European Journal of Wildlife Research (2023) 69:73
https://doi.org/10.1007/s10344-023-01706-x

RESEARCH

Prevalence of imbedded and ingested shot gun pellets in breeding sea ducks in the Baltic Sea—possible implications for future conservation efforts

Niklas Liljebäck[1] · Iben Hove Sørensen[2] · Jacob Sterup[3] · Fredrik Haas[4] · Ib Krag Petersen[3] · Johan Månsson[1]

Received: 22 February 2023 / Revised: 24 April 2023 / Accepted: 21 June 2023 / Published online: 5 July 2023

Abstract
Several sea duck species in Europe face dwindling population numbers with following increased conservation focus. Shot gun practices may put extra pressure on populations not only by direct hunting mortality but also crippling and lead poisoning from ingestion of pellets. In this study, we examined three sea duck species breeding in the Swedish Archipelago of the Baltic Sea by x-raying trapped incubating females to detect prevalence of imbedded and ingested shot gun pellets. The study was carried out during the 2021 and 2022 breeding seasons and designed to aid our understanding of the role of physical restraints of putative pellets to breeding performance at our study site. A total of 205 individual females of common eider ($n=113$), velvet scoter ($n=57$), and red-breasted merganser ($n=35$) were x-rayed without finding any imbedded or ingested pellets. For this study, a combination of decreasing hunting pressure, remoteness of study site, improved hunters' shooting performance along the flyway and depletion of crippling rates due to life-long negative effects of carrying imbedded pellets may explain our finding on non-detection. For common eider, specific interventions to reduce the negative impacts of shotgun practices have been reported successful, and our data suggest a continuing positive trend. Based on our findings, we advise future conservation efforts for the three species, breeding in this part of the flyway, to focus on other factors that may have negative impact on incubating female survival and reproduction.

Keywords Crippling · Lead poisoning · Common eider · Velvet scoter · Red-breasted merganser · Incubation · Baltic/Wadden sea flyway

Introduction

The majority of sea duck populations of Northern Europe have been subject to long-standing traditional harvest including hunting and collection of eggs and down (Green and Elmberg 2014). Due to recent and notable declines in several species (Kilpi et al. 2015), several measures, such as sex-specific and generally shortened open hunting seasons have been suggested, and in many cases implemented, to reduce the negative effects of hunting practices (Dagys and Hearn 2018; Lehikoinen et al. 2022).

Apart from the direct mortality caused by hunting, shooting may also cause negative effects on individual animal performance and even population development via hunting-induced crippling or lead poisoning through ingestion of pellets (Madsen and Noer 1996; Tavecchia et al. 2001; Hickling and Barrow 2004). These two indirect effects have gained particular attention in wildlife management for conservation related as well as ethical reasons (Elder 1950; Mudge 1983; Jönsson et al. 1985).

Birds may survive being hit by shotgun pellets penetrating the skin and other tissues, if they do not affect vital organs. If such individuals are not retrieved by the hunter, the pellet may become imbedded in body tissue. Crippling rate is defined as the proportion of sampled individuals carrying imbedded pellets, typically detected by X-ray

✉ Niklas Liljebäck
niklas.liljeback@slu.se

[1] Grimsö Wildlife Research Station, Dept of Ecology, Swedish Univ. of Agricultural Sciences, Uppsala, Sweden

[2] Danish Hunters' Association, Molsvej 34, 8410 Rønde, Denmark

[3] Dept. of Ecoscience, Aarhus University, C.F. Møllers Allé 8, 8000 Aarhus C, Denmark

[4] Department of Biology, Biodiversity Unit, Lund University, Ecology Building, S-223 62 Lund, Sweden

examination (Noer et al. 2007). Varying crippling rates between populations can be explained by differences in hunting practices such as hunting pressure and hunters' performance (Falk et al. 2006; Clausen et al. 2017) but also relates to traits of the quarry species, as large and long-lived species tend to show higher crippling rates (Hickling and Barrow 2004).

