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Shooting habits and habitats- effects of education and legislation on the phasing out of lead shot

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ABSTRACT

Achieving sustainability often requires fostering changes in norms and behaviours through a combination of restrictions and aware-raising activities. The phasing out of lead in ammunition to reduce lead poisoning in waterfowl provides a case in point. Twenty years after the Parties to the African Eurasian Waterbird Agreement (AEWA) committed to phase out lead shot in wetlands, such bans have been implemented in a third of Europe only. Furthermore, while evidence is scant, compliance varies widely where bans have been introduced. As a result, waterfowl are still suffering from lead poisoning.

Here, I survey the use of different types of shot while practicing and when taking game in different habitats in Sweden, one of the Parties to AEWA. Furthermore, I test the hypotheses that mandatory shooter education, or stakeholder communication, influence compliance with existing restrictions in Sweden, as well as the voluntary phasing out of lead shot where its use still is permitted.

More than half of the shooters practiced using lead and a third used lead shot over what they considered as wetlands, in both cases in violation of the current legislation. Furthermore, what constitutes a wetland appears to have been unclear to many shooters, especially in alpine areas. Both mandatory education and stakeholder communication were positively related to compliance.

Only 12–15 % used lead free alternatives in shooting over habitats where the use of lead shot is permitted. There was a weak positive relationship between stakeholder communication and the voluntary phasing out of lead shot, but no effect from education.

I suggest that the planned and ongoing phasing out of lead in ammunition should rest on a combination of legislation, enforcement, education and stakeholder communication in order to be successful. The findings add to our general understanding of how to turn environmental policy into sustainable management actions in practice.

1. Introduction

Tackling environmental challenges often hinges on influencing public norms and behaviour, striking a balance between restrictions through legislation on the one hand and stimulating voluntary change on the other (e.g. Axon et al., 2018). Changing attitudes is notoriously difficult, however (e.g. Heberlein, 2012). Compliance with any environmental legislation is likely to be low unless the legislation is viewed as proportional and appropriate, especially when opportunities for enforcement are limited (e.g. Foster et al., 2019; Atuo et al., 2020). Thus, acceptance by the relevant stakeholders is crucial for success.

The issue of minimising negative effects from lead in ammunition provides a clear example, where determined efforts have failed to strike an accepted balance for solving apparent problems. Already by the late 1800s, it was noted that waterfowl might suffer substantial mortality risks from lead poisoning after ingesting spent lead shot from the bottom of shallow waters (e.g. Forest and Stream, 1894). One hundred years later, the US implemented a ban on the use of lead shot in wetlands (U.S. Fish and Wildlife Service (USFWS, 1999; Stevenson et al., 2005). Similarly, the countries which are Parties to the African Eurasian Waterbird Agreement (AEWA) committed to phase out lead shot in wetlands by the year 2000 (AEWA, 1999).

Twenty years later, a complete ban on shooting lead shot over wetlands, or taking waterbirds using lead shot, has been implemented in less than one third of the surface area of Europe (Mateo and Kanstrup, 2019). Furthermore, compliance with the regulations in countries with a ban varies between good (Kanstrup and Skovbjerg Balsby, 2019a,2019b) and relatively poor (Cromie et al., 2010; Newth et al., 2013; Cromie et al., 2015), where this has been investigated. However, data on compliance is largely lacking (Mateo and Kanstrup, 2019). Recent

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evidence point to lead poisoning from ammunition being responsible for 8 % of winter mortality in ducks in Europe and 21 % of the winter population has been suggested to be affected negatively, mainly due to low implementation and low compliance. (Andreotti et al., 2018). The annual cost for this effect was estimated at 142–185 million euros. Other studies have shown the societal benefits of phasing out lead in ammunition to outweigh the costs (e.g. Pain et al., 2019).

