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PERSPECTIVE

The transition to non-lead rifle ammunition in Denmark: National obligations and policy considerations

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Abstract The issue of Denmark regulating use of lead-free rifle ammunition because of potential risks of lead exposure in wildlife and humans was examined from a scientific and objective policy perspective. The consequences of adopting or rejecting such regulation were identified. Denmark is obliged to examine this topic because of its national policy on lead reduction, its being a Party to the UN Bonn Convention on Migratory Species, and its role in protecting White-tailed Sea Eagles (*Haliaeetus albicilla*), a species prone to lead poisoning from lead ingestion. Lead-free bullets suited for deer hunting are available at comparable cost to lead bullets, and have been demonstrated to be as effective. National adoption of lead-free bullets would complete the Danish transition to lead-free ammunition use. It would reduce the risk of lead exposure to scavenging wildlife, and humans who might eat lead-contaminated wild game meat. Opposition from hunting organizations would be expected.

Keywords Denmark · Hunting · Lead-free bullets · Health · Regulation · Conservation

INTRODUCTION

It is established that exposure to lead from ingested spent ammunition poses toxic risks to wildlife (Watson et al. 2009; Haig et al. 2014) and humans, who are at risk when eating game meat killed with lead ammunition (Knott et al. 2010; Pain et al. 2010; Knutsen et al. 2015). There is no safe threshold for blood lead in humans (CDC 2012) and, presumably, for different species of wildlife. Denmark banned the use and possession of lead shot in 1996 and sport fishing weights in 2002, making it a global leader in hunting/angling lead reduction (Kanstrup 2015a), but use of lead rifle bullets is still allowed.

The UNEP Convention on Migratory Species (CMS) and the African Eurasian Waterbird Agreement (AEWA) have requested, repeatedly, Parties (including Denmark) to engage in lead reduction to prevent lead exposure of migrating birds along the European-African flyways (Thomas and Guitart 2005). The Conference of the Parties to the CMS (COP11, November 2014) resolved that all Parties replace lead ammunition with non-toxic substitutes within 3 years. This applies to lead gun shot and lead-based bullets used for hunting in all habitats. The CMS lacks regulatory powers, but each Party with demonstrated lead exposure in wildlife must determine how to achieve this goal at the political and regulatory levels (UNEP 2014).

Poisoning of European White-tailed Sea Eagles (*Haliaeetus albicilla*) and other scavengers occurs from the ingestion of lead bullet fragments in discarded gut piles and fatally shot-and-lost animals (Krone et al. 2009; Helander et al. 2009; Nadjafzadeh et al. 2013). White-tailed Sea Eagles are protected in Europe under the EU Birds Directive, Annex 1. Lead-free rifle ammunition[1] is made by major US, Scandinavian, and European companies (Thomas 2013, 2015a, b). This type of ammunition will be required, by law, throughout California in 2019 (Thomas 2015b). Germany also requires the use of lead-free rifle ammunition when hunting in state forests and on private land in 5 of 16 federal states, and is evaluating the use of this ammunition (Gremse and Rieger 2015). Lead-free rifle bullets could be used for hunting all species that are hunted with rifle in Denmark, including Red Deer (*Cervus elaphus*), Fallow Deer (*Dama dama*), and Roe Deer (*Capreolus capreolus*) (Knott et al. 2009; Kanstrup 2015a).

[1] Bullets that contain <1 % lead by mass.

The calibers used commonly are available to Danish hunters, and their prices are competitive with their lead-based equivalents (Thomas 2013, 2015a, b; Kanstrup 2015b).

A transition to lead-free rifle ammunition has to be justified both scientifically and politically. The scientific rationale has been identified. A symposium, convened for the International Council for Game and Wildlife Conservation (CIC) to evaluate the continued use of lead hunting ammunition and their lead-free substitutes, resolved the following:

Article 6:

> We recommend that a Road Map be developed by the CIC in close collaboration with other stakeholders to implement the phase-in of non-toxic ammunition for all hunting and shooting as soon as practicable. This roadmap should include clear objectives with timelines.