Position of found pellets in the birds' body, during x-ray examination, indicates whether the pellet has been ingested or imbedded as a result of crippling (Guillemain et al. 2007). X-raying wildlife has been used to quantify illegal shooting of endangered species (Newth et al. 2011; Berny et al. 2017), accidental wounding of protected species (Elmeros et al. 2012; Blanco et al. 2019), changes in hunters' shooting performance (Hebert et al. 1984; Noer et al. 2007), crippling rates in harvested populations (Noer and Madsen 1996; Falk et al. 2006), and risk of lead poisoning in waterbird populations (Havera et al. 1992; Tavecchia et al. 2001).

The common eider (*Somateria mollissima*), velvet scoter (*Melanitta fusca*), and red-breasted merganser (*Mergus serrator*) are three diving seaduck species that share a history as quarry species, and presently in focus of internationally coordinated management actions aiming to achieve favorable conservation status (Dagys and Hearn 2018; Lehikoinen et al. 2022; Helcom 2023). These three species have overlapping breeding and wintering ranges within the Baltic/Wadden Sea flyway (Skov 2011). The breeding number of common eider has shown a dramatic decline in the Baltic Sea (Ekroos et al. 2012; Helcom 2023), with a decreasing survival rate of adult females being emphasized as the most likely driver behind dwindling numbers (Öst et al. 2016). The breeding populations of velvet scoter and red-breasted merganser are also declining in the Baltic Sea (Helcom 2023), but explanatory processes have not been described in detail. Indirect effects of hunting, such as crippling and lead poisoning, are hypothesized to negatively affect sea duck populations (Dagys and Hearn 2018; Lehikoinen et al. 2022). Wintering grounds of the three studied species within the Baltic/Wadden flyway are found in Wadden Sea, Kattegat, and the southwestern Baltic Sea, near the coasts of Denmark, Germany, Netherlands, and Sweden (Fransson et al. 2001; Dagys and Hearn 2018; Lehikoinen et al. 2022). Preliminary data retrieved from birds tagged with light loggers in our study area (unpublished data) confirm that this is also where the birds breeding in the Swedish Archipelago winter. Harvest of seaducks within the Baltic/Wadden Sea flyway has shown a general decline over the last decades (Kilpi et al. 2015), partly due to hunting periods being stepwise restricted as a response to multiple changes in national and regional policy. For Germany and the Netherlands, no hunting of these species have been allowed during the last century, while total hunting ban within the flyway was implemented for velvet scoter and red-breasted merganser in 2020 and 2021, respectively. For common eider, the open hunting season has been restricted for both sexes, but especially so for females. Since 2022 in Finland, 2021 in Sweden (both sexes), and 2014 in Denmark, hunting of eider females has been closed. Only remaining hunting on eiders after 2022, within this flyway, is found in specific areas of Finland and Denmark, targeting only males. Total harvest of eiders within the Baltic/Wadden Sea flyway peaked with over 150 000 birds during 1970s. In 2021, 25, 000 eider males were shot in Denmark and 1500 in Finland, representing the entire hunting bag within the flyway, thus indicating a relatively low hunting pressure (Lehikoinen et al. 2022). However, even though bird species are protected, individuals may still be accidentally shot or crippled, e.g., when hunters face mixed flocks of both sexes and similar species (Brochet et al. 2019; Blanco et al. 2019).

In contrast to numerous studies on common eiders from both North America and Europe, we have not found previous data on crippling rates or pellet ingestion for velvet scoter or red-breasted merganser. In this study, we investigate the rates of imbedded and ingested gun pellets of the three species. The study was designed to aid our understanding if detected prevalence of pellets may add physical restraints to incubating females, affecting their breeding performance at our study site.

