respective emissions factors. In any case, the reduction in use of lead from intervention in bullets will comprise a very small share of that of shot, meaning that any climate impacts are considered to be insignificant when compared to those of shot intervention.

2.6.3.1.1 Ammunition substitution cost

As outlined in Section 1.4.3, the Agency estimates that 199,480 LC lead bullets are currently used on an annual basis in GB for LQS. From 2025 onwards, the Agency decreases this figure by 10% to account for the estimated impact of shooters voluntarily transitioning away from lead towards alternatives. As such, the Agency estimates the annual number of LC bullets used for LQS to be 179,530.

The Agency undertook desktop research to estimate the average price of large and small calibre bullets made from lead and from lead-free alternatives. Data was gathered from three shooting sales websites:

1) www.allcocksoutdoorstore.co.uk
2) www.shootingsportsuk.co.uk
3) www.bushwear.co.uk.

Based on data collected, the Agency calculated a mean price for lead and lead-free bullets across both calibre categories. This mean only included calibres for which both lead and lead-free bullets were identified in order to elicit a meaningful comparison. For instance, if there was a less used calibre that was more expensive than those more typically used, this is less likely to have an alternative readily available (due to limited demand). Including it in the average price of lead bullets would increase the mean lead bullet price value, without being a meaningful data point because no alternative is readily available for such a calibre. As such, comparing an average lead price figure with this calibre to that of alternatives would be less meaningful given that shooters would not be switching to alternatives in that calibre. The analysis includes both expanding and non-expanding bullet types. The Agency prefers to take one average price across both groups and apply this to both LQS and TS uses due to the limited data points.

The Agency's research yielded the following per bullet prices (2023 research deflated to 2022 prices):

LC lead bullet: £1.84

LC lead-free bullet: £2.98

SC lead bullet: £0.97

SC lead-free bullet: £0.99.

The Agency applies these respective prices to the annual use of LC lead and lead-free bullets under the baseline and in the restriction case. Under the baseline, the Agency estimates an annual expenditure on LC bullets of £368,000 in 2024, rising to £390,700 for the remainder of the 20-year appraisal period. In the event of restriction, the Agency estimates this figure to rise to £595,350. Totalled across the 20-year appraisal period, the Agency estimates that a restriction on LQS with LC lead bullets would result in an ammunition substitution cost of £3.5m in undiscounted terms, and **£2.4m** in PV terms.

2.6.3.1.2 Enforcement cost

Based on discussions with Environment Agency enforcement experts, the Agency estimate that the necessary compliance checks under a blanket restriction would cost £5,400 across the 20-year appraisal period in undiscounted terms, and **£3,600** in PV terms. This cost is based on the FTE requirements anticipated by the Agency to undertake the relevant compliance checks across GB. In the event of non-compliance, further action will likely be required which would see this cost rise. In any case, it is certainly not considered to be a significant cost relative to the others identified.

2.6.3.1.3 Total and summary statistics

Combining these two costs, the Agency estimates that a restriction on LQS with LC lead bullets would result in costs of £3.5m totalled across the 20-year appraisal period. Once discounted, this is **£2.4m**. The Agency estimates that such a restriction would avoid the release of **21t** of lead across the 20-year appraisal period, resulting in a cost-effectiveness ratio of **£89,700/t** lead avoided. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Birds (secondary poisoning)
- Mammalian scavengers/companion animals
- Neurodevelopmental impacts in children
- Chronic Kidney Disease impacts
- Cardiovascular impacts.

The Agency advises caution when interpreting the analysis above. Firstly, >99% of the monetised cost estimate pertains to the ammunition substitution cost, which:

1) Is based on less reliable price data than that of the shot cartridge analysis.

   A wider variety of bullet calibres are in use than shot bore sizes which introduces greater uncertainty when generalising prices into a mean value.

2) Assumes that the relative price differential remains constant across the 20-year time-period of appraisal. Prices may fluctuate during this period. The greater uptake of alternatives post-restriction may increase or decrease their relative price depending on several factors (which in-turn dictate the pre- and post-restriction marginal cost curves). Although this is also the case for the shot uses, alternatives to lead shot are more developed than those of bullets and are already used in several countries around the world

due to respective bans. Less bans on bullets currently exist; for instance, Denmark is only now banning the use of lead bullets, several decades after their shot ban. This means that the current price differential between lead shot and lead-free shot is likely more suitable for projecting longer term relative prices. Additionally, the fact that the ammunition substitution cost comprises <30% (compared to >99%) of the various shot use costs means that this methodological risk is less significant in a relative sense than for the bullets analysis.

These considerations mean that the above analysis may significantly change if assumptions around bullet prices change. For illustrative purposes, if the price of lead-free bullets were to equal that of lead bullets after e.g. 5 years of restriction, the PV costs of a restriction would reduce from £2.4m to **£0.7m**. Consequently, the cost-effectiveness ratio would change from £89,700/t to **£26,200/t**.

If a restriction is undertaken on this use, the Agency recommends a 3-year transition period. This is longer than that recommended in HSE (2022) to reflect recent supply concerns resulting from the Russian invasion of Ukraine. A mis-timed transition period would incur unnecessary costs. For instance, deer culls may be affected either in terms of higher operational costs due to limited alternative supply leading to price increases, or general feasibility of performing such culls may be impacted if supply is seriously impacted by war in Ukraine. Since this use only constitutes a small fraction of total emissions, the relative benefit of a fast transition is also considered less than that of the larger uses (shot).

2.6.3.2 *Restriction on live quarry shooting with small calibre lead bullets (<6.5mm)*

The Agency has identified the following costs that may occur under a restriction on LQS with LC lead bullets:

- Ammunition substitution cost
- Rifle re-barrelling cost
- Costs to manufacturers
- Enforcement cost
- Impacts from worse performing alternatives

Unlike with large calibre rifles, the use of alternatives in small calibre rifles requires that rifle to be re-barrelled. This is due to rifles requiring a new twist rate in the barrel to adjust for ballistics of alternative metals with different densities to lead. This impact becomes relevant below a certain calibre, which the Agency estimates to be roughly 6.5mm. This, in part, forms the rationale for the 6.5mm small calibre-large calibre dichotomy.

Additionally, through engagement with the GTA the Agency understands that the UK domestically produces small calibre rimfire ammunition for civilian use, which is not considered to be the case for centrefire ammunition (both small and large calibre) which are imported into the UK. As such, a transition away from lead is assumed to impose some cost on manufacturers.

Climate impacts have not been considered; alternative bullets are made from a variety of different metals such as tin, zinc and copper, each with their own respective emissions factors. In any case, the reduction in use of lead from intervention in bullets will comprise a very small share of that of shot, meaning that any climate impacts are considered to be insignificant when compared to those of shot intervention.

2.6.3.2.1 Ammunition substitution cost

As outlined in section 1.4.3, the Agency estimates that 697,030 SC lead bullets are currently used on an annual basis in GB for LQS, with an estimated lead weight of 2t.

Using the same desktop research outlined in section 2.6.1.1.1, the Agency assumes the following SC lead and lead-free average per bullet price:

SC lead bullet: £0.97

SC lead-free bullet: £0.99.

The Agency notes the smaller relative price difference for SC bullets compared to LC. This is corroborated by ECHA (2022a) who conducted their own desktop research and assume a SC price differential between €0-€0.40, compared to €0.75-€2.17 for LC bullets.

The Agency applies these respective prices to the annual use of SC lead and lead-free bullets under the baseline and in the restriction case. Under the baseline, the Agency estimates an annual expenditure on SC bullets of £673,235 over the 20-year appraisal period. In the event of restriction, the Agency estimates this figure to rise to £693,432. Totalled across the 20-year appraisal period, the Agency estimates that a restriction on LQS with LC lead bullets would result in an ammunition substitution cost of £0.3m in undiscounted terms and **£0.2m** in PV terms.

2.6.3.2.2 Rifle re-barrelling cost

As mentioned in section 2.6.1.2, SC rifles will require re-barrelling to amend the twist rate in order to use lead-free bullets. Rifle re-barrelling occurs under the baseline due to general wear of the gun. The frequency of such re-barrelling depends on how often the rifle is used. For instance, rifles used for LQS are likely to be re-barrelled far less frequently on average than those used for TS, as more rounds are typically fired from a TS in a given time period.

The Agency assumes that under the baseline, LQS rifles are re-barrelled on average every 10 years. Through personal communications, the GTA has confirmed this to be a reasonable assumption.

The Agency estimates there to be 383,557 rifles in GB. Home Office (2021) statistics state there to be 620,848 firearms covered by firearm certificates in England and Wales, with 57% of these being rifles, equalling 353,883 rifles. Using ONS (ONS, 2021) population data, the Agency adjusts this figure to incorporate Scotland, assuming an equal number of firearms held per capita in Scotland as in England and Wales. Accordingly, the Agency arrives at a GB estimate of 383,557.