Article 8:

> We find that voluntary or partial restrictions on the use of lead ammunition have been largely ineffective and that national and international legislation is required in order to ensure effective compliance and to create the assured market for non-toxic ammunition. (Kanstrup 2010).

A 2015 symposium devoted to this topic in Denmark concluded that

> … the presently-available and tested non-lead bullets meet all the efficacy requirements for rifle ammunition used in traditional hunting in Denmark. (Kanstrup and Knudsen 2015).

This paper details the national and international obligations Denmark has to end use of lead rifle ammunition, the economic consequences of such action, the possible impacts on Danish hunting, and the policy issues to be resolved. Objectively, the implications of Denmark not extending the current lead shot ban to rifle ammunition are examined.

DENMARK'S INTERNATIONAL AND NATIONAL OBLIGATIONS

Denmark is required to address the CMS Resolution (UNEP 2014) because lead rifle ammunition has been identified. Denmark's regulated ban on lead gunshot and fishing weights constitutes a strong legal and political precedent to extend the ban to lead rifle bullets, as the CMS Resolution requires. Denmark, as a Party to the Birds Directive, is further obliged to protect the recently established populations of White-tailed Sea and Golden Eagles (*Aquila chrysaetos*) (Ehmsen et al. 2011), which are likely to be negatively affected by lead ingestion from spent ammunition, as shown for the population development of White-tailed Sea Eagles in Germany (Sulawa et al. 2010). Dispersing young and adult eagles seek new territories in Denmark from neighboring countries (Saurola et al. 2013; Bairlein et al. 2014). Additionally, Denmark is part of a major flyway for European migratory birds, including large birds of prey (Zalles and Bildstein 2000). Nearly all migratory and resident birds of prey are facultative scavengers, or hunt live wounded prey. Mateo (2009) described 17 European raptorial species which were lead-poisoned from ingested fragments of spent ammunition. Ravens (*Corvus corax*) also ingest lead particles from shot carcasses, and show high lead blood levels during the hunting season (Craighead and Bedrosian 2008). Ravens occur also throughout Denmark and scavenge the remains of hunted animals.

Larsen et al. (2014) surveyed the presence of lead compounds in the Danish environment in relation to human health. While human exposure to lead from shooting (presumably indoor shooting ranges) was mentioned, there was no analysis of lead in hunted game and its consequences for human and wildlife health, except for a stated single high value of 232 000 μgPb/Kg in boar meat (Larsen et al. 2014). The publication concludes:

> Lead is classified as toxic to reproduction due to severe effects on fertility and on the brain development in the unborn and developing child. Lead is furthermore classified as toxic after repeated exposure and toxic for the aquatic environment.

LEAD EXPOSURE IN DANISH WILDLIFE AND HUMANS EATING GAME MEAT

Tissue lead analyses have not been conducted on dead White-tailed Sea Eagles, or any other scavengers, found in Denmark. Other than the single value of lead in imported boar meat (Larsen et al. 2014), lead levels in Danish game meat are measured only sporadically. Thus, it is not possible to determine, directly, the risk posed by lead ingestion to scavenging species and humans.

Rifle hunting/stalking is growing in popularity in Denmark. Roe deer is the most common deer species and is hunted with rifle or shotgun. Red deer and fallow deer can be hunted only with rifles. Table 1 shows the numbers of hunted species in 2013. About 14 % of the harvest (approximately 33 000 animals) were killed with rifles and, potentially, lead-core bullets.

It is common practice to gralloch (i.e., remove internal organs) killed deer (especially roe deer) where the hunting

Table 1 Annual kill (2013) of game species or groups of species, including the number of animals taken by shot gun and/or rifle. Some roe deer and smaller animals are taken with bow. * "Other" includes trapping. Numbers of red fox killed by shot and bullets inferred from Kanstrup (2015a, b). *Source* Naturstyrelsen (2014)