Resolving the problem of primary lead poisoning of birds from lead shot is a complex task, as evidenced by the apparent lack of success so far. In terms of human dimensions, we need a better understanding of the use of lead shot and the alternatives in different habitats and for different purposes. Furthermore, it is necessary to understand what factors influence shooter (throughout the paper, shooter and shooting refers to taking any game using a shotgun) behaviour and compliance with the legislation in place. A ban on lead shot that does not provide for the interest of sportsmen has been suggested to be unlikely to resolve the lead poisoning issue due to low compliance. Instead, dialogue, education and communication between researchers, sportsmen, and policy makers may provide a more efficient phase-out of lead in ammunition (Pokras and Kneeland, 2008). At the same time, awareness-raising actions alone often may be insufficient to propagate behavioural change (e.g. Axon et al., 2018).

Here, I use an attitude survey aimed at Swedish shooters to test the hypotheses that legislation, mandatory education and stakeholder communication increase compliance with the current legislation and facilitates voluntary phasing out of lead shot. I analyse shooter choice of shot type across different habitats and in practicing in Sweden, where the use of lead shot in wetlands, in practicing and in competitive shooting (with a few exceptions) was banned in 2002 (Swedish Codes of Statutes, 1998). I contrast the results with compliance in other countries.

The findings will aid the ongoing tailoring of the legislation and management concerning the use of lead shot nationally and internationally, as well as the communication and the enforcement of the legislation. Furthermore, the results will add to the general understanding of how to turn policy into sustainable management actions in practice.

2. Material & methods

2.1. Swedish legislation on the use of lead shot

Sweden is a Party to AEWA and banned the use of lead shot over designated Ramsar sites in 1994 (SEPA, 1994) and banned the use of lead shot in wetlands and over open water in 1998 (Swedish Codes of Statutes, 1998). Wetlands were defined as "an area covered by vegetation where the water table is just under, level with, or just above the ground and where the water level is allowed to follow the natural, seasonal fluctuations". The ban was supposed to come into effect in 2001, but was postponed until 2002. In the meantime, the use of lead shot for taking ducks and geese was prohibited, regardless of habitat (SEPA, 1998). In 2002, the focus was put back on habitats, rather than species (Swedish Codes of Statutes, 2002). In 2007, the ban on lead shot was restricted to *shallow* open water rather than all open water (Swedish Codes of Statutes, 2007a). There is essentially no formal enforcement of the legislation, except for rare instances when the Swedish Coast Guard may police state owned waters along the coasts.

The use of lead shot for practice was also banned in 2002, except for the Olympic disciplines, the Swedish discipline 'Shooting trail' and for taking the mandatory hunters' exam (throughout the paper, 'hunter' and 'hunting' refers to taking any game without type of gun being specified or known) (Swedish Codes of Statutes, 2002). Both of the latter activities involve shooting at targets in variable environments, where ricochets are more likely to occur than at a shooting range. Furthermore, steel targets may be used. Functionaries at shooting ranges will monitor shot type used routinely, but informal practicing is common outside established ranges where there is no enforcement.

In 2002, all use of lead in hunting and shooting (rifles and shotguns) was banned (Swedish Codes of Statutes, 2002), effective in 2008. This decision was revoked by the new government in 2007 (Swedish Codes of Statutes, 2007b), but the ban on using lead shot in wetlands was retained.

2.2. Stakeholder responsibilities & communication

Since 1939, the largest hunters' organization in Sweden, The Swedish Association for Hunting and Wildlife Management (SJF; approx. 155 000 members), has held a public commission from the Swedish government to assist authorities with competence on hunting, shooting and game management, as well as educating and communicating with hunters. This responsibility is not restricted to SJF members only, but covers all hunters. Thus, SJF performs some of the duties that public authorities would handle in other countries. The smaller National Hunters' Organization (JRF: approx. 40 000 members) does not hold a corresponding commission, but also trains hunters.