Our study population of eiders breeding in the Swedish Archipelago is within the same flyway as an earlier study on eiders breeding or wintering in Denmark (approximately 500 km southwest of the present study site, Holm and Haugaard 2013). In the Danish study, crippling rates decreased remarkably from 34.1% in 1997 to 5.5% in 2011. Implementation of an action plan to reduce crippling was deemed the most plausible explanation for the positive development for this Danish population. Given the reported spatial intermixing during wintertime of breeding common eiders within the flyway (Fransson et al. 2001; Lehikoinen et al. 2022), which coincide with open hunting season for eider in the region, we assume that data retrieved in the two studies can be used as comparable temporal indices of crippling within the Baltic/Wadden Sea flyway.

Ingested lead pellets have been reported as a concern for diving ducks breeding in the Baltic Sea (Hollmén et al. 1998). Toxic effects from ingested lead pellets are normally found after 3–4 weeks among ducks (Mudge 1983), and lead pellets can pass through the gastrointestinal tract or, alternatively, be completely dissolved within 4–5 weeks (Locke et al. 1967). Incubating eiders in the Baltic Sea were found to suffer from high lead blood concentrations, with some individuals even exceeding levels expected to be lethal or having sublethal effects (Lam et al. 2020). Isotope analyses have suggested lead originating from ammunition as the most likely source for eiders, and ingestion of lead pellets was identified as the most plausible mechanism of uptake (McPartland et al. 2020).

We expect to find imbedded pellets in all three species as they are relatively large-bodied and long-lived, typical characteristics of species with high crippling rates. Furthermore, all three species may occur in flocks of mixed species. As the common eider is the largest species and females until recently faced open hunting season, albeit with low and decreasing hunting pressure, we hypothesize that the crippling rate is higher for the eider relative to the other two species. Earlier studies in the Baltic Sea have suggested regular occurrence of pellets in the gizzard of eiders (Falandysz et al. 2001; Pain et al. 2019), but we expect low risk of recent intake and consequently low prevalence of ingested pellets as our study site is remote with limited human access.

Methods

All birds in this study were females trapped by hand, handnet, or mistnet during incubation. All birds were measured, weighed, and ringed. The primary purpose of catching the birds was to mount or retrieve light loggers, deployed to study migration routes, phenology, and wintering sites of the three species. The hatching success of trapped females was followed up by recurrent nest visits. All birds were trapped on the island of Hävringe, in the outer Archipelago of Oxelösund in the Baltic Sea (lat. 58,60,255, long. 17,317,536). This is a rocky island situated in the central part of the Baltic/Wadden Sea flyway (Lehikoinen et al. 2022), approximately 11 hectares in size, and sparsely covered by shrubs, bushes, and few trees. Human presence on the island is generally limited to short-term visits during weekends and public holidays, and the 13 private cabins located on the island are used mainly in the summertime. (Fig. 1)

After ringing, the birds were kept in a cotton bag. The bag was placed in a plastic box without lid to keep the bird in place on the X-ray detector. In 2021, 30 velvet scoters, 20 mergansers, and 1 eider were x-rayed using a VIVIX-S 1417N detector in combination with a portable Econet Vet20BT x-ray unit. In 2022, 112 eiders were x-rayed using the same detector as in 2021, whereas 27 velvet scoters and 15 mergansers were x-rayed using a Sedecal SP-VET-4.0 with Beam device r 72/170A DHHS. The X-ray was set at 50 kW and 3 mAs. All birds were x-rayed directly after ringing and released immediately after examination. All X-ray pictures were pre-checked if bones, tissues, and metal ring were clearly visible to ensure that any pellets would be detected.

Catching was permitted by the Swedish Environmental Protection Agency (NV-03951–21 and NV-04563–22). Handling of birds and x-raying were done according to permits from the Animal Ethics Committee of Central Sweden (# 5.8.18–03584/2017).