	Shot	Bullet	Other*
Roe deer	40 000	87 400	
Other ungulates		18 200	
Hare	55 300		
Rabbit	10 400		
Red fox*	20 000	17 500	
Other mammals	9000		8000
Partridge	28 800		
Pheasant	710 800		
Wood pigeon	278 500		
Mallard	486 000		
Other dabbling ducks	158 500		
Diving ducks	71 200		
Geese	77 100		
Gulls	21 700		
Coot	10 900		
Woodcock	34 000		
Snipe	10 700		
Crows and magpie	90 000		25 000
Rook		90 700	
Other birds	9800		
Total	2 122 700	213 800	33 000

takes place. Although this practice is normally regarded by government as disposal of animal by-products, the European and Danish regulations make an explicit exemption for entire bodies or parts of wild game not collected after killing, in accordance with good hunting practice.[2] It is assumed that few hunters either remove the gralloch from the hunting area or bury it. However, at some (mainly state-owned) districts, disposal of grallochs of red and fallow deer is organized at central slaughter facilities close to the hunting area by official companies specialized in such disposal. No statistics exist for this practice, but it represents a minor part of the red and fallow deer harvest, and therefore only a small proportion of the total bag of all deer species. Hence, the number of gut piles left in nature is close to the number of killed deer. To this should be added the number of unretrieved, fatally wounded animals that remain available to scavengers. It is estimated that over 1200 wounded deer were never retrieved in 2014/2015 (Flinterup, pers comm.[3]).

[2] Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October, 2009.

[3] Flinterup, M. Consultant in the Danish Hunters' Association, Molsvej 34, DK.8410 Rønde. October, 2015.

Although no data on the prevalence of lead exposure in Danish White-tailed Sea Eagles exist, given the occurrence of lead exposure from spent lead ammunition in this species in both Sweden and Germany, the estimated number of Danish gut piles available each year (over 34 000), and the close proximity of Denmark to these two countries, the potential for exposure exists, both for eagles and other scavengers.

Guidelines for New Nordic Diet recommends that Danes reduce their consumption of domestic meat by 35 %, and take 4 % of their meat as venison, since venison is presumed to be healthier, more palatable, and more environmentally sustainable. Presently, Danes consume 0.8 % of their meat as venison. Most hunters keep the main portion for themselves (Saxe 2015). Although Denmark does not monitor regularly lead levels in marketed game meat, there is no reason to believe that they differ from game meat in other countries. Data from Norway, Poland, Sweden, the UK, and Canada reveal that meat from hunter-killed deer species and Wild Boar (*Sus scrofa*) may contain metallic lead levels far exceeding the European Commission 0.1 mg Pb/kg criterion for domestically reared meats, especially in minced meat (Knott et al. 2010; Fachehoun et al. 2015: Knutsen et al. 2015). The Danish roe and red deer are the same species as in other European countries. The manner of hunting them is the same, using the same types of lead-core rifle ammunition. Shot animals are handled in the field and prepared for human consumption in the same manner across these countries. While the European Commission has set the maximum level of lead in domesticated meats at 0.1 mg Pb/Kg under Commission Regulation 1881/2006 (EC 2006), no comparable level has been set for wild game meat. The European Food Safety Authority did not set up a guidance level because there was no clear threshold below which the Panel was confident that adverse effects would not occur (EFSA CONTAM 2010). National food safety agencies in the UK, Germany, Norway, Spain, and Sweden provide advice on the consumption of wild game meat that might contain lead (Knutsen et al. 2015), but not Denmark.

DEVELOPMENT, AVAILABILITY OF LEAD-FREE BULLETS, AND ECONOMIC ISSUES

Non-lead bullets are made primarily of copper or copper alloys. American and European companies have made proprietary types of bullets in all the calibers, bullet shapes, and weights typical for hunting anywhere in the world (Thomas 2013, 2015a). California is the only US jurisdiction that currently requires use of non-lead bullets for hunting in one region of the state. However, in 2019, hunting in the entire state will require non-lead ammunition (Thomas 2015a). Several German states have required use

of non-lead rifle ammunition when hunting in state forests, and are examining the implementation of this transition (Gremse and Rieger 2015). The term "availability" includes whether the product is made, whether it is sold in Denmark, especially at a local level, and whether it is sold at a comparable price with lead-based ammunition. Underlying these considerations is the issue of regulation that would create the assured market for non-lead ammunition among all Danish hunters, as it has done for non-lead shotgun ammunition.

