Risks from Lead Ammunition and Mitigation Measures
A Summary of the Scientific Literature 2020-2023

Appendix to 2023 Open Letter from European and other concerned global scientists on the restriction on the placing on the market and use of lead in outdoor shooting and fishing proposed by ECHA under REACH Regulation.

This Appendix provides a supplement to the ECHA documentation and comprises a summary review of new science largely published since ECHA completed its work on the restriction proposal.

Key points from the scientific literature 2020-2023

Risks

- More scavenging and predatory wild bird and mammal species, including threatened and protected European species, are at risk of lead poisoning than previously thought.
- Sub-lethal effects of lead in birds have been documented at lower exposure levels than previously known.
- Some exposed European raptor species are likely to have substantially suppressed populations due to lead poisoning from ammunition.
- Correlative studies on humans and dogs link increased blood lead to wild game consumption.
- Lead concentrations in the meat of wild-shot small game animals across most of Europe are high and appear to have increased over time.
- High levels of lead have been found in some commercial minced raw petfood containing wild pheasants so companion animals, as well as hunters' dogs fed lead-contaminated trimmings, are at risk of negative health effects.
- Mincing (=grinding) of game meat was identified as a possible factor contributing to high lead concentrations in petfood even after removal of whole shotgun pellets.
- The US Centers for Disease Control and Prevention (CDC) has reduced the Blood Lead Reference Values (BLRV) for children from 5 µg/dL to 3.5 µg/dL.

Mitigating risks

- Additional non-lead bullet types, including smaller calibres (22 LR) have been found suitable for shooting large and/or small mammals.
- While effectiveness, safety and availability of non-lead ammunition may still be perceived as constraints to transition, the majority of these issues have been overcome.

- In the UK, voluntary initiatives by hunters to reduce the use of lead gunshot, and by wholesalers and retailers to sell only meat from game animals killed using non-lead ammunition, have had little effect so far.
- The need for amendment of Regulation EC1881/2006 to include a maximum lead level for game meat has been identified.
- Previously defined scientific and policy rationales for using non-lead ammunition for Olympic and related sporting events were highlighted.
- Hunters' perceptions of non-lead ammunition are mixed but seem to become more favourable with use.
- Ongoing, consistent and focused communication on the benefits of non-lead ammunition use is essential.
- Trust-building measures are needed between shooters and other stakeholders so that anti-poisoning initiatives are not misinterpreted as anti-hunting.

Harmonizing global health and environmental protection

- Improved inter-agency integration within and beyond Europe would help implement solutions to human and environmental health risks from lead ammunition.
- The WHO does not appear to recognise lead from ammunition as a lead source in food and no maximum allowable level of lead in game meat has been set under FAO/WHO Codex Alimentarius.

Literature review methods and notes

This literature review was conducted to summarise relevant information published between 2020 and September 2023. This is intended to supplement information included within the ECHA restriction proposal on the placing on the market and use of lead in projectiles (for firearms and airguns), and in fishing sinkers and lures for outdoor activities. Some overlap will exist, but much of this information will not have been covered within the ECHA restriction proposal.

Literature was obtained by searching for published literature highlighted in informal email exchanges between lead scientists, and by using the Google Scholar search engine https://scholar.google.co.uk/. Various combinations of following words or terms were used:

- Lead, ammunition, shot, bullet, poisoning, bird or mammal or reptile or animal
- Non-lead, non-toxic, shot, bullet, ammunition
- Lead, ammunition, human health, blood lead
- Policy, regulation, lead, ammunition

Because a ban on the use of lead gunshot in and around EU wetlands has been operational across the EU since February 2023, references dealing specifically with this topic or risks to wildfowl were excluded unless they were of relevance to the current restriction proposal. For example, references that evaluate the success of mitigation measures were considered relevant. A large proportion of references found originated from studies in Europe or North America. While some of these are included in the reference list below, this document focusses on studies from, or of direct relevance to,

the current restriction proposal in the EU, and does not attempt to summarize all of the global literature. Similarly, information from military use of lead ammunition and from indoor firing ranges was excluded.

The summary below is intended as a non-comprehensive, accessible synthesis of the literature review that incorporates all key areas.

Summary of Scientific Literature 2020-2023

Risks from lead ammunition

Wild non-avian species: Recent papers show that scavenging by mammals of unrecovered hunted ungulate carcasses and discarded viscera is more common than previously recognized in European mammals (Krofel *et al.* 2021; Brown *et al.* 2023), including the Endangered Iberian lynx (Tobajas *et al.* 2023). Elevated bone lead concentrations were reported in some grey wolves found dead in Germany (Ludolphy *et al.* 2023). High lead levels found in the tissues of bear and wolf species in North America, associated with areas of higher large game harvest density and later in the hunting season, suggest that risk is associated with the availability of hunter-shot carcasses and remains (Kelly *et al.* 2021; Brown *et al.* 2022). Additional evidence includes elevated lead exposure in crocodiles from lead fishing weights in South Africa (Humphries *et al*. 2022), and in turtles, probably from a historic skeet shooting range, in Hawaii (Shaw *et al.* 2023).