Reducing problems from lead in ammunition has been prioritized in the commission to the SJF since the lead ban was revoked (SJF, 2020a) and the SJF has been tasked to "work towards negligible negative effects of lead in ammunition on health and on the environment". Previously, the SJF has collaborated with researchers and authorities on primary lead poisoning in ducks as part of the commission (e.g. Danell, 1980), but focus has shifted to secondary poisoning of raptors and scavengers (e.g. Axelsson, 2009) and then to health impacts from lead in game meat in later years (e.g. Kollander et al., 2014). The SJF has communicated the results and given advice to hunters and shooters through its home page information (SJF, 2020b,c), reports (e.g. Axelsson, 2009; Widemo and Holmqvist, 2009; Kollander et al., 2014), blog posts (e.g. Widemo, 2018) and articles in the member magazine (e.g. Svensk Jakt, 2013). Furthermore, the SJF has taken an active role in the European Federation for Hunting and Conservation (FACE) Ammunition group, sharing the results with the hunting and shooting community in addition to interacting with national authorities such as the Swedish Environmental Protection Agency (SEPA; the national authority responsible for game management, hunting and shooting) and the Swedish Chemicals Agency, in addition to the European Chemicals Agency.

As the decision for a complete ban was overturned before it came into force, the Ministry for the Environment expressed a wish for voluntary actions by all hunting, shooting and competitive shooting organisations aimed at reducing the use of lead and communication of the risks associated with lead in ammunition. This was done in addition to specifying the public commission to the SJF.

There is very limited information supplied by the SEPA to hunters and shooters on effects from using ammunition containing lead, and the current legislation. This is potentially because of the public commission to the SJF and the call for voluntary actions by the Government.

2.3. Hunter and shooter education

Sweden introduced a mandatory hunting exam for new hunters in 1985, but taking the exam was and still is voluntary for those holding a gun permit for the purpose of hunting or shooting at the time. The training courses are given by the two hunters' organisations using different education materials but following common guidelines from the SEPA. Courses cover game management, game biology, hunting methods and hunting legislation.

2.4. The survey

I developed an 18-page questionnaire booklet focused on hunting, shooting and attitudes to ammunition and guns used in hunting and shooting. In addition, the respondents were asked to state their gender, their education (mandatory school; vocational training; upper secondary school; university; post-graduate) and whether they were members of specified hunting or shooting associations. Here, I analyse the responses to questions covering the use of different types of shot in shooting in different habitats and in practicing for shooting. I also asked whether the respondents had engaged in competitive shooting using a shotgun.

It is mandatory to pay an annual fee to be permitted to hunt in Sweden and this is administrated by the SEPA. I obtained names and postal addresses of 300 randomly selected permit holders from each of Sweden's 21 counties from the SEPA in March 2016, giving a total sample size of 6300 recipients out of approximately 258 000 permit holders residing in Sweden. Information on whether the permit holder had taken the theoretical exam, and when, was included in the data from the SEPA, in addition to data on age and county of residence for permit holders.

I used a four-contact scheme (Dillman et al., 2009) where all respondents received a pre-notifying letter three days before receiving the questionnaire and a cover letter, followed by a combined reminder and thank you message two weeks later. Those who had failed to respond within three weeks received another questionnaire with a cover letter kindly asking them to fill out the survey, had they not done so already. The name and the address of the individual respondents was retained until the survey closed, in order to be able to send out reminders, but data was added as anonymous entries. The survey was mailed to the respondents on April 1st 2016 and responses received until 15th of August 2016 were analysed.

I performed a non-response bias analysis by comparing the two variables known for both respondents and non-respondents: age and whether the permit holder had completed the theoretical hunters' exam. There were no significant differences in the probability of having taken the hunters' exam, but respondents were significantly older (mean age = 55.5 years, S.E. = 0.25) than non-responders (mean age = 49.8 years, S.E. = 0.33). Furthermore, the proportion of respondents claiming to belong to either of the two hunters' organisations were compared to the official member numbers in relation to the number of hunting permit holders. Deviations were within a few percent. Finally, I compared the sex ratio amongst respondents to the sex ratio amongst all permit holders (using data from the SEPA) and they were identical at 6.5 %. Given the relatively high response rate and sample size (see below), no follow-up survey of non-responders was performed.