Denmark currently imports all hunting rifle ammunition and cartridge reloading components. Six major European companies and at least six US companies make non-lead rifle ammunition in all of the commonly used calibers for hunting deer in Denmark (Thomas 2013, 2015a). These same US and European companies already have a market presence in Denmark. Ammunition cannot be sent by Danish postal service, precluding online purchase. Hunters normally purchase their products from local gun stores.

There was no major retail price difference between lead-based and equivalent non-lead rifle ammunition in the US, based on listed online prices for a major retailing company (Thomas 2013). A well-established market for lead-free bullets exists in this country, especially in regions of California, where use of lead-free rifle ammunition is mandatory (Thomas 2015a, b). Where differences existed, they were not of such a magnitude as to thwart participation in hunting. Kanstrup (2015b) concluded that non-lead rifle ammunition is largely available in Danish hunting stores at prices comparable to equivalent lead products. Thus, there is no economic barrier to Danish hunters making the transition to lead-free bullet use, especially in view of the relatively low numbers fired each year, and the other costs of participating in hunting in Denmark.

Kanstrup et al. (2016) compared the efficacy of lead-core and lead-free, copper, bullets to hunt Danish red and roe deer under real field situations over two seasons. The lead-free bullets performed as effectively as traditional lead-core bullets when used by sport hunters in producing rapid death of both deer species. These conclusions are supported by the results of field research on the lethality of lead-free bullets for hunting German Wild Boar, Red Deer, and Roe Deer (Trinogga et al. 2013).

TOXICITY AND SAFETY OF LEAD-FREE SUBSTITUTES

Anecdotal reports of potential toxicity of ingested lead-free bullet fragments to humans and wild scavengers have been made, ostensibly to thwart adoption of lead-free bullets (Thomas et al. 2015). Scientific studies indicate that the copper from lead-free bullets mobilized under simulated storage and human digestion conditions did not pose health risks to humans (Irschik et al. 2013; Paulsen et al. 2015). Paulsen et al. (2015) did advise that levels of aluminum, nickel, and lead be kept as low as possible during bullets' manufacture. Franson et al. (2012) experimentally dosed falcons (*Falco sparverius*) with pure copper pellets and observed no deleterious effects on the birds' health. No national or international regulation exists for the composition of non-lead rifle ammunition (Thomas 2016). Only California regulations stipulate that non-lead bullets must contain less than 1 % lead by mass. According to this criterion, all of the non-lead bullets tested by Paulsen et al. (2015) pass this test, except for RWS Bionic Yellow with 1.9 % lead content.

Safety concerns about ricochet of lead-free bullets have been raised (mainly in Germany), as when bullets deflect from oblique hard surfaces. All rifle bullets, regardless of composition, profile, and size, are prone to ricochet. This applies especially to high-velocity, copper-jacketed, pointed-profile bullets (e.g., Spitzers) and, to a lesser extent, to lower-velocity, round-nosed and exposed lead-core bullets. In the USA, the issue of ricochet has not arisen as an objection to the use of lead-free bullets. There, preventing ricochet is seen as the responsibility of individual hunters to practice disciplined shooting, especially in rocky or forested terrains (Thomas et al. 2015).

POTENTIAL IMPACTS ON DANISH HUNTING

The phase-out of lead gun shot for hunting in Denmark during 1985–1996 did not impact the popularity of traditional hunting (Kanstrup 2015a). Similarly, a phase-out of lead rifle bullets is not expected to have a significant influence on future participation in hunting. The deer species hunted in Denmark are all hunted with rifle calibers (Kanstrup et al. 2016) that, potentially, would require non-lead ammunition available at prices equivalent to prices for lead ammunition, and with a similar efficacy. Fox (*Vulpes vulpes*) and other small game are hunted with smaller calibers (e.g., .17 HMR), for which non-lead alternatives are still not available. Rooks are regulated under the EU Bird Directive Article 9, and are usually hunted with caliber .22 LR, for which there are still no highly effective, non-lead alternatives. There are no physical obstructions to the development of non-lead ammunition for these calibers, and a wider market demand would stimulate their development; however, a wider time frame must be given to their substitution.