The Agency weights this figure by the share of bullet emissions attributed to small calibre ammunition, arriving at an estimated 174,042 small calibre rifles in GB. Further weighting by the share of these emissions attributed to LQS (6,007 rifles), and assuming that this stock of rifles is re-barrelled uniformly on an annual basis within the 10-year re-barrel period (i.e. 10% re-barrelled every year), an estimated 601 SC LQS rifles are re-barrelled per year under the baseline.

In the event of restriction, assuming a 5-year transition period, the Agency assumes that all 6,007 rifles will be uniformly re-barrelled prior to the implementation of restriction in 2029. As such, 1,201 rifles are assumed to be re-barrelled annually across the 5-year period of 2024-2029. It is assumed that these rifles will not need to be re-barrelled again for 10 years on average, and so the same pattern will re-occur in 2034-2038.

The profile of re-barrelling assumed in the Agency's analysis is summarised in Table 2.14 below:

Table 2.14: Rifle re-barrelling profile across the 20-year appraisal period

Year	Rifles re-barrelled: **baseline**	Rifles re-barrelled: **restriction**
2024	601	1,201
2025	601	1,201
2026	601	1,201

2027	601	1,201
2028	601	1,201
2029 *(Restriction assumed to come into force)*	601	-
2030	601	-
2031	601	-
2032	601	-
2033	601	-
2034	601	1,201
2035	601	1,201
2036	601	1,201
2037	601	1,201
2038	601	1,201
2039	601	-
2040	601	-
2041	601	-
2042	601	-
2043	601	-
TOTAL	**12,014 (every rifle, twice)**	**12,014 (every rifle, twice)**

As shown in Table 2.10, the number of rifles re-barrelled under the baseline and restriction case is assumed to be the same. Those rifles re-barrelled would have been re-barrelled anyway. However, this cost is brought forward in time, and the majority of rifles will be re-barrelled earlier than they otherwise would have. Once comparing the discounted costs under baseline and restriction, the opportunity cost associated with premature re-barrelling is captured.

Based on personal communications with a gun vendor, the Agency assumes that the cost of re-barrelling and subsequent re-proofing of a rifle to cost roughly £1,200. As such, an estimated £720,860 is assumed to be spent on re-barrelling per year under both the baseline and restriction case, across the 20-year appraisal period. This sums to £14.4m. Once discounted, however, costs under the restriction case exceed those of the baseline by an estimated **£0.9m** totalled across the 20-year appraisal period.

2.6.3.2.3 Costs to manufacturers

As demonstrated in Section 2.6.1.3.1, the Agency received detailed information on the costs to shot cartridge manufacturers in the case of a lead shot restriction. Similar information was not received for the other uses in scope of this restriction proposal.

Through engagement with the GTA, the Agency understands that the UK civilian rimfire manufacturing industry is still in the process of trying to develop a lead-free .22 rimfire bullet with satisfactory performance. They state that in the event of restriction, they would need to review the decision around continued manufacture in the UK vs relocation.

Due to limited data, the Agency is unable to quantify the costs to manufacturers of a restriction on the use of SC lead bullets for LQS or conclude on the magnitude of impacts. An EU restriction may induce many, or even all of these impacts, under the baseline if the EU market comprises a significant enough share of UK rimfire manufacturers total sales. For instance, if, say, 80% of .22 rimfire bullets produced were exported to the EU, an EU restriction would presumably trigger the additional research and development or cause the seller to leave the market, as may happen under a GB restriction. If this is the case, it can reasonably be assumed that the costs attributable to a GB restriction are negligible. If this is not the case, manufacturer costs can be attributed to a GB restriction. Here, foregone producer surplus is likely to ensue if manufacturers choose to exit relevant markets (and in-turn, sellers further down the supply chain), which would also induce foregone consumer surplus for consumers and any wider impacts related to an inability to continue this use, such as limitations to pest control. If manufacturers do not exit the market, they may invest more in research and development of lead-free alternatives than they would have under the baseline.

2.6.3.2.4 Enforcement cost

Based on discussions with Environment Agency enforcement experts, the Agency estimate that the necessary compliance checks under a blanket restriction would cost £5,400 across the 20-year appraisal period in undiscounted terms and **£3,600** in PV terms. This cost is based on the FTE requirements anticipated by the Agency to undertake the relevant compliance checks across GB. In the event of non-compliance, further action will likely be required which would see this cost rise. In any case, it is certainly not considered to be a significant cost relative to the others identified.

2.6.3.2.5 Impacts from worse performing alternatives

As outlined in Section 2.2, current alternatives available for this use are considered by the Agency to perform less well than lead. Concerns are particularly centred around accuracy at longer ranges and additional noise when compared to current sub-sonic SC lead bullets.

SC bullets are used in pest control, which is highly dependent on the ability to stealthily and accurately shoot the target animal. With less accurate and supersonic ammunition, the ability to control pests may be affected, having several potential undesirable impacts including to the environment. Other pest control measures exist, but it can be assumed that these are less effective, accessible, cost-effective, etc., for the given use, otherwise they would already be used instead of ammunition. The Agency is unable to quantify this impact.

2.6.3.2.6 Total and summary statistics

Combining these three monetised costs, the Agency estimates that a restriction on LQS with SC lead bullets would result in total costs **£1.1m** in PV terms. This does not include any foregone producer surplus for manufacturers and sellers, and the resulting foregone consumer surplus, nor the impacts from worse performing alternatives (such as implications for pest control).

The Agency estimates that such a restriction would avoid the release of **27t** of lead across the 20-year appraisal period, resulting in a cost-effectiveness ratio of **£41,400/t** lead avoided. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Birds (secondary poisoning)
- Mammalian scavengers/companion animals
- Neurodevelopmental impacts in children
- Chronic Kidney Disease impacts
- Cardiovascular impacts.

If this use were restricted, the Agency recommends a 5-year transition period to give sufficient time for further development to occur in small calibre alternatives.

The Agency notes that this cost-effectiveness ratio reports a smaller set of risks when compared to that of LQS with LC bullets. In reality, the Agency anticipates that a restriction on LQS with LC would be a more cost-effective intervention than that of SC bullets. Cost-effectiveness (and any quantitative analysis) is limited by the extent to which parameters can credibly be estimated. The cost-effectiveness ratio for a restriction on SC lead bullets appears more favourable because:

1. Not all relevant costs have been monetised, which is not the case for LC bullets, and
2. As outlined in Section 2.6.3.1.3, the estimated costs of a LC lead bullet restriction depend almost entirely on the assumption that the current price differential will hold throughout the full 20-year appraisal period. The Agency has maintained this assumption in the absence of evidence to suggest the contrary, but it is plausible that the relative price of lead-free bullets will fall once they are more widely adopted. However, the current price differential for SC bullets appears less significant, and it also constitutes a smaller share of total costs, meaning this assumption has less ability to undermine analysis.

For these reasons, the Agency advises caution when relying solely on quantitative summary statistics to consider the case for restriction in these uses. The Agency considers the socioeconomic case for restriction on these two uses to be weaker than on the shot uses, with the socioeconomic case for restriction on SC lead bullets to be weaker than that of LC lead bullets. This is not fully conveyed in the partial monetisation of costs alone.

2.6.3.3 *Restriction with derogation on target shooting with large and small calibre bullets*

Due to the similarity of the two uses and the impacts of intervention therein, this section will combine the costs of a restriction with derogation on target shooting for both small and large calibre bullets.

In their response to the public consultation, the National Rifle Association (NRA) (Organisation #127) NRA noted that 95% of affiliated ranges are periodically de-leaded. This is done on a health and safety rationale, due to the risk of ricochet that develops once lead builds up in the stop butt of a range. As such, it can be assumed that 95% of spent lead from this use is already being recovered under the baseline by existing health and safety protocols set by the NRA. The NRA consultation response estimates there to be 300 affiliate outdoor ranges in the UK. Personal communications with the NRA suggest that there is likely to be a small number, perhaps roughly a dozen, of pop-up rifle ranges that are not affiliated with the NRA. Once adjusting for the GB share of the UK population, and accounting for the small number of non-affiliate ranges, the Agency estimates there to be a total of roughly 300 shooting ranges in GB.

When non-affiliate ranges are discovered to exist, the NRA works directly with them to establish the necessary health and safety protocols, in the absence of which the NRA has the authority to close the range. As such, the Agency assumes that these ranges will implement the NRA health and safety measures under the baseline, assuming that 95% of previously non-affiliate ranges will de-lead under the baseline, and that 95% of the total 300 estimated ranges de-lead under the baseline.

The NRA consultation response notes that 71% of affiliate ranges use club members for de-leading. As such, roughly ~75% (71%/95%) of those sites that de-lead do not require the use of contractors. When club members de-lead, the Agency does not consider this to constitute a cost. The act of a group of shooters, likely friends, taking time at the end of a day at the range to collect the spent lead they have shot likely does not cause a welfare loss. As such the opportunity cost of their time spent on this is not considered to be greater than any utility they derive from this time spent with their fellow shooters. The act of gathering their spent lead may induce positive feelings surrounding the fact that they are looking after and tidying their ranges, etc. Additionally, although not relevant on a social cost-benefit level due to constituting a transfer, this spent lead is sold as scrap metal, and so members recuperate it with the knowledge that it will be sold on for their/the club's financial gain.