Results

A total of 113 individual common eiders, 57 velvet scoters, and 35 red-breasted mergansers were x-rayed in 2021 and 2022 (Table 1). No birds were found carrying neither imbedded nor ingested pellets. A total of 11 velvet scoters and 2 red-breasted mergansers were re-examined when retrapped in 2022 but no pellets were found.

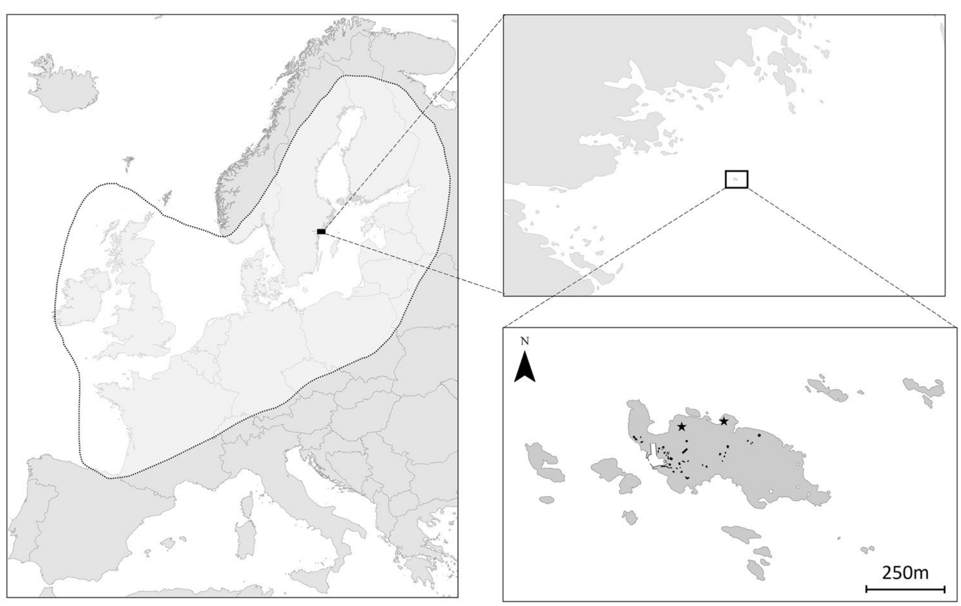

Fig. 1 Map depicting the Baltic/Wadden Sea flyway (according to Lehikoinen et al. 2022) as a shaded area with the location of the study site. The Island of Hävringe is illustrated below on the right map and with buildings as black squares and lighthouses as black stars

Table 1 Number of x-rayed and trapped birds for respective species and years 2021 and 2022. The number of birds re-trapped and re-examined by x-ray in brackets (only 2022)

	2021		2022		Total
Species	X-ray	Trapped	X-ray	Trapped	X-ray
Common Eider	1	51	112(0)	125	113 (0)
Velvet scoter	30	30	27 (11)	50	57 (11)
Red-breasted merganser	20	20	15 (2)	24	35 (2)
Total X-ray	51		154 (13)		2015 (13)

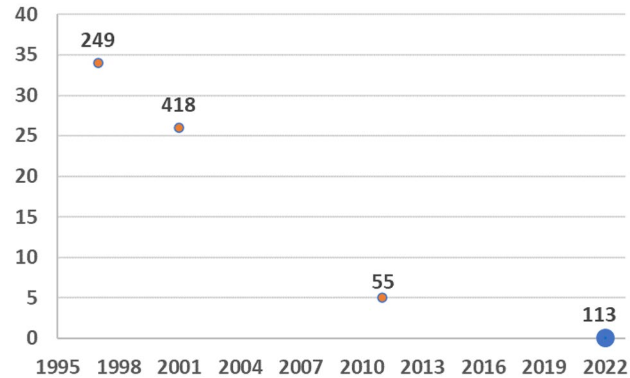

Fig. 2 Crippling rates found for eider females in Denmark in 1997, 2001, and 2011 (brown dots) retrieved from Holm and Haugaard (2013) for comparison with data from this study (blue dot) in Sweden in 2021 and 2022 (0%). The number of eiders x-rayed is indicated above each point

Discussion

Contrary to our expectations, the crippling rate and prevalence of ingested pellets in females of common eider, velvet scoter, and red-breasted merganser during the breeding period are below detection rate, even though a total of 205 birds were examined.