2.5. Data analysis

The number of hunters and shooters differed substantially between counties and the responses were weighted by the relative proportion of hunters as compared to the national total for producing national average behaviours. I estimated the probability of using lead shot while practicing, while shooting over wetlands and while shooting over dry, open land or forests, using generalized linear models with binomial distributions and logit links (logistic regression). Analyses were restricted to respondents who had practiced using a shotgun or engaged in hunting or shooting (using a rifle or a shotgun; the questions asked did not allow me to make a distinction) during the last 12 months, respectively. Educational level was treated as a continuous variable and the number of practice shots fired was log-transformed. Continuous variables were standardized to facilitate quantitative comparison of estimate sizes.

Model selection was performed using Akaike's Information Criterion to find the model with the best subset of variables. If ΔAIC was < 2 for several top ranked models, I selected the most parsimonious model amongst them. In two out of three cases, the most parsimonious model out of the sub-set of top ranked models also had the lowest AIC score. Sample sizes vary between models depending on how many respondents had practiced or engaged in shooting in different habitats. Furthermore, only respondents who had responded to all questions included in the models could be analysed. There were too few women shooters for including sex as a factor in the models, but I compared the proportions of men and women who used lead and who did not use lead under different scenarios. Statistical tests were performed in Statistica 13.4 (TIBCO, 2018) except for G-tests comparing behaviours between the sexes (Sokal and Rohlf, 1995); P = 0.05 was used as α.

3. Results

The response rate was 68 %, after removing potential recipients for whom the surveys were returned to sender by the postal service. Out of the respondents, 93.5 % were men, 74.1 % had taken the hunters' exam and 20.0 % had done so later than 2002 (when lead was banned in wetlands and in practicing). Furthermore, 74.5 % owned a shotgun and 67.1 % had practiced using a shotgun during the last 12 months. Amongst the hunting permit holders, 16.7 % claimed to have engaged in competitive shooting using a shotgun also. Amongst the respondents, 65.4 % claimed to be members of SJF, whereas 15.2 % claimed to be members of JRF.

Out of those who had practiced using a shotgun, the proportions predominantly using steel or lead shot for practice were 41.5 % and 57.4 %, respectively. Amongst respondents who had stated type of shot used, shooters predominantly using steel in practicing had practiced more often (n = 853, 1094; t = 6.97, P < 0.001) and shot approximately 2.4 times as many shells as shooters predominantly using lead (n = 872, 1220; t = 17.7, P < 0.001). Only 0.5 % of the shooters had practiced using bismuth or tungsten shot. The proportion of shooters having shot the 'Shooting trail' discipline (where lead is allowed) in preparation for hunting was 13.9 %. Furthermore, 0.8 % claimed to have practiced or competed in trap or skeet in preparation for hunting, while also being a member of The Swedish Shooting Sport Federation (mandatory for competing in ISSF disciplines).

Shooters who had shot fewer shells, who did not have the hunters' exam and who were older were more likely to use predominantly lead for practice (Table 1). Amongst exam holders, 52 % predominantly used lead whereas the corresponding number for respondents without an exam was 74.5 %. Furthermore, members of the smaller hunter's organization JRF and respondents with a lower level of education were more likely to use predominantly lead, all factors in order of importance (Table 1). The proportion of JRF members predominantly using lead was 59.9 %, whereas the corresponding number was 55.3 % for non-members. Amongst hunters and shooters having taken the hunter's exam, those having taken the exam more recently were less likely to use lead shot while practicing (Logistic regression, Wald statistic = 68.9, P < 0.001). Furthermore, women were less likely to use lead shot practicing, as compared to men (G-test, n = 146, 2522; G = 9.98; P < 0.01).