POTENTIAL REGULATORY AND ENFORCEMENT FRAMEWORK

Gunshot and fishing sinkers are banned under Danish law related to chemical products, which also includes

products with a potential lead content, e.g., paint, solders, and roof coverings. Fishing sinkers are regulated under the ban on import and sale of lead products. Sale, possession, and use of gunshot were banned in 1996 under the Hunting Act regulations.[4] The legal prohibition on the importation, sale, possession, and use of lead ammunition provides the current basis of hunters' compliance with the mandatory use of lead-free shotgun ammunition. The same legal framework could provide the same basis for banning lead hunting bullets. Enforcement of hunting regulations is the responsibility of the police, although other authorities perform regular inspections, including confiscation and technical investigation of "suspicious" ammunition. Although the lead shot ban is not completely respected (Kanstrup 2012) (e.g., hunters who illegally import lead shot cartridges), there is a consensus that the regulation is generally enforced and fulfilled. In theory, the Danish government could enforce regulation of lead bullets under the same legislation.

PHASE-IN TIMETABLES AND EXTENSION/ AWARENESS

Thomas (2015a) identified eight European and European–US companies that make lead-free rifle bullets in 27 different calibers, all available to Danish hunters. The results of the field testing of copper bullets for hunting roe and red deer indicate that bullets of caliber >6 mm could be authorized for immediate use throughout Denmark (Kanstrup et al. 2016). Copper bullets of caliber <6 mm may not stabilize as well when fired from the same rifle barrel. This is a function of the twist rate of the barrel's rifling (Caudell et al. 2012). A transition to the regulated use of these smaller caliber bullets should take longer to allow hunters to change gun barrels to a more appropriate twist rate, and/or to await the development of denser lead-free bullets. Any transition to lead-free bullet use must be based on product development, which, in turn, is based on assurances that the products will have a strong market demand. The role of government is to provide the assured market demand by passing the appropriate legislation (Thomas 2015b). It is also incumbent on government to increase public awareness of the need for the transition, the nature of lead-free bullets, and how to use them. This could involve cooperative extension initiatives with Danish hunting organizations.

[4] Demand nr. 444 of 07/052014 on arms and ammunition allowed for hunting.

CONSEQUENCES OF DENMARK REJECTING THE TRANSITION

Denmark would have to defend not adopting the 2014 Resolution of the CMS, which would be difficult given the existing national ban on lead gunshot and sinker use. Such a decision would be made with full awareness of the numbers of animals shot by hunters, the potential for exposure of wildlife from discarded gut piles, and the potential exposure of hunters and other consumers from lead-contaminated meat. The Danish government would have to condone, publicly, the risk of future lead exposure to both humans and wildlife. This should be seen in the context of rising deer populations and a general recommendation to Danes to eat more game meat (6-fold increase according to New Nordic Diet) (Saxe 2015). Denmark would then have lost its leading international role in removing this form of lead exposure from the environment. This could be interpreted as an endorsement of the continued use of lead in hunting rifle ammunition. While that decision might be favored by many hunters, the public image of hunters as conservationists would be diminished. It is possible that individuals and conservation organizations favoring a total ban on lead ammunition might petition the government directly and via the media to regulate completely all forms of lead ammunition. In such a political move, the relative number of active hunters in Denmark (Kanstrup 2015a) versus the number of petitioners becomes an important issue.

Although the main driver of Danish hunting is recreation, the food product of hunting is often used as a major argument to defend hunting rights. Offsetting public concerns about the welfare and ethics of intensively reared farmed animals is the belief that animals living in the wild, and hunted humanely, represent a more sustainable source of food. This trend is increasingly used by hunters and their organizations to reinforce their political platform to sustain hunting. In this context, any indication of a health hazard connected to the consumption of game meat would be detrimental. Danish consumers are very aware of the health risks related to lead, and could reject consumption of game meat if there were a wider public awareness of the present connection between hunting with lead ammunition and a potential risk.