Where contractors are used for de-leading, the Agency considers this to constitute a cost.

If this option is undertaken, the Agency considers that a 2-year transition period is sufficient to allow for the development of this code of practice for RMMs, and for ranges to establish the techniques required to comply.

Under the case of restriction with a derogation for sites with adequate de-leading in place (RMMs), the Agency anticipates the following societal costs to be incurred:

1) Administrative and enforcement costs
2) Range compliance costs

2.6.3.3.1 Administrative and enforcement costs

This option would require the Environment Agency to work with the appropriate shooting organisations (e.g., the NRA) to expand the existing range safety guidance with respect to environmental risks and how to address them. The updated guidance would be made available to shooting ranges, helping them identify and address the risks that may be present on their sites. In the absence of following these requirements, they would be unable to use lead ammunition on their range.

Given that the NRA note they currently recovery 100% of spent bullets based on existing protocols at sites that de-lead, the Agency does not consider this to be burdensome to establish, rather a formal establishment of what is already in place with input from the relevant regulator if necessary. In the absence of relevant data, the Agency will assume that establishing expanding this guidance will cost £1000 in foregone time from NRA and EA staff. This assumption will be developed during the SEA consultation period.

There may be additional costs to the sites in relation to:

- Notifying
- Becoming familiar with the updated guidance
- Ensuring appropriate action is being taken to reduce environmental risk

However, these are assumed to be negligible since:

- The notification process is not intended to be onerous, and
- In many cases the actions required to manage environmental risk (as reflected in the updated guidance) are already being conducted for the purpose of shooter safety.

The regulator will also be required to check that such standards are in place over time. Based on conversations with EA enforcement experts, the Agency considers the required enforcement to cost £104,000 over the 20-year appraisal period in undiscounted terms, and **£73,800** in PV terms.

As such, the total administrative and enforcement costs are estimated at £105,000 in undiscounted terms and **£74,800** in PV terms.

2.6.3.3.2 Range compliance costs

As noted earlier in this sub-section, the Agency will assume no cost to pertain to ranges which use members to de-lead, but a cost is assumed wherever a contractor is required, for example at larger ranges with big sand stop-butts that require the use of a digger or other machinery.

Assuming that 5% of the estimated 300 ranges would be required to de-lead under this option, and that 25% of those are estimated to require contractors to do so, the Agency assumes that an estimated additional 3.75 ranges would be required to de-lead via contractors than is the case under the baseline.

In the absence of data on current frequency and cost of de-leading, the Agency will assume this to occur on an annual basis on average, costing £10,000 per range. In this case, the annual additional de-leading cost constitutes £37,500 per year, totalling £675,000 across the 20-year appraisal period in undiscounted terms. Once discounted, this is estimated at **£477,900**. The Agency will be seeking to verify this cost assumption during the SEA public consultation.

2.6.3.3.3 Totals and summary statistics

In total, the PV costs of this option are estimated at **£0.6m**. It would entail the recovery of the estimated 5% of the quantity of bullets from this use that are currently not recovered, estimated to be 93t. As such, the cost-effectiveness ratio of this option is estimated at **£5,900/t** lead avoided. The tonnage proxy within this cost-effectiveness ratio represents the following risks associated with this use:

- Ruminants/grazing animals
- Soil contamination
- Water contamination.

It should be noted that this cost-effectiveness ratio is calculated using several arbitrarily assumed costings, so its use is limited when compared to the more robust findings in the analysis of shot restrictions. The Agency is seeking to validate its assumptions during the SEA consultation period.

2.6.3.4 *Airgun intervention (both uses)*

As outlined during the options analysis, the Agency has not identified any option for managing the risk from this use that would be monitorable and enforceable. As such, the Agency does not recommend restriction of this use, and will not provide further socioeconomic analysis on it within this dossier.

2.6.4 Benefits

This section explores the societal benefits that would result from a restriction on the various uses of lead ammunition, including the Agency's proposed derogations. Benefits constitute the avoided ongoing risks that arise from environmental and human exposure to lead ammunition within the uses in scope of this restriction proposal.

For the shot uses, the Agency has been able to partially monetise the benefits of a restriction. This, however, has not been possible for the bullet uses. This is largely because no quantitative risk assessment has been undertaken for these uses. The Agency's monetised benefits assessment depends on estimates of the numbers of bird deaths due to exposure to spent lead ammunition, so no monetised estimate can be provided without a quantified estimate of risk.

2.6.5 Societal benefits - restriction on lead shot

It is challenging to monetise or quantify the benefits of a restriction on this use (and the others in scope), due in-part to their non-market nature. Despite this, the Agency has been able to monetise some benefits of restriction, outlined below with the relevant methodological assumptions and limitations. Where quantification is not possible, benefits are described qualitatively. The benefits of the restriction can be assessed in terms of avoided impacts to the environment and human health, explored in detail in Section 1 of the dossier and summarised in the relevant subsections ahead.

2.6.5.1 *Benefits of restriction - LQS with lead shot*

This subsection will outline the benefits of restricting the use of lead shot in LQS in a monetised, quantitative or qualitative sense.

2.6.5.1.1 Environmental benefits

As summarised in Table 1, the environmental risk groups existing from this use are:

- Birds (primary poisoning)
- Birds (secondary poisoning)
- Ruminants/Grazing animals
- Mammalian scavengers/companion animals
- Soil
- Water

The Agency has monetised the benefit of avoided primary poisoning to terrestrial birds under a restriction of this use. The Agency has been unable to monetise the benefit of avoiding other risks under restriction due to no quantitative risk assessment having been undertaken for the other environmental risks. Several forms of uncertainty are inherent to the Agency's monetised assessment of benefits, resulting in a cost-effectiveness framework being the preferred quantitative approach within the SEA.

2.6.5.1.2 Avoided primary poisoning of terrestrial birds

The Agency has employed a unit value/benefits transfer approach to estimate the monetised benefits of avoided primary poisoning of terrestrial birds under a restriction on the uses of lead shot. The Agency has taken two different approaches to the benefits transfer, each yielding different results. The method resulting in the least societal benefits has been selected for use in the summary statistics throughout this dossier. This has been done to transparently reflect the uncertainty and challenge in undertaking such a benefits assessment, and to minimise the risk of the Agency overestimating the benefits of restriction as part of wider conservatism within the SEA. Modelled benefits outweigh modelled costs under both approaches. A generalised overview of the Agency's approach to the benefits assessment will first be outlined prior to the Agency exploring the challenges of this analysis and the reasons why separate approaches have been provided, alongside their results.

The benefits transfer uses Carson et al. (2003). Here, the authors undertake a contingent valuation study to monetise lost passive use values arising from the damage to natural resources caused by the Exxon Valdez oil spill in 1989. The natural resources valued within the study (study good) were the estimated 75,000-150,000 bird deaths, across 12 different species, in addition to some number of mammal deaths (undefined within the paper). The authors provide respondents with an overview of the oil spill, including details of the clean-up methods, caveated with the fact that natural processes are anticipated to remove almost all remaining oil from beaches within a few years of the oil spill. The authors provide respondents with pre-spill populations for each of the 12 affected bird species and mammals, in addition to death estimates from the spill. Pictures of oiled birds were not shown to participants, rather photos of the relevant species in full health.

Respondents are told that no population level impacts are anticipated and that large bird kills can happen naturally, not just due to events such as the oil spill. Respondents are then introduced to the concept of a second spill occurring, with an effective and feasible prevention programme having been identified. This programme would entail two large coast guard ships escorting each tanker throughout its journey to help prevent accidents and control the spread of oil if one did occur. To fund this, a one-time federal tax would be levied on households and on oil companies taking oil out of Alaska. Respondents are then asked if they would be willing to pay for this programme based on a variety of costs.

Unit benefits transfer approach 1

The authors inform respondents that this tanker escorting programme would last for 10 years and that beyond this point all tankers will be double-hulled. Responders are informed of a 'possible second spill' (p.11) that would be prevented by this 10-year programme. As such, the Agency considers respondents to picture a baseline where at some point in the next 10 years, a second oil spill of similar scale would have occurred. The willingness-to-pay (WTP) of households to fund a programme that avoids this is therefore interpreted as the WTP to avoid a repeat of the environmental harm caused by the first spill: the deaths of some 75,000-150,000 birds and some number of mammals (undefined in paper).

The policy good within the Agency's benefits transfer is the terrestrial bird deaths occurring each year due to primary poisoning from ingestion of lead shot. As summarised in Table 1.22, the Agency has considered four exposure scenarios ranging from 0.1% to 5% when assessing the primary poisoning risk of this use. This analysis uses the exposure scenario of 1%, considering it to be a suitable central estimate, and below the mean of the four exposure scenarios resulting in a more conservative assessment of benefits than if the mean scenario were taken (in the absence of known probabilities).