Earlier studies report crippling rates of adult diving ducks ranging from 0 to 55% (e.g., Falk et al. 2006). The only previous example of non-detection of pellets in studies of diving ducks was found for local populations of ring-necked duck (*Aythya collaris*) and canvasback (*Aythya valisineria*) in North America 1985–1986 (Havera et al. 1992). Other studies typically detect crippling rates of 5–25% for hunted dabbling ducks (e.g., Hicklin and Barrow 2004), and for hunted goose populations rates exceeding 20% are frequently reported (e.g., Noer and Madsen 1996).

Breeding eiders along the Swedish coast of the Baltic Sea, including our study area, share wintering waters with Danish breeders (Fransson et al. 2001), and the majority of eiders harvested in Denmark are shot in January (Madsen et al. 2021). The large spatial overlap during the hunting season between breeding eiders studied by Holm and Haugaard (2013) and the present study implies that the populations share crippling risk over time. Sampling within any of these populations may thus produce a temporally comparable index of crippling rates. In this context, our data suggest, while acknowledging the decreasing hunting pressure on eiders within the flyway, a continued positive development (Fig. 2).

Hickling and Barrow (2004) reported crippling rates between 16 and 55% (mean 32%) for eiders in Arctic Canada during the period 1993–1998 and found the risk of crippling to be high in comparison to other hunted duck populations investigated. Similar crippling rates were found for eiders in Greenland in 2000–2001 (22%, Falk et al. 2006). Furthermore, the use of shotguns can also cause crippling by ricochets, and even with highly skilled hunters, low crippling rates can still be expected in hunted bird populations (Heberet et al. 1984). Consequently, our finding of no crippling stands out in relation to previous studies of eiders and other sea ducks.

Merkel et al. (2006) found only weak evidence of crippling restraining body condition among adult eiders but detected a significant effect on juvenile birds. Also, Madsen and Riget (2007) found that pink-footed geese in spring did not show any measurable effect on body condition when comparing crippled and non-crippled birds. The long-term effects on survival among birds carrying pellets are poorly investigated. Madsen and Noer (1996) found in a 5-year study that pink-footed geese carrying imbedded pellets had lower survival than birds with no pellets. Even if studies so far failed to prove that imbedded lead pellets contribute to elevated blood lead concentrations in birds, carrying pellets, of any metal, may affect individual survival to be lower than expected from natural mortality (Tavecchia et al. 2001; Guillemain et al. 2007).

High lead blood concentrations found in breeding eider females have been explained by putative prevalence of pellets in the gastrointestinal tract (Flint et al. 1997; Hollmén et al. 1998). But Lam et al. (2020) argue that remobilization of toxicants from the bone and liver is the prominent pathway for exposure to lead during the incubation period. Such “leakage” from stored lead also explains detected increases in blood concentration during incubation as this relates to depleting energy reserves in the female. Franson et al. (2002) reported that lead concentrations in blood from incubating eider females in the Finnish part of the Baltic Sea differed between sampling sites and argued that relatively low concentrations point to exposure during non-breeding and later re-activation rather than recent ingestion of pellets. In the present study, no ingested pellets were detected, but lead blood concentrations were not measured. Continuous x-raying, in combination with measurements of blood lead levels may deepen our understanding if this pollutant via other sources than ingestion of pellets, may affect breeding performance in our study site.