CONSEQUENCES OF DENMARK FAVORING THE TRANSITION

Denmark would be seen to have discharged in full its responsibility and obligation to the CMS 2014 Resolution (UNEP 2014). However, Danish hunters and their

representative organizations would likely oppose any government proposal. Their argument would be reinforced by the current policy of the Association of European Manufacturers of Sporting Ammunition (AFEMS) on the sustainable use of lead in hunting ammunition, i.e., that ingested metallic lead does not pose threats to human or wildlife health (AFEMS/WFSA 2015). The Danish government would have to consider the political consequences of acting contrary to the interests of this constituency, especially in the face of only indirect, or inferred, Danish evidence of health risks posed by lead bullet use. However, the government could use the example of Germany's requiring the use of lead-free bullets (Gremse and Rieger 2015) as their rationale. Moreover, the creation of a regional lead-free ammunition zone in Europe could act as a policy precedent for other neighboring countries to pass similar regulations.

A decision to ban the use of lead bullets would stimulate further production, marketing, and sales of lead-free products to satisfy an increased demand from hunters. Such a ban would also stimulate development of ballistically improved lead-free bullets in calibers < 6 mm, including rim-fired cartridges in .22 caliber. For caliber 6 mm and larger, it is generally accepted that the modern, well-maintained, rifles can be used to fire accurately non-lead as well as lead bullets. However, for those small caliber rifles that may not fire copper bullets as accurately, the rifle should be either substituted, or the barrel be changed to one having the appropriate rifling (Caudell et al. 2012). The purchase price of a new rifle depends on many factors, but a Danish standard model retails between 1000 and 1500 Euros. Changing the barrel would cost approximately 500 Euros.

A key factor determining support for a ban would be the timing and extent of the phase-in period, which should reflect the availability of substitute ammunition and the creation and application of education-awareness programs, ideally in close collaboration with hunter organizations. Consistent with this approach, the government would have to consider how to achieve regulation and enforcement of a ban on lead bullet use, and how this would relate to training (as opposed to hunting) and rifle shooting competitions.

Denmark could issue immediately a public health advisory about health risks from eating game meat shot with lead ammunition, especially for pregnant women and children. In the longer term, Denmark, as a member of the European Union, could present the need for change in regulations on allowable levels of lead in marketed game meat by proposing amendment of Commission Regulation 1881/2006 (EC 2006) to include provision for all hunter-killed wild game and processed meats.

DISCUSSION

Continued use of lead bullets by Danish hunters must be examined in an international context. Only one jurisdiction, California, has regulated an end to their use, but only from 2019. The CIC, while aware of the problems of lead exposure from lead ammunition, has yet to act on the advice received in 2010, despite the availability of non-lead substitutes. While individual arms companies have developed the lead-free products, organizations representing shooting refuse to encourage their use (AFEMS/WFSA 2015). Most government public health agencies and wildlife divisions appear not to be concerned about health risks, despite the evidence (Cromie et al. 2015). Thus, it is understandable that Denmark has not yet initiated the transition to lead-free rifle ammunition.

Although the Danish government has not collected extensive data on lead levels in wild game meat and humans who frequently consume shot game (Larsen et al. 2014), there is evidence from neighboring countries hunting the same game animals in the same manner that risks to human health exist (Knott et al. 2010; Knutsen et al. 2015). The same consideration applies to scavenging wildlife that ingests lead bullet fragments (Helander et al. 2009; Krone et al. 2009; Nadjafzadeh et al. 2013; Pain et al. 2015). Thus, there is already evidence to support a governmental regulation of lead bullets, although skeptics could argue that an extensive data collection should already exist to support such regulation. The Danish government's experience with the banning of lead gunshot could act as a powerful precedent in this case.

Substitutes for lead-core rifle bullets in all commonly used calibers used by Danish hunters already exist (Thomas 2015a) and there is no extra economic cost to their use (Kanstrup 2015b). Their efficacy in killing common deer species is similar to that of equivalent lead-core bullets when used by Danish hunters. Thus, there appears little barrier to their adoption for hunting, except for, possibly, the need to change rifle barrels, and the political implications of change.

Exposure of Danish consumers to lead from game meat arises from animals killed in Denmark and those imported into the country. Danish game meat killed with lead bullets is also exported within the EU. Regulating an end to this potential health risk requires not only political action within Denmark, but action to define allowable lead levels in game marketed among EU and non-EU nations. In this regard, Denmark's role in amending EC Regulation 1881/2006 would show great international leadership.

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