Table 2.15 is derived from the data summarised in table 1.21. The Agency has removed feral and wild Rock Dove deaths from its benefits assessment, in addition to the Common Woodpigeon. This is due to uncertainty over whether a reduction in the population size of these species constitutes a net cost or a net benefit to society. For instance, woodpigeons are agricultural pests; a reduction in their population size could plausibly be claimed to reduce the costs to society from crop damage within the UK. AHDB (2014) state a damage cost from woodpigeons of £125/hectare(ha)/year for oil seed rape (OSR), £250/hectare/year for peas, and £330-£1,250/hectare/year for brassicas. Equally, some members of society might place a significant value on the life of these species. For instance, RSPCA have guidance on how to care for injured pigeons (RSPCA, 2023). Once these species have been removed from the analysis, the 1% exposure scenario results in an estimated **30,661** terrestrial bird deaths from primary poisoning via lead shot.

Table 2.15: Policy good

Species name	Breeding population estimate (UK)	Breeding population estimate (GB)	1% exposed
Red-legged Partridge	145,494	141,129	1,411
Stock Dove	643,560	624,253	6,243
Common Quail	748	726	7
Willow Grouse	404	392	4
Red Grouse	529,530	513,644	5,136
Ptarmigan	17,000	16,490	165
Black Grouse	9,654	9,364	94
Grey Partridge	74,254	72,026	720

Eurasian Woodcock	114,216	110,790	1,108
Eurasian Collared Dove	1,617,794	1,569,260	15,693
European Turtle Dove	7,176	6,961	70
Western Capercaillie	1,114	1,081	11
	3,160,944	**3,066,116**	**30,661**

Carson et al. (2003) conclude upon a median WTP of $37/household, and a mean WTP of $79.20/household. The Agency takes the conservative step to apply the (lower) median WTP in its analysis rather than the mean. Taking the mid-point of the 75,000-150,000 birds (112,500), the Agency scales this WTP value by a factor of 0.27 (30,661 / 112,500), to arrive at a WTP of $10.08. Using the OECD purchasing power parity (PPP) index (2023), the Agency converts this adjusted median household WTP to a 2003 GBP value of £7.02. Once inflated to 2022 prices, this is £10.79. This approach assumes linear sensitivity to scope, i.e. the WTP of respondents to avoid 27% of the damage to the natural resources is assumed to equal 27% of that of the full damage. The authors did test for sensitivity to scope, suggesting this to have been found. In reality, this may follow more of a non-linear profile than that assumed by the Agency. This concern, among others, is addressed in approach 2.

The most recent ONS (2021) statistics estimate there to be 27.8m households in the UK. Adjusting this for GB as a share of the UK population, the Agency estimates there to be 26,966,000 GB households. Applying this to the median household WTP derived via the unit benefits transfer above yields an estimated societal WTP to avoid the death of 30,661 birds of **£291,001,260**.

It is also necessary to account for the fact that society would not experience this benefit immediately after a restriction is brought into place. Legacy emissions would continue to cause some share of these primary poisoning deaths until historic emissions are no longer accessible to birds. For example, once a bird has ingested shot, that shot cannot cause primary poisoning in another bird (but it can still cause secondary poisoning and other environmental impacts). Equally, shot may sink into soil over time and therefore no longer be ingested by birds. To adjust for the impact of such legacy emissions, we estimate an exponential decay function based on Bowers and Samuel (2000), and Lewis et al. (2021). In, Bowers and Samuel (2000), the authors report a reduction in prevalence of elevated blood lead levels (BLL) in American Black Ducks from 11.7% to 6.5% from 1986-88 to 1997-99. This was done to test the efficacy of implementing non-toxic shot. The United States introduced a ban on the use of lead shot for waterfowl hunting in 1991. To estimate our function, we take 1998 as the mid-point of the follow up BLL tests (1997-99) and assume that the 1986-88 prevalence stayed constant until 1991 when the restriction was introduced. Lewis et al. (2001) compare BLL in American Black Ducks in 1978, pre-ban, to those in 2017, 27 years post-ban. They find that the number of American Black Ducks demonstrating BLL that indicate exposure fell from 79% in 1978 to 20% in 2017.

The general formula for exponential decay can be expressed as:

$$f(t) = a(1 - r)^t$$

Where *t* = time period*, a* = initial value*, r* = decay rate.

Up until the enforced restriction (*t* ≤ 0), the prevalence of elevated blood lead levels in American Black Ducks was 11.7%. Therefore, *a*=11.7.

7 years after the restriction, it was measured again to be 6.5%. As such, the function becomes:

$$f(7) = 6.5 = 11.7[1 - (r)]^7.$$

Solving this for *r*, for any value of *t,* gives:

$$r = 1 - \left(\frac{6.5}{11.7}\right)^{\frac{1}{t}}$$

Using this function, we estimate a decay factor for each year of our time series, tending to 1 over time. For example, in 2024 (*t* = 1), the decay factor can be calculated as:

$$1 - \frac{\left(11.7 * \left(\frac{6.5}{11.7}\right)^{\frac{1}{7}}\right)^1}{11.7} \approx 0.081.$$

This modelling assumes 100% compliance with the ban. The data in Bowers and Samuel (2000) are likely more suited for extrapolating an annual exponential decay factor, due to reporting percentage change over a shorter number of years than that of Lewis et al. (2021). However, the long time period of study in Lewis et al. (2021) does provide a good framework for accounting for any non-compliance due to measuring BLL 27 years post-ban. This long time-period of study allows for far more decay in legacy emissions to have occurred. It can reasonably be assumed that after 27 years of emissions ceasing, no more primary poisoning should be occurring. As such, the fact that 20% of American Black Ducks are demonstrating BLL indicating some level of exposure (compared to 79% pre-ban) suggest that some level of non-compliance is occurring. As such, the Agency weights the decay factor by (.79/.20) in an attempt to account for any potential share of 'legacy emissions' that may have occurred due to continued non-compliant use of lead post-ban. For *t* = 1, this yields:

$$1 - \left(\frac{\left(11.7 * \left(\frac{6.5}{11.7} \right)^{\frac{1}{7}} \right)^{1}}{11.7} \right) * \left(\frac{1}{\frac{(79-20)}{79}} \right) \approx 0.11.$$

The factors range from 0.11 in 2029 as calculated above, presumed to be the first year of the restriction being implemented, to 0.96 in 2043. In other words, this decay factor predicts that 4% of the number of birds that currently die from lead shot will die from legacy emissions 15 years after the release of new lead shot into the environment has ceased. This approach assumes that the American Black Duck data allows for a suitable comparison with our proposed restriction. The data were gathered for a waterfowl ban, rather than a generalised restriction. The impact of legacy emissions may differ when comparing wetlands to other landscapes. Nonetheless, this decay factor serves the purpose of significantly reducing the scale of benefits in order to account for the impacts of legacy emissions. Additionally, respondents within Carson et al. (2003) presented their WTP on the basis of an on-going future oil spill protection programme. As such, they have implicitly discounted the benefits this programme will provide to them in future years. Application of a decay factor in general is a conservative step in the benefits assessment because it delays benefits that were presumably implicitly discounted by the respondents of the study, in turn arguably constituting some form of double discounting.

To calculate the annual avoided terrestrial primary poisoning benefit of a restriction on the use of LQS with lead shot, the Agency first multiplies the estimated GB WTP figure of £291,001,260 by the share of annual shot emissions that come from this use (23%). This figure is then multiplied by the relevant decay factor. Lastly, the Agency accounts for the fact that under the baseline and restriction scenarios it is assumed a 10% reduction in lead shot used for live quarry shooting will occur in the year 2025. As such, the Agency computes the same calculation as above but multiplied by 0.1 and takes this away from the estimated annual benefit every year, to compensate for the fact that the avoided bird deaths for an estimated 10% of birds (assuming a linear relationship between emissions and bird deaths) are brought forward in time due to the voluntary measures.

Under this approach, the Agency estimates that the benefit of avoided primary poisoning for terrestrial birds for this use sums to £557.5m across the 20-year appraisal period. This is **£350.1m** in PV terms.

Unit benefits transfer approach 2

As previously outlined, the payment vehicle within Carson et al. (2003) is a one-off federal tax. The Agency has assumed that respondents considered the intervention outlined within Carson et al. (2003) to avoid one oil spill within a 10-year period. They provided their one-off WTP to fund such a programme that the Agency assumes would prevent 75,000-150,000 bird (and some mammal species) deaths.

Within the context of this restriction, a similar study might elicit household WTP to fund an intervention that would prevent continuous pollution events (the deposit of spent lead ammunition into the environment). Across a 10-year time period, using the 1% exposure scenario selected within approach 1 it may be assumed that ~300,000 terrestrial birds will die from primary poisoning from spent lead shot (excluding the pigeon species outlined previously in this section). Across the Agency's 20-year appraisal period, this figure would double.