The proportion of respondents who stated that they had gone shooting during the last 12 months was 67.2 %. Shooters predominantly had used lead shot in forests, in open habitats and in alpine areas, but

Table 1
Factors significantly predicting whether Swedish hunting permit holders predominantly used lead shot when practicing with a shotgun. Sample size was 2040 respondents.

Explanatory variable	Estimate	Standard Error	Wald statistic	P-value
Age	0.285	0.059	23.4	< 0.001
Education	−0.130	0.056	5.3	0.002
Hunters' exam	−0.287	0.075	14.4	< 0.001
Number of practice shots	−0.978	0.082	141.5	< 0.001
Member JRF	0.244	0.071	11.8	< 0.001
Member SJF	–	–	–	–
Participant' Shooting Trail'	–	–	–	–

[a]Variables included in the most parsimonious model within 2 AIC of the best model are presented.

mainly had used steel shot in wetlands and over open sea (Table 2). Even so, roughly one third of the shooters used lead in wetlands and over open sea (Table 2).

Shooters having taken the hunting exam and shooters being members of the larger hunters' organization SJF were less likely to use lead shot in wetlands (Table 3). The proportion of exam holders using lead in wetlands was 25.3 %, whereas 40.9 % of respondents not having a hunters' exam used lead in wetlands. The proportion of members of the SJF using lead in wetlands was 25.7 %, compared to 36.3 % for non-members. Amongst shooters having taken the hunter's exam, those having taken the exam more recently were less likely to use lead in wetlands (Wald statistic = 5.1, P = 0.02). Women were equally likely to use lead shot shooting over wetlands as men (G-test; n = 82, 1561; G = 0.06, P > 0.05).

Shooters spending fewer days hunting and members of the larger hunters' organization SJF were more likely to use lead-free ammunition predominantly over dry, open land or in forests (Table 4). The proportion of members of the SJF predominantly using lead-free alternatives was 10.1 %, compared to 7.7 % for non-members. There was no significant effect of time since taking the hunters' exam amongst shooters having the exam (Wald statistic = 0.90, P = 0.34) and no significant difference between men and women in the propensity to use lead-free shot over dry, open land or in forests (G-test; n = 122, 2280; G = 0.16, P > 0.05).

4. Discussion

This study rests on a comparable response rates as previous surveys of Swedish hunting permit holders and the rate was relatively high compared to mail surveys in general (Boman et al., 2011). This limits the scope for effects from non-response bias, but respondents were older than non-responders. This should be kept in mind when interpreting the results. Another potential problem is that shooting lead over wetlands, and practicing using lead (in most cases), is illegal in Sweden and respondents may refrain from admitting to having used lead in violation with the law even in an anonymous survey. Thus, compliance may in fact be lower than suggested by the results. Sex ratio, membership rates and the proportion having taken the theoretical hunters' exam were, however, comparable between respondents and non-responders, suggesting non-response bias to be of little concern for those factors.

Using lead shot while practicing, or while shooting over wetlands, had been banned for 15 years in Sweden at the time of the survey. Nevertheless, more than half of the shooters who practiced using a shotgun claimed to use lead predominantly. Almost a third of the respondents shooting over wetlands claimed mainly to use lead shot, and voluntary phasing out of lead when hunting in other habitats was in the order of 10–20 %. Thus, lead shot are used frequently in practicing and in shooting across habitats. Clearly, the actions taken have not been successful for achieving compliance with the legislation, or for achieving voluntary phasing out of lead, at least so far.

4.1. Compliance with the ban on practicing using lead shot

Denmark, Sweden, and The Netherlands prohibited the use of lead

Table 2
Choice of shooting habitat and shot material amongst shooters who had engaged in shooting during the last 12 months in Sweden. Sample size was 3729 respondents.