Hunting pressure and crippling rates can be strongly correlated in hunted bird populations (Falk et al. 2006; Clausen et al. 2017), but analysis of such covariation should be made with caution as the relationship may be confounded by changes in ammunition and hunting practices (Hebert et al. 1984; Noer and Madsen 1996; Noer et al. 2007; Ellis and Miller 2022) but also hunters' attitudes, and performance (Clausen et al. 2017). For this study, a combination of decreasing hunting pressure, improving hunters shooting performance, and depletion of crippling rates due to lifelong negative effects on individuals carrying imbedded pellets may explain found non-detection. Notwithstanding the complex causality between harvest and crippling, our result suggests that present hunting pressure on the populations investigated does not contribute to measurable crippling rates.

Our findings suggest that, at present, neither crippling nor direct uptake of lead from gun pellets, during breeding, pose prominent threats to incubating females at our study site. Our data suggest that conservation interventions to reduce the negative impacts of shotgun practices in the Baltic Sea seem to be successful for the species investigated. Based on these findings, we advise future conservation initiatives for the three species, breeding in this part of the Baltic/Wadden sea flyway, to focus on other factors that may have negative impact on incubating females' survival and reproductive success.

Acknowledgements Funding for purchasing an X-ray device was kindly provided by the Marie-Claire Cronstedts Foundation. Field work was funded by the Jægernes Naturfond, Swedish Association for Hunting and Wildlife Management, Danish Hunters' Association, and Swedish University of Agricultural Sciences. The National Property Board (SFV) as landowners allowed us to do scientific studies on the Island. We acknowledge the people living on Hävringe for respecting our work for the ducks. Adam Stålnäbb and his work localizing incubating females was of fundamental importance for this study. We thank Dr. Pierre Defos du Rau and anonymous reviewer for constructive comments and input improving this article.

Author contribution Funding acquisition: N. Liljebäck, J. Månsson, I.H. Sørensen, I.K. Petersen. Conceptualization and writing of the first draft: N. Liljebäck, J. Månsson. Field work and collecting data: all authors. Writing and editing: all authors.

Funding Open access funding provided by Swedish University of Agricultural Sciences.

Declarations

Competing interests The authors declare no competing interests.

References

Berny PJ, Mas E, Vey D (2017) Embedded lead shots in birds of prey: the hidden threat. Eur J Wildl Res 63:1–6. https://doi.org/10.1007/s10344-017-1160-z

Blanco G, Cuevas JA, Frías Ó, del Barrio JLG (2019) A shot in the dark: sport hunting of declining corvids promotes the inadvertent shooting of threatened red-billed choughs. J Nat Cons 52:125739. https://doi.org/10.1016/j.jnc.2019.125739

Brochet AL, Van Den Bossche W, Jones VR, Arnardottir H, Damoc D, Demko M et al (2019) Illegal killing and taking of birds in Europe outside the Mediterranean: assessing the scope and scale of a complex issue. Bird Cons Intern 29:10–40. https://doi.org/10.1017/S0959270917000533

Clausen KK, Holm TE, Haugaard L, Madsen J (2017) Crippling ratio: a novel approach to assess hunting-induced wounding of wild animals. Ecol Indicators 80:242–246. https://doi.org/10.1016/j.ecolind.2017.05.044

Dagys M, Hearn R (2018) International single species action plan for the conservation of the velvet scoter (Melanitta fusca) W Siberia & N Europe/NW Europe population. AEWA Technical Series No. 67. Bonn, Germany

Ekroos J, Fox AD, Christensen TK, Petersen IK, Kilpi M, Jónsson JE et al (2012) Declines amongst breeding eider *Somateria mollissima* numbers in the Baltic/Wadden Sea flyway. Orn Fen 89:81–90

Elder WH (1950) Measurement of hunting pressure in waterfowl by means of X-ray. In Trans N Am Wildl Conf 15:490–504

Ellis MB, Miller CA (2022) The effect of a ban on the use of lead ammunition for waterfowl hunting on duck and goose crippling rates in Illinois. Wildl Biol 2:1–7. https://doi.org/10.1002/wlb3.01001