Approach 1 essentially assumes that an annual pollution event roughly 27% of the severity of the individual Exxon Valdez oil spill (in terms of terrestrial bird deaths due to primary poisoning from lead shot) is currently occurring. As such, if households were WTP a certain amount to fund a programme that would avoid another oil spill, they should be willing to pay 27% of this on an annual basis to avoid primary poisoning of terrestrial birds from spent lead shot.

Several significant assumptions have been made in approach 1. Firstly, it is assumed that individuals are expressing WTP on the basis of avoiding a second individual oil spill in the future. However, although Carson et al. (2003) do express that respondents are introduced to the concept of a 'possible second spill' (p.11), the programme outlined to mitigate the impact of this does provide continuous protection against any amount of oil spills that could have happened across the 10-year period. As such, respondents may in fact be valuing the ability to avoid any number of oil spills. If this were the case, the Agency's assumption that the WTP elicited during Carson et al. (2003) represents the value placed on avoiding 75,000-150,000 bird (and some mammal) deaths would be compromised. In turn, this means that the Agency's approach of applying the one-off WTP derived during the study on an annual basis would not be defensible.

Secondly, approach 1 assumes linear sensitivity to scope. This topic has been an area of contention in the non-market valuation literature for several decades (Lopes and Kipperberg, 2020). For instance, Boyle et al. (1994) found no statistically significant difference in WTP to avoid the deaths of 2,000, 20,000 and 200,000 migratory waterfowl. Such findings do not support the Agency's approach 1 whereby the numbers of avoided bird deaths presented in Carson et al. (2003) is scaled to match that of the Agency's risk assessment under a 1% exposure scenario (excluding the relevant pigeon species). Kipperberg and Lopes (2020) do note that thousands of contingent valuation studies have been undertaken over the last few decades with many of them demonstrating sensitivity to scope. Nonetheless, due to diminishing marginal returns it can safely be assumed that any sensitivity to scope will, at some point, become non-linear.

In light of these concerns, the Agency has also undertaken approach 2. Here, the Agency does not apply the full (post-decay) value derived from Carson et al. (2003) on an annual on-going basis. Instead, it is assumed that household WTP within this study was for protection against continuous pollution from any number of oil spills, as is the case from continuous pollution from discarded lead shot. Additionally, no weighting has been made on the basis of estimated bird deaths. The findings of Boyle et al. (1994) suggest that household WTP to avoid the deaths of 30,661 may be no different to that of 75,000-150,000. Instead, the Agency here assumes that the societal welfare derived from preventing pollution from spent lead shot (with the environmental endpoint of terrestrial bird deaths) is the same as the societal welfare derived from preventing pollution from spilt oil at sea. In any case, the environmental impacts of spent lead shot reach far beyond the 30,661 terrestrial birds estimated to die annually due to primary poisoning from lead shot.

Multiplying the median WTP within Carson et al. (2003) of $37, which is estimated at £39.60 in real (2022) PPP terms, by the estimated number of GB households yields a total WTP of £1.07bn. The Agency weights this by the share of emissions attributable to LQS[6] (23%) and accounts for the fact that under the baseline and restriction scenarios it is assumed a 10% reduction in lead shot used for live quarry shooting will occur in the year 2025.

In contrast to approach 1, a marginal decay factor is calculated for this approach to avoid an overcounting of impacts. For instance, under approach 1, the decay factors in the years 2029 and 2030 are 0.11 and 0.21. The decay factor of 0.21 captures not only the decay that has occurred in 2030, but also in the year 2029. This makes sense when the WTP is treated as an annual on-going basis. Under approach 2, the decay factor for the year 2030 becomes (0.21- 0.11) = 0.10 to reflect the fact that a single one-off WTP is profiled across the appraisal period. This decay factor is applied to both the baseline 10% emissions reduction as well as the reduction under the restriction case (10% reduction in 2025, 100% reduction from 2029).

Using this approach, the Agency estimates that the benefits of avoided primary poisoning for terrestrial birds for this use sum to £220.3m across the 20-year appraisal period. This is **£154.9m** in PV terms. The estimated PV benefits under approach 1 were £350.1m. As noted previously, the Agency considers approach 2 to be generally more defensible (as well as clearly providing a more conservative

[6] The Agency acknowledges that such an assumption implies linear sensitivity to scope, despite this approach to benefits being undertaken in part to circumvent such assumptions. However, this tonnage proxy approach has been taken throughout the analysis and the Agency finds no reasonable way in which this can be avoided in order to apportion impacts to each use.

estimate).

Several assumptions have been taken in both approaches to estimating the monetised benefits of avoided primary poisoning to terrestrial birds from a restriction on LQS with lead shot. The uncertainty surrounding the robustness of this estimate as a result of these assumptions leads the Agency to give greater weight to its cost-effectiveness analysis, rather than the cost-benefit analysis. However, under both approaches monetised environmental benefits outweigh total costs of restricting this use, even without incorporating the following environmental benefits (or factoring in the monetised human health benefits, which follow in the next section):

- The numerous waterfowl species at risk of primary poisoning from lead shot due to migratory patterns (whose populations are estimated at over 2 million in the UK, as shown in). These species have not been included in the assessment of benefits due to the risk assessment not considering exposure scenarios, as explained in Section 1.4.6.1.1.
- Secondary poisoning of birds, mammalian scavengers/companion animals and grazing animals. If monetised, these impacts could be significant. For instance, Morling (2022) estimates that £4.9m-£8m of tourist spend on the Isle of Mull is attracted every year by White-tailed Eagles (2019 prices). This is one of several raptors at risk and Morling (2022) does not account for non-use values.
- Sub-lethal impacts on birds (the value society places on wildlife poisoning that does not result in death, but still causes significant suffering).
- Other environmental impacts beyond those to wildlife, notably risk to water and soil.

2.6.5.2 *Impacts to human health*

The most relevant health endpoints associated with exposure to lead are neurotoxic effects in children and the offspring of pregnant women, as well as increases in the incidence of chronic kidney disease (CKD) and in cardiovascular effects (increase in systolic blood pressure) in adults. For details on the assessment of human health impacts see Section 1.5.

2.6.5.2.1 IQ loss

The implication of exposure to lead has been estimated as a 1 point or more decrease in IQ in children. Green and Pain (2015b) estimated that somewhere in the region of 3,800 – 48,000 children in the UK were at a potential risk of incurring a one point or more reduction in IQ as a result of exposure to ammunition-derived lead. The Agency takes forward the lower bound of this estimate, multiplying it by 90% to account for the fact that an assumed 10% of emissions from this use cease in 2025 under the baseline. This is a simplified assumption in the absence of a more formal understanding of how voluntary measures would affect neurodevelopment risk.

As such, the Agency assumes that (3,800 * 0.9) = 3,420 IQ points that would have been lost under the baseline will not be lost in the event of a restriction.

There is a large literature investigating the link between IQ and lifetime earnings. Schwartz (1994) and Salkever (2014) provided the basis for research into the impact on earnings from a fall in IQ due to childhood lead exposure (Salkever, 2014) . Grosse et al. (2002) estimate that a 1 point increase in IQ increases lifetime earnings by 1.76-2.38%. Salkever (1995) provides an estimate of 2.379%, equal to the upper bound of Grosse et al. (2002). Later work by Grosse in 2007 suggests that these values may have overestimated the association of IQ with earnings (US EPA, unknown). Grosse (2021) quotes a reduced range of 0.5% to 2.5%, with a central estimate of 1.4% per IQ point. The author estimates an IQ-earnings relationship of $10,600-$13,100 per IQ point, using a 3% discount rate.

Using the OECD PPP index (OECD, 2023) and inflating to 2022 GBP prices, this IQ-earnings relationship becomes £7,344-£9,076 per IQ point. The Agency will take forward the lower bound to mitigate the uncertainty that arises from extrapolating US earnings data to a UK context, which will not be perfectly compensated for with the PPP index. Additional conservatism is derived from the authors use of a 3% discount rate, as opposed to the 1.5% discount rate that is used in the UK for health impacts (HM Treasury, 2020).

Using the above data, the Agency values the foregone loss of 3,420 IQ points due to a restriction on this use at **£26.2m** in PV terms (3% discount rate). The Agency notes that this risk also exists due to the use of lead bullets in LQS but, on the basis of a straightforward weighting of lead shot used in LQS versus lead bullets (99.8:0.2), assumes 100% of the impact to be due to lead shot. As noted in section 1.4.6.6, the Agency anticipates that a greater share of the lead used in bullets will be present in the food chain than that of lead shot. As such, a simple tonnage weighting may misestimate the relative risks. The Agency will consider how to address this, if at all, during the public consultation period.

The Agency acknowledges that this is a simplified approach to estimating the true societal cost of foregone IQ points, ignoring factors such as latency. However, the Agency considers the methodology to be appropriate and proportionate given the smaller scale of this benefit relative to those of the environment.

2.6.5.2.2 Chronic Kidney Disease (CKD) impacts

LAG (2015a) estimate a lower bound of the number of adults in the UK at risk of CKD due to dietary exposure of lead in game meat to be 129. They note that depending on the modelling assumptions, the number of adults at risk can range from ‘hundreds to tens of thousands’. To address this large uncertainty, the Agency takes forward the lowest quantified number at risk of 129 for UK, becoming 125 when adjusted for GB as a share of UK population.