Habitat	Shooting (%)	Lead (%)	Steel (%)	Bismuth (%)	Tungsten (%)
Forest	85.8	88.8	11.1	0.4	0.4
Open, dry	78.9	85.3	14.0	0.6	0.6
Alpine	36.5	70.2	25.4	2.6	2.0
Wetlands	52.0	31.6	60.7	5.5	2.6
Open sea	36.4	34.0	56.9	5.9	3.1

Table 3
Factors significantly predicting whether Swedish hunting permit holders used lead shot when shooting over wetlands. Sample size was 1227 respondents.

Explanatory variable	Estimate	Standard Error	Wald statistic	P-value
Age	–	–	–	–
Education	–	–	–	–
Hunters' exam	−0.350	0.073	22.7	< 0.001
Number of days hunting	–	–	–	–
Member JRF	–	–	–	–
Member SJF	−0.206	0.070	8.6	0.003

[a]Variables included in the most parsimonious model within 2 AIC of the best model are presented.

Table 4
Factors predicting whether Swedish hunting permit holders predominantly used lead shot when shooting in forests or over dry, open land. Sample size was 2422 respondents.

Explanatory variable	Estimate	Standard Error	Wald statistic	p-value
Age	0.124	0.076	2.64	0.10
Education	–	–	–	–
Hunters' exam	–	–	–	–
Number of days hunting	0.380	0.100	15.2	0.003
Member JRF	–	–	–	–
Member SJF	−0.168	0.082	5.8	0.04

[a]Variables included in the most parsimonious model within 2 AIC of the best model are presented.

shot for clay target shooting in 1996, 2002, and 2004, respectively, except for the Olympic disciplines (Thomas and Guitart, 2013). So far, scientific assessment of compliance has been lacking. Shooters were asked what type of shot they predominantly used while practicing, and the results suggest that close to 60 % of the Swedish shooters predominantly use lead while practicing. Taking the number of shots fired by each individual into account, where those who practice more tend to use steel more often, would suggest that approximately 40 % of the shots fired were lead. This calculation is based on all shells being assigned to the predominant shot type stated. While there are exceptions when lead still may legally be used, the results show that this cannot explain the continued use of lead in practicing. The respondents who claimed to have engaged in disciplines where lead is allowed amounted to no more than 15 % of the shooters. Furthermore, the discipline that by far engaged the majority of the 15 % did not significantly predict predominant choice of shot type.

Number of practice shots fired over the last 12 months had the strongest predictive power on choice of shot type. In organized shooting of clay pigeons at shooting clubs, the ban is enforced through having voluntary safety officers, or staff, running the activities. Furthermore, hunting permit holders who are competitive shooters also will probably want to practice with the same ammunition they use when competing. However, many shooters practice under less formal conditions, for example with members of their shooting parties outside of established shooting ranges. While this is legal, the ban on using lead shot still applies. Here, there is no formal enforcement. The results showing that shooters predominantly using lead for practice practiced less often and shot fewer shells probably reflect a difference in how formal the settings of the practicing events are. Women were less likely than men were to practice using lead, but only made up a few percent of the shooters.

Respondents having taken the theoretical hunters' exam, and having done so more recently, were almost twice as likely to use predominantly steel when practicing. Thus, it seems as if targeted education influences the choice of ammunition in practice. Additionally, there was a correlation with general educational level. There was a weak but highly significant effect of age, potentially as older shooters are less likely to have taken the theoretical exam and more likely to have done so before the ban came into place. However, respondents were older on average as compared to non-responders, so the actual compliance may be higher. Due to the weak effect of age, the difference is expected to be relatively small.

Interestingly, respondents being members of the smaller hunters' organization JRF were more likely to practice using lead than expected by chance. The JRF does not have a corresponding commission as the larger SJF for reducing negative effects from lead in ammunition. While being far from propagating non-compliance, the JRF claims that" *It is no secret that lead is toxic. Therefore, it might be prudent to review all usage and dispersal of lead in society. But lead in ammunition for shooting or practicing isn't a large problem, neither for human health nor for other reasons*" (JRF, 2020). One possible explanation is that JRF members are more likely to believe that negative effects from lead in ammunition are negligible as compared to random shooters, thus reducing the rate of compliance amongst JRF members.