Elmeros M, Holm TE, Haugaard L, Madsen AB (2012) Prevalence of embedded shotgun pellets in protected and in legally hunted medium-sized carnivores in Denmark. Europ J of Wildl Res 58:715–719. https://doi.org/10.1007/s10344-012-0621-7

Falandysz J, Ichihashi H, Szymczyk K, Yamasaki S, Mizera T (2001) Metallic elements and metal poisoning among white-tailed sea eagles from the Baltic South Coast. Marin Poll Bull 42:1190–1193. https://doi.org/10.1016/S0025-326X(01)00217-X

Falk K, Merkel F, Kampp K, Jamieson SE (2006) Embedded lead shot and infliction rates in common eiders *Somateria mollissima* and king eiders *S. spectabilis* wintering in southwest Greenland. Wildl Biol 12:257–265. https://doi.org/10.2981/0909-6396(2006)12[257:ELSAIR]2.0.CO;2

Flint PL, Petersen MR, Grand JB (1997) Exposure of spectacled eiders and other diving ducks to lead in western Alaska. Can Jof Zool 75:439–443. https://doi.org/10.1139/z97-054

Franson JC, Hollmén T, Hario M, Kilpi M, Finley DL (2002) Lead and delta-aminolevulinic acid dehydratase in blood of common eiders (*Somateria mollissima*) from the Finnish archipelago. Orn Fen 79:87–91

Fransson T, Pettersson J, Larsson P (2001) Svensk ringmärkningsatlas [Swedish Bird Ringing Atlas], vol 1. Ljungföretagen Tryckeri AB. Örebro, Sweden