Nguyen (2018) estimates the quality-adjusted life year (QALY) loss resulting from various different stages of CKD. For males, they estimate a respective QALY loss for CKD2, CKD3 with albuminiuria and CKD4/5 of 3.5, 2.8, 4.2. In females, they estimate respective QALY losses of 4.8, 2.3, and 6.8. Due to uncertainty in the exact type of CKD cases that are captured in the incidence studied in this SEA, and of the sex of those affected, the Agency uses the average of these values to assume that a case of CKD induces a loss of **4.07 QALYs**. Multiplied across the 125 adults assumed at risk, the Agency estimates that **509 QALYs** would be gained under the restriction case when compared to the baseline.

Using the Green Book (2020) QALY unit value of £70,000 (2021 prices, equalling £73,205 once inflated to 2022 prices), the Agency estimates the benefit from avoiding these CKD cases to be £33.5m (undiscounted). This does not include the welfare impacts of close contacts affected by a relative/friend suffering from CKD, healthcare costs, etc. The Agency is unable to estimate the time during which this benefit would materialise, and so assumes that it appears during the last year of the appraisal period. This decision was made such that the benefit would be discounted to the greatest extent, rendering the analysis more conservative. This is important given the large uncertainty in the number of cases of CKD avoided, especially as the overall risk to adults from exposure to lead in game meat is considered low.

In PV terms, the benefit of avoided CKD case is estimated at **£25.3m** (1.5% discount rate). As with the monetised estimate of IQ impacts, the Agency assumes that all CKD impacts are attributable to the shot use rather than bullets on the basis of a straightforward comparison of the quantity of lead attributed to each use.

2.6.5.2.3 Cardiovascular effects

As highlighted in Section 1, lead exposure is associated with several adverse cardiovascular effects, with systolic blood pressure being the most studied. A quantitative risk assessment was not undertaken for this risk, but the Agency notes that a restriction of lead shot in LQS would eliminate the on-going risk of cardiovascular impacts from exposure to lead in game meat.

2.6.5.2.4 Totals and summary statistics

In PV terms, the monetised benefits of a restriction on the use of lead shot in LQS are estimated at **£206.4m** across the 20-year appraisal period. The estimated monetised costs of this restriction would be **£123.7m**, resulting in a benefit-cost ratio of **1.7**. This is with a partial monetisation of benefits and conservative assumptions used throughout the analysis, leading the Agency to conclude that these findings likely understate the extent to which such a restriction would provide net benefit to society. Table 2.15 below summarises the benefits of a restriction on this use.

Table 2.16: summary of benefits: restriction on lead shot in LQS

Description of benefit	**Type of benefits**	**PV benefit (20yrs)**
Avoided bird deaths via primary poisoning	Environmental	£154.9m
Avoided bird deaths via secondary poisoning	Environmental	N/Q
Avoided sub-lethal effects in birds (suffering in poisoned birds who do not die from primary or secondary exposure)	Environmental	N/Q
Avoided risk to other wildlife, namely ruminants/grazing animals and mammalian scavengers/companion animals.	Environmental	N/Q
Avoided soil contamination	Environmental	N/Q
Avoided water contamination	Environmental	N/Q
Avoided neurodevelopmental impacts (proxied by avoided IQ loss)	Human health	£26.2m
Avoided increased incidence in CKD	Human health	£25.3m
Avoided cardiovascular effects	Human health	N/Q
Total		**£206.4m**

2.6.5.3 *Benefits of restriction plus derogation - TS with lead shot*

The set of environmental risks identified are the same for both a restriction of lead shot for TS and LQS. The Agency uses tonnage as a proxy for risk and weights the monetised environmental benefits by share of emissions coming from each of the shot uses. The benefits of a restriction on the use of lead in TS are almost identical to those of a restriction with derogation, but slightly larger due to a complete elimination of lead emissions from this use, unlike under the derogation. The Agency weights the monetised benefits from this use under the assessment of the derogated use to account for the fact that an estimated 37t/year of the 5,360t annual TS emissions would continue under the derogation. Due to their similarity, benefits of a blanket restriction will not be detailed in this dossier, but summary statistics of the Agency's modelling of the benefits are provided in Section 2.7.

Due to there being no dietary exposure to lead through game meat from this use, the Agency assumes no human health benefits to apply. However, this restriction would reduce environmental contamination with lead and consequently secondary exposure through other food sources and water, and direct exposure through hand-to-mouth and inhalation routes. However, no assessment of these impacts has been undertaken due to large uncertainty surrounding them.

2.6.5.3.1 Environmental benefits

The same environmental benefits outlined in Section 2.7.1.2.1 apply here, constituting the avoidance of ongoing environmental risks outlined throughout Section 1. The same methodologies (approach 1 and approach 2) are used here as in Section 2.7.1.2.1 to monetise the benefit of avoided primary poisoning in terrestrial birds from a derogated restriction on this use.

Approach 1

Weighted for the share of total annual shot emissions that would be prevented as a result of a derogated restriction on this use, the Agency estimates the monetised benefit of avoided bird deaths due to primary poisoning to total £2.0bn across the 20-year appraisal period (undiscounted). Once discounted, this becomes **£1.27bn**. Without a derogation, the estimated PV benefits of a blanket restriction are estimated at £1.28bn.

The estimated monetised costs of this derogated restriction are **£415.5m**, resulting in a benefit-cost ratio of **3.1**.

Approach 2

Weighted for the share of total annual shot emissions that would be prevented as a result of a derogated restriction on this use, the Agency estimates the monetised benefit of avoided bird deaths due to primary poisoning to total £814.2m across the 20-year appraisal period (undiscounted). Once discounted, this becomes **£580.4m**. Without a derogation, the estimated PV benefits of a blanket restriction are estimated at £584.4m.

Under this approach, the Agency's analysis results in a benefit-cost ratio of **1.4** for the derogated restriction.

Several assumptions have been taken in both approaches to estimating the monetised benefits of avoided primary poisoning to terrestrial birds from a restriction on LQS with lead shot. The uncertainty surrounding the robustness of this estimate as a result of these assumptions leads the Agency to give greater weight to its cost-effectiveness analysis, rather than the cost-benefit analysis. However, under both approaches monetised benefits outweigh total costs of restricting this use, even without incorporating the following environmental benefits:

- The numerous waterfowl species at risk of primary poisoning from lead shot due to migratory patterns (whose populations are estimated at over 2 million in the UK, as shown in Table 1.23). These species have not been included in the assessment of benefits due to the risk assessment not considering exposure scenarios, as explained in Section 1.4.6.1.1.
- Secondary poisoning of birds, mammalian scavengers/companion animals and grazing animals. If monetised, these impacts could be significant. For instance, Morling (2022) estimates that £4.9m-£8m of tourist spend on the Isle of Mull is attracted every year by White-tailed Eagles (2019 prices). This is one of several raptors at risk and Morling (2022) does not account for non-use values.
- Sub-lethal impacts on birds (the value society places on wildlife poisoning that does not result in death, but still causes significant suffering).
- Other environmental impacts beyond those to wildlife, notably risk to water and soil.

The benefits of a derogated restriction of this use are summarised in .

Table 2.17: Summary of benefits: derogated restriction on lead shot in TS

Description of benefit	Type of benefits	PV benefit (20yrs)
Avoided bird deaths via primary poisoning	Environmental	£580.4m
Avoided bird deaths via	Environmental	N/Q

secondary poisoning		
Avoided sub-lethal effects in birds (suffering in poisoned birds who do not die from primary or secondary exposure)	Environmental	N/Q
Avoided risk to other wildlife, namely ruminants/grazing animals and mammalian scavengers/companion animals.	Environmental	N/Q
Avoided soil contamination	Environmental	N/Q
Avoided water contamination	Environmental	N/Q
Total		**£580.4m**

2.6.5.4 *Benefits of restriction - LQS with lead bullets*

The Agency has been unable to quantify the benefits of a restriction on the use of bullets of any calibre in LQS. Table 2.18 summarises the benefits of a restriction on lead bullets in LQS. The Agency notes that whist human health risks exist from this use, the SEA assumes all monetised human health benefits from restricting all uses of lead ammunition in LQS to pertain to a shot restriction on the basis of a straightforward weighting of lead quantities used in shot versus bullets. The Agency estimates ~1,600t/a of lead shot to currently be used for LQS, compared to ~3t/a from bullets (not including air pellets). However, the Agency notes several uncertainties when considering the relative human health risks from lead shot versus lead bullets, as outlined in 1.5. During the public consultation period the Agency will consider whether apportionment of this impact within the SEA is robustly feasible.