Neither JRF nor SJF highlight that lead shot is banned while practicing under most circumstances on their respective homepages (JRF, 2020; SJF, 2020b, c)

Before the ban in 2002, virtually all practice using a shotgun would have been with lead shot. In 2008, the Swedish Chemicals Agency (2008) concluded that overall, roughly 65 % of the shotgun shells sold in Sweden were steel, 80 % of the shells sold were for practice and 70 % of the shells for practice were steel shot. Today, more than 95 % of the ammunition currently sold for practice is steel (C. Larsson, pers. comm.) and lead shot for practice is more expensive than steel (e.g. www.torsbohandels.com). Thus, the ban, and communication about the new legislation, has reduced the use of lead shot significantly. Even so, the compliance revealed by this study must be regarded as low, despite steel shot for practice being cheaper and more easily available than lead shot in Sweden. Probably, many shooters who rarely practice do so with their shooting ammunition, rather than buying dedicated ammunition for practice.

4.2. Compliance with the ban on shooting lead shot over wetlands

Roughly one third of the respondents who had engaged in shooting over wetlands, or open water, claimed to have used lead shot predominantly. The corresponding numbers for forests and dry, open habitats, where lead is permitted, was 85–89 %. Shooters having taken the hunters' exam were less likely to use lead shot in wetlands, especially if they had taken the exam more recently. Furthermore, members of SJF, the hunting organization with a commission to reduce the negative impacts of lead in ammunition, were less likely to use lead in wetlands. However, this effect was slightly smaller than from having taken the exam. Thus, education and communication might have affected compliance, despite official enforcement of the ban being rare or, in most cases, non-existent. Alternatively, SJF members may not be a random subset of shooters with respect to attitudes to lead in ammunition. This might include accepting to be a member of an organization holding a public commission to minimise the negative effects of lead in ammunition. Thus, the observed patterns could also be explained by SJF members being likely to comply with the legislation for other reasons than communication efforts from their organization, or from a combination of communication efforts and preconceived attitudes. The public commission to the SJF explicitly states that all hunters and shooters should be targeted by communication efforts. The significant differences between SJF members and others suggest that the organization is better at reaching its own members, or that the differences are due to other effects at least in part.

Compliance with existing bans on using lead in wetlands varies widely across countries. In the U.S., taking waterfowl using lead shot was banned in 1991 and Canada followed suit in 1999. In both cases the legislations cover both habitats and species (Stevenson et al., 2005; U.S. Fish and Wildlife Service (USFWS, 1999) and compliance appears to be very high (Havera et al., 1994; Stevenson et al., 2005). Denmark has had a complete ban on lead shot irrespective of habitat and species since 1996; compliance has increased gradually and appears to be very high currently (Kanstrup and Skovbjerg Balsby, 2019a). Spain also has had an increase in compliance with the ban on using lead shot in selected wetlands, after the legislation was enforced more strongly (Mateo and Guitart, 2013). By contrast, 45 % of English shooters admitted to sometimes or never complying with the lead ban (Cromie et al., 2010; Newth et al., 2013), which is more similar to the result of 32 % of Swedish shooters predominantly using lead over what they themselves define as wetlands.

Choice of shot type over open water was similar as over wetlands, suggesting that shooters view this as something that is covered by the restrictions on using lead shot. However, lead shot were frequently used in alpine areas. In Sweden, shooting in alpine areas will likely be mainly for willow grouse, *Lagopus lagopus,* just above the tree line. Typically, this will be in wet habitats with a mosaic of peat, rock and willow thickets, where shot may fall in what constitutes wetlands under the current definition. To my knowledge, willow grouse habitats have never been communicated as wetlands by the authorities or the hunters' organisations. Furthermore, there is no control of shot type used. This may explain why the choice of shot type was more similar to the use over open, dry habitats.