Green AJ, Elmberg J (2014) Ecosystem services provided by waterbirds. Biol Rev 89:105–122. https://doi.org/10.1111/brv.12045
Guillemain M, Devinea O, Lebreton JD, Mondain-Monval JY, Johnson AR, Simom G (2007) Lead shot and teal (Anas crecca) in the Camargue, Southern France: effects of embedded and ingested pellets on survival. Biol Cons 137:567–576. https://doi.org/10.1016/j.biocon.2007.03.016
Havera SP, Whitton RM, Shealy RT (1992) Blood lead and ingested and embedded shot in diving ducks during spring. J of Wildl Man 56:539–545. https://doi.org/10.2307/3808870
Hebert CE, Wright VL, Zwank PJ, Newsom JD, Kasul RL (1984) Hunter performance using steel and lead loads for hunting ducks in coastal Louisiana. J of Wildl Man 48:388–398. https://doi.org/10.2307/3801170
HELCOM (2023) Abundance of waterbirds in the breeding season. HELCOM core indicator report. Online from March 2023
Hicklin PW, Barrow WR (2004) The incidence of embedded shot in waterfowl in Atlantic Canada and Hudson Strait. Waterbirds 27:41–45. https://doi.org/10.1675/1524-4695(2004)027[0041:TIOESI]2.0.CO;2
Hollmén T, Franson JC, Poppenga RH, Hario M, Kilpi M (1998) Lead poisoning and trace elements in common eiders *Somateria mollissima* from Finland. Wildl Biol 4:193–203. https://doi.org/10.2981/wlb.1998.022
Holm TE, Haugaard L (2013) Effects of a Danish action plan on reducing shotgun wounding of common eider *Somateria mollissima*. Bird Study 60:131–134. https://doi.org/10.1080/00063657.2012.748715
Jönsson B, Karlsson J, Svensson S (1985) Incidence of lead shot in tissues of the bean goose (Anser fabalis) wintering in South Sweden. Swed Wildl Res (Sweden)
Kilpi M, Lorentsen SH, Petersen IK, Einarsson A (2015) Trends and drivers of change in diving ducks (Vol. 2015516). Nord Council Ministers
Lam SS, McPartland M, Noori B, Garbus SE, Lierhagen S, Lyngs P et al (2020) Lead concentrations in blood from incubating common eiders (*Somateria mollissima*) in the Baltic Sea. Envir Int 137, 105582. https://doi.org/10.1016/j.envint.2020.105582
Lehikoinen P, Alhainen M, Frederiksen M, Jaatinen K, Juslin R, Kilpi M, Mikander N, Nagy S (compilers) (2022) International single species action plan for the conservation of the common eider *Somateria m. mollissima* (Baltic, North & Celtic Seas, and Norway & Russia populations) and S. m. borealis (Svalbard & Franz Josef Land population). AEWA Technical Series No. 75, Bonn, Germany. http://hdl.handle.net/10138/351367
Locke LN, Irby HD, Bagley GE (1967) Histopathology of mallards dosed with lead and selected substitute shot. Bul Wildl Dis Assoc 3:143–147. https://doi.org/10.7589/0090-3558-3.4.143
Madsen AB, Christensen TK, Madsen J, Balsby TJS, Bregnballe T, Clausen KK et al (2021) Vildtbestande og jagttider i Danmark. Report no 434, Aarhus Universitet, Denmark
Madsen J, Noer H (1996) Decreased survival of pink-footed geese Anser brachyrhynchus carrying shotgun pellets. Wildl Biol 2:75–82. https://doi.org/10.2981/wlb.1996.035
Madsen J, Rigét F (2007) Do embedded shotgun pellets have a chronic effect on body condition of pink-footed geese? J Wildl Man 71:1427–1430. https://doi.org/10.2193/2006-108
McPartland M, Garbus SE, Lierhagen S, Sonne C, Krokje Å (2020) Lead concentrations in blood from incubating common eiders (*Somateria mollissima*) in the Baltic Sea. Environ Int 137:105582. https://doi.org/10.1016/j.envint.2020.105582
Merkel FR, Falk K, Jamieson SE (2006) Effect of embedded lead shot on body condition of common eiders. J Wildl Man 70:1644–1649. https://doi.org/10.2193/0022-541X(2006)70[1644:EOELSO]2.0.CO;2
Mudge GP (1983) The incidence and significance of ingested lead pellet poisoning in British wildfowl. Biol Cons 27:333–372. https://doi.org/10.1016/0006-3207(83)90090-3
Newth JL, Brown MJ, Rees EC (2011) Incidence of embedded shotgun pellets in Bewick's swans Cygnus columbianus bewickii and whooper swans Cygnus cygnus wintering in the UK. Biol Cons 144:1630–1637. https://doi.org/10.1016/j.biocon.2011.02.014
Noer H, Madsen J (1996) Shotgun pellet loads and infliction rates in pink-footed geese Anser brachyrhynchus. Wildl Biol 2:65–73. https://doi.org/10.2981/wlb.1996.034
Noer H, Madsen J, Hartmann P (2007) Reducing wounding of game by shotgun hunting: effects of a Danish action plan on pink-footed geese. J Appl Ecol 44:653–662. https://doi.org/10.1111/j.1365-2664.2007.01293.x
Öst M, Ramula S, Lindén A, Karell P, Kilpi M (2016) Small-scale spatial and temporal variation in the demographic processes underlying the large-scale decline of eiders in the Baltic Sea. Pop Ecol 58:121–133. https://doi.org/10.1007/s10144-015-0517-y
Pain DJ, Mateo R, Green RE (2019) Effects of lead from ammunition on birds and other wildlife: a review and update. Ambio 48:935–953. https://doi.org/10.1007/s13280-019-01159-0
Skov H (2011) Waterbird populations and pressures in the Baltic Sea (Vol. 550). Nord Council Ministers
Tavecchia G, Pradel R, Lebreton JD, Johnson AR, Mondain-Monval JY (2001) The effect of lead exposure on survival of adult mallards in the Camargue, southern France. J Appl Ecol 38:1197–1207. https://doi.org/10.1046/j.0021-8901.2001.00684.x