The ratio of lead emissions from LQS with shot versus bullets (excluding air pellets) is estimated to be 99.8:0.2. The impact of losing 1 IQ point on future earnings is unlikely to equal 0.002 times the impact of losing 0.002 IQ points. Indeed, a loss of 0.002 IQ points likely has no discernible effect, whatsoever. Such non-linearity leads the Agency to attribute 100% of human health impacts to a LQS shot restriction when using the straightforward per tonnage methodology. It is worth noting that the monetised human health benefits attributed to the LQS shot restriction may underestimate the true impact because they use the lower bound IQ loss estimates, lower bound IQ-earnings relationship, and lower bound CKD incidence.

Although benefits cannot be monetised, the cost-effectiveness ratio for a restriction on lead bullets for LQS are noticeably less favourable than for the shot restrictions, at an estimated £41,360/t for SC and £89,700/t for LC (see Section 2.6.1 for important methodological considerations when interpreting these figures). Additionally, no benefits in terms of avoided primary poisoning, avoided soil contamination, and avoided water contamination are anticipated as a result of restricting this use. As a result, the tonnage proxy is representing a smaller set of environmental risks. The Agency is unable to recommend a restriction on a SEA basis due to limitations in data meaning that a comparative scale of costs and benefits is not possible. Further assessments on proportionality will be undertaken during the consultation period.

Table 2.18 outlines the benefits of a restriction on lead bullets for LQS.

***Table 2.18**: Summary of benefits: derogated restriction on lead bullets in LQS*

Description of benefit	Type of benefits	PV benefit (20yrs)
Avoided bird deaths via secondary poisoning	Environmental	N/Q
Avoided sub-lethal effects in birds (suffering in poisoned birds who do not die from primary or secondary exposure)	Environmental	N/Q
Avoided risk to mammalian scavengers/companion animals.	Environmental	N/Q
Avoided neurodevelopmental impacts (proxied by avoided IQ loss)	Human Health	N/Q
Avoided increased	Human health	N/Q

incidence in CKD		
Avoided cardiovascular effects	Human health	N/Q

2.6.5.5 *Benefits of restriction plus derogation - TS with lead bullets*

As outlined in Section 2.6.1.3, the Agency estimates that 5% of annual emissions from this use are not recovered as part of a de-leading process. In section 1, the Agency has reported the quantity of lead bullets from this use to be that of 39t and 73t for small and large calibre bullets, respectively. This includes both the 95% of bullets estimated to be recovered through de-leading, and the 5% which are not recovered. Although the Agency assumes risk to be managed in those emissions that are recovered, the full total was used when presenting the volumes/emissions by use to accurately reflect the scale of this use relative to the others. The Agency's cost-effectiveness analysis only considers the 5% of emissions not recovered.

Under the baseline, the Agency assumes that current RMMs in place for health and safety reasons continue as usual. The Agency assumes the risks from this use to be managed in the estimated 95% of ranges with de-leading in place. As such, the benefits of a derogated restriction on this use pertain to the reduction in risk from the remaining 5% of ranges that would implement de-leading post-restriction. Crucially, however, a derogated restriction on this use also guarantees the risk from emissions to be controlled if range standards/requirements change in the future. If, hypothetically, de-leading (or other appropriate risk management measures) were no longer required by the range governing body due to other measures being adopted to avoid ricochet, this derogated restriction would eliminate 100% of the estimated 112t/a, rather than 100% of the estimated (0.05 * 112t)/a. As such, the benefits of this derogated restriction depend on the baseline assumed.

The Agency has been unable to quantify the benefits of a derogated restriction on this use. Benefits are the reduction in risk to ruminants/grazing animals, soil, and water, associated with a reduction in lead emissions to the environment of an estimated 93t across the 20-year time-period appraised. As noted above, this derogated restriction also ensures that the 95% of emissions from this use that are currently recovered will continue to be recovered, even if the governing body for shooting should consider such health and safety RMMs to no longer be needed (not anticipated by the Agency). If recovery were not already in place at 95% of ranges, this derogated restriction would recover an estimated 1,860t across 20 years.

Although the Agency has been unable to monetise benefits, the estimated cost-effectiveness ratio of £5,900/t is similar to those of the shot restrictions recommended: LQS £5,700/t; TS £5,300/t. A reduced set of environmental risks pertain to this use than that of the shot uses, however, and so a comparison of cost-effectiveness ratios does not transparently reflect the costs of reducing the same risk. Additionally, several cost figures used in the cost-effectiveness ratio for this use are currently estimates by the Agency based on expertise rather than data. Nonetheless, the Agency considers the benefits (both those monetised and non-monetised) of the shot restrictions to significantly outweigh the costs, and so considers their cost-effectiveness ratios to certainly justify intervention. As such, a caveated comparison to this based on other uses can provide a helpful benchmark in lieu of monetised benefits.

A derogated restriction would also protect against future additional risk that would arise if the governing body's health and safety requirements were to change.

Based on the above considerations, and those outlined earlier in the SEA, the Agency considers a derogated restriction on this use to be proportionate, and as such recommends this be undertaken.

2.7 Uncertainties and sensitivity

There are various uncertainties around the impacts of restriction. To strengthen the Agency's analysis in light of these uncertainties, conservative assumptions have been used wherever possible, and a thorough sensitivity analysis has been conducted for the shot restriction proposals. Sensitivity analysis has not been performed for the bullet uses, partly due to the Agency not possessing meaningful data to base it on beyond arbitrary increases/decreases in the few variables that underpin the quantitative analysis, and because a semi-quantitative analysis of impacts has been undertaken. Because of this, such uncertainty can arguably be better explained qualitatively than through arbitrary changes of the few quantitative variables. In the case of the shot restriction, the Agency's recommendations are weighted much more on the results of quantitative analysis, within which there are a significant number of variables. Many of these variables have meaningful ranges which can be tested. As such, the Agency has been able to undertake an in-depth investigation of how such ranges affect the cost-benefit conclusions. However, during the consultation period the Agency will be considering whether sensitivity analysis on the bullet uses is a proportionate use of Agency resources.

Within the shot sensitivity analysis, three scenarios are considered: *optimistic*, *central*, and *pessimistic*. Optimistic refers to the case where the ratio of benefits to costs is as high as could be reasonably assumed, and *pessimistic* vice versa - considered an absolute worst-case scenario by the Agency. All analysis of costs and benefits presented thus far has been that of the *central* case, but as the Agency has previously noted, many of the variables underpinning this central case are conservative. As such, the *central* estimate is still considered by the Agency to underestimate the benefits and overestimate the costs of restriction, with the true impacts perhaps most likely to lie somewhere between the *central* and *optimistic* cases.

Table 2.19 outlines the variables/assumptions tested in the shot restriction sensitivity analysis and their respective values, with and displaying resulting summary statistics.

Table 2.19: Summary of sensitivity analysis: shot restrictions.

Assumption	Optimistic	Central	Pessimistic	Notes
Proportion of shotguns unable to use standard steel with or without basic modification	90%	22%	22%	No value less than 22% selected. The Agency considers 22%, if anything, to already be a pessimistic assumption. 90% selected in the optimistic case-this is an arbitrary assumption to test the impact of a proportion more akin to that of SEAC (95%). This significantly reduces the estimated costs of restriction.
Price of alternative shotgun ammunition relative to lead	Keep same as central case as this is already favourable	steel = £112/250, bismuth = £422/250, lead = £129/250	Steel inflates by 20% in 2024 from EU restriction, 30% in 2029 from GB restriction.	Arbitrary increase in the relative price of steel ammunition to account for uncertainty in the assumption that relative prices with stay the same as they currently are. This addresses any potential risk of supply concerns surrounding steel shot (which the Agency considers to already be addressed via the 5

Assumption	Optimistic	Central	Pessimistic	Notes
				year transition periods recommended.
BEIS carbon values + GHG scenario (£)	134	268	402	Values taken from the BEIS (2021) low, central, and high carbon values. These increase on an annual basis, see BEIS (2021) for more detail.
Proportion of individuals picking to buy new gun or switch to bismuth when unable to use steel shot.	100% bismuth	50:50 split	100% new gun purchase	Over a 20-year period, a 100% switch to bismuth results in lower societal costs than 100% purchase of new shotgun. True scenario will be somewhere between the optimistic and pessimistic, so this captures all possibilities.
Price of a new shotgun (£)	2,232	2,232	4,000	This is the LQS central price, different price used for TS (slightly cheaper). £4,000 value is arbitrary but aims to account for the possibility that the Agency's average shotgun price is too low.
Benefits transfer using mean in addition to median	Mean	Median	Median	Using the mean WTP more than doubles the estimated environmental benefits when compared to the median WTP.

Table 2.20: Present value costs and benefits under sensitivity analysis

Use	Optimistic PV costs	Central PV costs	Pessimistic PV costs	Optimistic PV benefits	Central PV benefits	Pessimistic PV benefits
LQS shot restriction	£43.4m	£123.7m	£330.1m	£383.2m	£206.4m	£206.4m
TS shot restriction with derogation	£156.3m	£415.5m	£1.11bn	£1.24bn	£580.4m	£580.4m
TS shot blanket restriction	£163.4m	£422.8	£1.12bn	£1.25bn	£584.4	£584.4m

Notes: figures in millions rounded to 1 d.p. Figures in billions round to 2 d.p. to allow for greater transparency in scale.