Comparing compliance between countries is difficult. Often, compliance is assessed by obtaining and x-raying birds shot; for example, Cromie et al. (2010, 2015) found that 68–70 % of ducks investigated had been shot using lead in England, while Kanstrup and Skovbjerg Balsby (2019b) found that only a few percent of the birds bought over the counter in Denmark had been taken with lead. Obviously, assessing compliance from analyses of shot type within birds taken can only be used in countries where restrictions are focused on certain species or where there is a complete ban, unless you know the habitats where the birds were taken. Furthermore, shooters selling their bag might not be representative of the average shooting behaviours (Kanstrup and Skovbjerg Balsby, 2019b). Differences between countries make things even more complicated for migratory species. For example, ducks and geese migrate between the Fennoscandian countries, where waterfowl cannot be taken using lead in Finland regardless of habitat, while waterfowl can be taken using lead outside of wetlands in Sweden and Norway. In Denmark, all shooting with lead shot is banned. A migratory duck found with embedded lead shot in any country could have been shot at in habitats, or countries, where this is legal. Similarly, birds with ingested shot could have picked them up in habitats, or countries, where it is legal to use lead, or may have picked up old shot in the sediment from before a ban was put in place.

Surveys can be tailored to the legislation in each country and circumvent these problems, but rely on respondents answering truthfully. In order to take a step further, questions about behaviours, such as in this study, should be combined with questions about attitudes that may answer *why* shooters act in a certain way. A combined approach using repeated measures over time seems best suited to the purpose of measuring compliance reliably.

4.3. Voluntary phasing out of lead shot

Between 12 and 15 % of the shooters predominantly used non-lead shot in habitats where lead was permitted. Such voluntary phasing out of lead was less likely amongst respondents spending many days shooting, but more likely amongst members of the SJF. Thus, the task of minimising negative impacts from lead in ammunition through communication with hunters and shooters may have had a small effect on voluntary choice of lead free alternatives. The SJF have given the advice that hunters and shooters should consider lead free alternatives as part of their public commission (SJF, 2020d), but the SJF also has taken a clear stance against any further legislation (SJF, 2020e). The higher proportion of shooters using non-lead amongst SJF members may also be due to them not being a random subset of shooters with respect to attitudes to lead. There was no effect of having taken the theoretical hunters' exam, which is focused on the legislation rather than voluntary phasing out lead.

Only a small proportion of the shooters voluntarily used lead-free shot and ardent shooters being more likely to use lead would reduce any positive effects even further. There are few published studies of voluntary phasing out of lead in ammunition, but Stevenson et al. (2005) found that 25 % of shooters stated that they had started using non-lead alternatives in upland shooting in Canada. Neither the results from this study nor results from other published studies suggest that there are major effects of voluntary actions on the phasing out of lead shot in any habitat.

5. Conclusions

My results suggest that both mandatory education and communication from stakeholder organisations may increase compliance with restrictions in the use of lead shot. However, compliance with existing legislation was low in Sweden and there is nothing to suggest that actions at the current level will remedy the situation satisfactorily. Phasing out lead in ammunition in accordance with decisions already made will have to rest on a combination of education and dialogue on the one hand and legislation and enforcement on the other hand, but with increased efforts. Compliance will hinge critically both on the acceptance of risk assessments as being objective and resulting management actions as being proportionate and fair. Alternatively, access to lead ammunition must be (successfully) restricted.

The use of lead shot was more than twice as high in alpine areas as compared to what shooters defined as wetlands, even though most alpine areas where shooting occurs are wetlands in Sweden. Thus, the respondents appeared to have had problems determining what constitutes a wetland. Restrictions focused on groups of species rather than habitats may be easier to apply, but simultaneously may be less effective for reducing primary poisoning of waterfowl. Definitions used should be unambiguous and well communicated through actions of authorities and relevant stakeholders both. In short, restrictions must be both understood and accepted in order to be applied in practice. Currently neither appears to be the case.

CRediT authorship contribution statement

Fredrik Widemo: Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The author declares no conflict of interest.

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