Wild birds: New evidence has both supported the importance of lead poisoning in previously well-studied raptor (bird of prey) species in Europe and beyond, and documented exposure and/or poisoning in several previously unstudied species (Pay *et al.* 2020; Pérez-García *et al.* 2020; Monclús *et al.* 2020; Bassi *et al.* 2021; Green *et al.* 2022; van den Heever *et al.* 2023; Villén-Molina 2023). Evidence includes: matching of feeding distribution with the abundance of discarded remains of hunted animals (Singh *et al.* 2021); presence of ammunition fragments in regurgitated pellets (Pérez-García *et al.* 2020); matching of isotope ratios (chemical signatures) in ammunition with those in bird tissues with elevated lead levels (Ishii *et al.* 2020; Pay *et al.* 2020; Taggart *et al.* 2021; van den Heever *et al.*2023); temporal variation in elevated tissue lead levels matching that of availability of carrion from hunted animals (Helander *et al.* 2021; Taggart *et al.* 2021). Obligate and facultative scavengers are the most susceptible to lead poisoning (Monclús *et al.* 2020; Bassi *et al.* 2021; Green *et al.* 2022). Larger raptors with higher annual survival and delayed breeding are primarily exposed to lead from *bullets* as they generally take the slaughter remains of larger game species. In contrast, smaller raptors with lower annual survival tend to be exposed to lead from *shotgun pellets* in smaller game animals, although there is overlap.

Field studies of raptors have documented sub-lethal effects of lead poisoning at blood lead levels below those previously considered indicative of effects. A laboratory study of zebra finches associated early low level lead exposure with poorer appearance and capabilities of adult male birds (Goodchild *et al.* 2021). These results, along with data suggesting that background levels of lead exposure (in the absence of exposure to lead from ammunition) in some raptors appear to be far lower than previously recognised (Helander *et al.* 2021), suggest that both 'background' levels of exposure and effect threshold levels need to be revised downwards.

Several large-scale modelling studies across both Europe (Green *et al.* 2022) and North America (Slabe *et al.* 2022; Hanley *et al.* 2023) have estimated the extent of likely population level effects from lead exposure in raptors. These suggest that lead-related population suppression is likely to be substantial

in some lead-exposed species, especially in those with a high annual survival rate and late age at first breeding. Given that exposure of raptors to ammunition-derived lead has been occurring for over a century, these effects are likely to be limiting population size below the level it would otherwise be at, rather than causing current declines i.e., there are fewer birds in the population overall than there would be in the absence of lead.

Captive and domestic animals: Relatively few studies previously have investigated risks from the ingestion of lead of ammunition origin to domestic mammals including hunters' dogs and companion animals. However, recent research has documented increased blood lead concentrations both in hunters' dogs fed scraps from culled game (Fernández *et al.* 2021) and in domestic dogs fed game meat (Rosendahl *et al.* 2022). The fashion for feeding pets raw petfood has increased globally, and such raw food can include wild game meat, which is both shot and frequently minced. Sub-samples from three raw pheasant petfood products in the UK were found to have mean lead concentrations 49-245 times higher than the maximum level of 11.36 and 5.68 ppm (mg/kg) dry weight (d.w.) permitted in animal feed/complementary feed and complete feed respectively (Pain *et al.* 2023). After removal of subsamples in which whole shot were present (in effect replicating what might happen during human food consumption of game meat), the weighted mean lead concentration across the three raw pheasant products was 220.99 ppm d.w. This is far higher than that reported for wild-shot pheasant sold for human consumption in the UK. The most likely reason is that the mincing process used for raw petfood further fragments lead. This is a research topic which has not yet received much attention for minced (=ground) game meat products, such as game sausages, consumed by humans.

Human health: The number of studies documenting elevated lead concentrations in the meat of small and large game animals hunted with shotgun and rifle ammunition respectively continues to grow and includes new data for Europe (Lenti *et al.* 2021; Pain *et al.* 2022; Green *et al.* 2023), Africa (Nkosi *et al.* 2022), Australasia (Hampton *et al.* 2023) and the Americas (Wilson *et al.* 2020; Tisdale *et al.* 2021). In Europe, lead concentrations in the meat of small game animals appear to have increased substantially in the last decade studied (2011-2021) compared with the two previous decades, for unknown reasons (Pain *et al.* 2022). While the vast majority of studies illustrate elevated tissue lead levels in wild-shot small and large game animals, this contrasts with low lead levels found in meat from kangaroos and wallabies shot in Australia, where head shooting is mandatory (Hampton *et al.* 2023).