Table 2.21: Benefit-cost and cost-effectiveness ratios under sensitivity analysis

	BCR			CER		
Use	**Optimistic BCR**	**Central BCR**	**Pessimistic BCR**	**Optimistic CER (£/t Pb)**	**Central CER (£/t Pb)**	**Pessimistic CER (£/t Pb)**
LQS shot restriction	8.8	1.7	0.6	£2,000	£5,700	£15,300
TS shot restriction with derogation	7.9	1.4	0.5	£1,900	£5,200	£13,900
TS shot blanket restriction	7.7	1.4	0.5	£2,000	£5,300	£20,000

As seen in , the Agency estimates the benefit-cost ratio of a restriction on LQS to range from 0.6-8.8, and a derogated restriction on TS to range from 0.5-7.9, depending on the assumptions made during modelling. The BCRs under the central case are 1.7 and 1.4 respectively, though this incorporates many conservative assumptions and a partial monetisation of benefits.

3 Conclusions

For all uses considered in this dossier, risks to the environment have been identified, with some uses also posing risks to human health. Considering these risks and socioeconomic evidence, the Agency has considered the actions that could be taken to proportionately control these risks. These are summarised below

3.1 Live quarry shooting

The Agency concludes that the use of lead ammunition for shooting live quarry presents a risk the environment and also human health that is not adequately controlled and needs to be addressed. No risk management measures were identified that would adequately address the risks to either the environment or human health to allow continued use.

3.1.1 Shot

Lead shot is already banned for use over wetlands in GB, so alternatives are already available on the GB market, especially steel shot. Some shooters have already made the transition to these, and a number of UK shooting and rural organisations have voluntarily committed to using alternatives to lead shot for the hunting of live quarry by 2025, whilst some supermarkets have also committed to only selling game meat from animals killed using non-lead ammunition.

The Agency has undertaken a cost-effectiveness analysis and a cost-benefit analysis on the restriction of LQS with lead shot, concluding the restriction to be cost-effective and benefits of such a restriction to outweigh the costs. Furthermore, this restriction is considered effective, practical, monitorable, and enforceable. As such, **the Agency recommends that this use should be restricted**, with a 5-year transition period to allow for manufacturers of lead shot to transition to a complete production of alternatives. The appropriate duration of this transition period will be further considered during the SEA consultation.

3.1.2 Bullets

Alternative larger calibre bullets are available, but with some concerns about supply at the time of publication. The Agency considers adequately performing small calibre bullets are not yet widely available.

There appears to be a move to lead-free ammunition by some users of large calibre bullets. Additionally, the EU restriction on lead in ammunition also proposes a ban on lead bullets for LQS. It is therefore likely that more alternatives will be developed and brought to market over time.

The placing on the market of lead bullets cannot be restricted, since they would still need to be available for indoor target shooting, which is out of scope of this restriction proposal. This may create challenges regarding the enforceability of any restriction on lead bullets in relation to live quarry shooting. At this stage, the Agency is unable to determine whether and to what extent lead bullets that remain available for target shooting would continue to be purchased for target shooting but actually used for live quarry shooting (which would be unlawful in the event that a restriction is implemented). Such an outcome would undermine the effectiveness of a restriction on the placing on the market of lead bullets for live quarry shooting.

There is an additional practical concern regarding a potential restriction on live quarry shooting with lead bullets. With the use of non-lead bullets not typically being permitted on some ranges, there may be challenges for live quarry shooters that are unable to "zero" their rifles and practice shooting. This could lead to undesirable outcomes for shooter safety and animal welfare, e.g., missed shots, wounding quarry without killing.

The Agency has been unable to undertake a cost-benefit analysis of a restriction on these uses. Cost-effectiveness and qualitative analysis suggest that a restriction on these uses would be considerably less cost-effective than that of the shot uses. The Agency is **unable to conclude whether the benefits of restricting the use of bullets in LQS would outweigh the costs**. As such, the Agency does not recommend a restriction on this use.

It should be noted that given the low overall cost to implement a restriction on this use, and therefore the corresponding low bar required for proportionality, the Agency may propose a restriction should the concerns around enforceability and practicality be sufficiently resolved.

The Agency's assessment of impacts suggests that the technical and economic feasibility of a restriction on large calibre bullets is greater than that of small calibre bullets. As such, the Agency considers a restriction on either use to be less cost-effective when compared to that of shot, and a restriction on the use of small calibre bullets to be less cost-effective than that of large calibre bullets.

3.1.3 Airgun ammunition

The Agency has been unable to identify any monitorable or enforceable risk management measures for airgun ammunition. As such, the Agency does not recommend restriction on this use.

3.2 Target shooting

3.2.1 Lead shot

The Agency has concluded that the use of lead shot for sports shooting presents a risk to the environment. No risk management measures were identified that would adequately address the risks to the environment to allow continued use in entirety.

Alternatives to lead shot are already available. However, the Agency is aware that the use of lead shot is required for international competitions in some shooting disciplines. This issue can be addressed through a derogated restriction, where a small number of athletes as identified by the relevant sporting body can continue to use lead shot.

Although the Agency considers that the benefits of both a blanket restriction and restriction with derogations outweigh their respective costs, the ratio of benefits to costs for a derogated restriction is more favourable due to allowing for the continued use of lead shot by athletes training and competing internationally. As such, **the Agency recommends a derogated restriction where a select number of athletes as identified by the relevant sporting body (e.g., British Shooting) can continue to use lead shot**. As with LQS, a 5-year transition period to allow for manufacturers of lead shot to transition to a complete production of alternatives.

3.2.2 Lead bullets

A risk to the environment exists at ranges that do not currently have de-leading procedures in place. The NRA estimate this to be roughly 5% of their ranges. It likely also includes any ranges not governed by the NRA, which the Agency considers to be a very small number of ranges, who are assumed to fall under NRA governance under the baseline.

The Agency does not consider a blanket restriction to be a proportionate intervention for this use. The Agency considers lead alternatives to currently be worse performing in terms of accuracy than lead bullets, particularly for small calibres. Additionally, the NRA do currently not allow the use of lead alternatives due to concerns about ricochet risk in stop butts.

The Agency instead recommends a derogated restriction. Ranges with appropriate measures in place to reduce the identified risks to the environment, such as existing de-leading protocols (RMMs) would be able continue the use of lead ammunition. Given that this already covers 95% of NRA ranges, it is arguably unlikely to be disproportionately costly for ranges to implement. Indeed, comparison of cost-effectiveness ratios suggest the societal cost per tonne of lead abated is relatively similar to that of the shot restrictions.

The Agency recommends a derogated restriction on this use, whereby ranges with sufficient RMMs can continue the use of lead bullets, with a 2-year transition period. Those without RMMs would be required to use lead-free alternatives or cease operation.

3.2.3 Airgun ammunition

The Agency has been unable to identify any monitorable or enforceable risk management measures for airgun ammunition. As such, the Agency does not recommend restriction on this use.

4 Glossary

AEWA	African-Eurasian Migratory Waterbirds
AHVLA	Animal Health and Veterinary Laboratories Agency
ATSDR	Agency for Toxic Substances and Disease Registry
BASC	British Association for Shooting and Conservation
BLL	Blood Lead Levels
BMDL	Lower confidence limit of the benchmark dose
BMR	Benchmark response
BOCC	Birds of Conservation Concern
CI	Confidence Interval
CKD	Chronic Kidney Disease
CLP	Classification, Labelling and Packaging of substances and mixtures
COT	Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
CPSA	Clay Pigeon Shooting Association
CSR	Chemical Safety Report
DALYs	Disability Adjusted Life Years
Defra	Department for the Environment, Food and Rural Affairs
DNEL	Derived No Effect Level
DNSIYC	Diet and Nutrition Survey of Infants and Young Children
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
EiF	Entry into Force
EQS	Environmental Quality Standard
EU	European Union
EUML	European Union Maximum Level

EU MRL	European Union Maximum Residue Level
FACE	European Federation for Hunting and Conservation
FITASC	Federation International des Armes de Chasse
FSA	Food Standards Agency
FSAS	Food Standards Agency in Scotland
GB	Great Britain
GBP	Great British Pounds Sterling
HSE	Health and Safety Executive
IQ	Intelligence Quotient
IOC	International Olympic Committee
ISSF	International Sports Shooting Federation
IUCN	International Union for the Conservation of Nature
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LAG	Lead Ammunition Group
MCL	Mandatory Classification and Labelling
MOE	Margin of Exposure
NDNS	National Diet and Nutrition Survey
NPV	Net Present Value
PACEC	Public and Corporate Economic Consultants
PHE	Public Health England
PNEC	Predicted No Effect Concentration
PV	Present Value
RAC	Risk Assessment Committee
RMM	Risk Management Measure
TP	Transition Period
UK	United Kingdom

VSLY	Value of a Statistical Life Year

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