A number of new studies using advanced radiological techniques found many small lead fragments in animals hunted with shotgun ammunition and bullets, highlighting the impracticality of butchering game to remove lead from ammunition (Broadway *et al.* 2020; Green *et al.* 2022; Leontowich *et al.* 2022; Haase *et al.* 2023). In one study lead particles from rifle bullets were detected down to single micrometre size (Leontowich *et al.* 2022). This is important as smaller lead particles are more readily solubilised in the intestine and absorbed into the bloodstream. So far, X-ray imaging studies of lead particles in game animals killed using lead shotgun pellets have found particles with diameters down to the limits of detection of about 70 micrometres. However, studies of animals killed using rifle bullets using methods with much better resolution have found many lead particles much smaller than this. New research illustrates that acidic marination (e.g., recipes with vinegar) of game prior to cooking enhances the bioavailability (essentially likelihood of uptake) of lead from ammunition and thus blood lead concentration, when experimentally fed to in pigs (Schulz *et al.* 2021). Several new studies have found associations between blood lead concentrations in people and consumption of wild-shot game (Tammone *et al.* 2021; Berkey *et al.* 2022; Wepler *et al.* 2022). Collectively, research studies suggest that the effects of hunting and game consumption on blood lead are likely to be additive, i.e., exposure appears to be both from hunters consuming lead fragments from ammunition in their food and from inhaling and/or ingesting lead from ammunition during hunting or associated with hunting activities.

As no level of lead is considered to be safe for children, 'levels of concern' are no longer used by the US Centers for Disease Control and Prevention (CDC) and instead Blood Lead Reference Values (BLRV) are used to highlight the most exposed children. In 2021 the CDC reduced this BLRV from 5 µg/dL to 3.5 µg/dL to help enable more prompt action to be taken to reduce exposure and mitigate health effects (CDC 2021). In the high exposure end of the spectrum, the medical history of a hunter regularly consuming wild-shot game meat led to the suggestion that for patients with variable and non-specific symptoms, lead toxicity from eating wild-shot game should be considered by doctors in the differential diagnosis (Parry & Buenz 2020).

The environment: Numerous studies have been conducted on soil contamination with lead at shooting ranges and lead transfer to local water sources, plants and animals. As significant and unsurprising contamination at such sites of heavy lead deposition is well established, additional references were not reviewed. However, far fewer studies consider contamination at hunting ranges. One such recent study adds to the literature, finding elevated plant lead concentrations at shooting compared with non-shooting locations within an estate in Spain where driven red-legged partridge hunts take place annually (Peña *et al.* 2022).

Mitigating Risks

Non-toxic ammunition

In Australia, field data suggested that lead-free bullets were suitable for ground-based shooting of sambar deer and aerial shooting of wild boar without markedly affecting efficiency or animal welfare outcomes (Hampton *et al.* 2021; 2022).

A trial using one rifle to compare lead-free Copper-22 LR bullets with one type of lead bullet for shooting wild rabbits in Australia found the lead-free bullet to be less precise and to wound rabbits more often (Hampton *et al.* 2020). A subsequent study found comparable precision between the lead-free Copper-22 and lead-based bullets for 4 of 5 rifles tested, suggesting that these lead-free bullets do offer suitable precision for hunting small mammals (McTee & Ramsay 2021).

In one study (Oura *et al.* 2023) three types of .30 calibre bullets were fired into ballistic gelatine. The authors found that a full metal jacket bullet had a fragment cloud of similar diameters to that of an expanding soft-point bullet, but with larger fragments which were deposited in the second half of, rather than throughout, the gelatine block. These results were surprising as the full metal-jacketed bullet was expected to remain intact and this is relevant to Europe as .30 is the main calibre used for moose hunting in Scandinavia.

Efficacy of mitigation measures

In the European countries where this has been studied, there is little evidence that voluntary initiatives banning the use of lead shotgun ammunition (Green *et al.* 2021; 2022; 2023; Green 2023), or partial regulatory restrictions banning the use of lead shotgun ammunition only in wetlands or for shooting wildfowl, have been effective (Stroud *et al.* 2021; Widemo 2021; Cromie *et al.* 2022; Pain *et al.* 2022; Green *et al.* 2023). Only in Denmark, where the 1996 ban on the use of lead gunshot covered all shooting, and possibly in a local situation where shooting was carefully controlled (McIntosh *et al.* 2023), was compliance demonstrably high (Pain *et al.* 2022). Nonetheless, at one wetland site in Denmark, high densities of lead pellets remained available to feeding wildfowl decades after the lead

shot ban, presumably because of low settlement rates resulting from soil characteristics (Kanstrup *et al.* 2020).

In North America and Australia, in circumstances where compliance with lead gunshot bans was high, recent evidence illustrates that bans substantially reduced, but did not eliminate, poisoning of wildfowl (Lewis *et al.* 2021; Nzabanita *et al*. 2023). This may relate both to the level of compliance and the duration of lead shotgun pellet availability following deposition, the latter of which will vary with substrate characteristics and settlement rates.

In Japan, eagles have continued to die from lead poisoning on Hokkaido Island despite a statutory ban on the use of all lead ammunition for shooting large game (Ishii *et al.* 2020). The Japanese Environment Ministry plans to introduce further ammunition restrictions from 2025 with the intention of elimination lead poisoning in birds from bullets by 2030 (The Yomiuri Shimbun 2021).

These studies collectively highlight the urgency of replacing lead ammunition with non-toxic alternatives in terrestrial habitats, partly to reduce the accumulation of legacy shot and associated risks for wildlife. Complete transition, as in Denmark, would ensure additional protection for waterbirds in many situations, in addition to protection for terrestrial birds, human health and the environment.

Perceptions and policies

A number of studies have supported the need for an EU restriction on the use of lead ammunition in order to align EC regulations on lead from ammunition with lead from other anthropogenic sources, and to better protect the environment, wild birds and human health (e.g., Kanstrup & Thomas 2020; Pain *et al.* 2020). A number of studies highlighted the need for supplementary actions, specifically amendment of Regulation EC1881/2006, to incorporate a maximum level of lead in marketed game meats to better protect human health and harmonise food safety standards for lead in meats traded across and imported into the EU (Thomas *et al.* 2020; 2021; 2022; Thomas & Kanstrup 2023). One study examined the proposed REACH restriction and concluded that this broad restriction is justified by the evidence and would facilitate enforcement (Treu *et al.* 2020). The previously-described need for Olympic sports shooting disciplines to use non-lead ammunition was again highlighted (Thomas *et al.* 2021). Several papers described the need for a more transdisciplinary regulatory approach to transitioning to non-lead ammunition across the EU and globally that better harmonizes inter-agency human and environmental health approaches. This disconnect is supported by the lack of recognition, in a recent WHO publication on human health risks from exposure to lead and mitigation measures needed (WHO 2023), that lead from ammunition is a potential food contaminant.

Several studies examined hunters' perceptions of lead and non-lead ammunition (Kanstrup *et al.* 2021; Sundström 2023). While studies suggested that hunters' attitudes to transitioning to non-lead ammunition were mixed, one study found that enhanced familiarity with non-lead ammunition through increased usage correlated with more positive attitudes towards its adoption (Sundström 2023). Other studies highlighted positive changes in attitudes among a range of stakeholders, including game retailers, towards acceptance of the need for transition to non-lead ammunition (Pain *et al.* 2020a, b; Ellis & Miller 2023). Across studies, key factors identified to facilitate a successful transition to non-lead ammunition included:

- Defining a realistic phasing-out period and chemical composition standards for non-lead substitutes;

- Consistent communication with all stakeholders emphasizing the benefits of non-lead ammunition use to wildlife and the benefits of an enhanced public perception of hunting;
- Consistent, focussed and ongoing communication and engagement with and among shooting stakeholders to improve acceptance of non-lead ammunition and to allow adaptation;
- Measures to build trust between hunters and other stakeholders so that promotion of a transition to non-lead ammunition, i.e., an anti-poisoning agenda is not interpreted as anti-hunting.

One review highlighted that while the effectiveness, safety and availability of non-lead ammunition may still be perceived as constraints to transition, the majority of these issues have been, or could readily be, overcome. However, lack of trust appears still to be an issue (Ellis & Miller 2023).

Since 2020, during the period in which the EU REACH proposal to ban lead ammunition for hunting was under development, two major regulatory initiatives were announced. The first came in 2020 when the Danish government announced their intention to ban the use of lead-based bullets for hunting (Kanstrup *et al.* 2021). This will come into force in April 2024 (Sonne *et al.* 2023). In Japan, it was reported that the Japanese Environment Ministry intends to gradually restrict the use of lead ammunition from 2025 to ensure that birds no longer die of lead poisoning caused by hunters' lead bullets by 2030[1].

Other initiatives reported since 2020 have been largely voluntary, including that in the UK nine shooting and rural organizations issued a statement in 2020 calling on their members to voluntarily transition away from the use of lead shotgun ammunition for hunting by 2025 (BASC 2020). Such voluntary initiatives have not, to date, proved effective, as described above Green *et al.* 2021; 2022; 2023; Green 2023).

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