Embedded lead shot and infliction rates in common eiders Somateria mollissima and king eiders S. spectabilis wintering in southwest Greenland

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"As the Eider is a bird very resistant to shot, often 2-3 birds are wounded for each that is shot dead…" (Müller, South Greenland, 1906)

The large numbers of common eiders *Somateria mollissima* and king eiders *S. spectabilis* wintering in southwest Greenland are subject to intensive hunting, and in addition to direct harvest an unknown number of birds are wounded and become carriers of embedded lead shot. We conducted the first assessment of the magnitude of this undesirable side effect of hunting in Greenland by X-raying 879 common and 114 king eiders collected by local fishermen and hunters during three winters (2000-2002). On average, 22% of all common eiders carried embedded shot, but proportions were strongly age dependent; of first-winter (1W) birds 13.2%, of immatures (IM) 16.4%, and of adults (AD) 29.1% were carriers. For king eiders the proportions were similar: 11.3, 10 and 20%, respectively, were carriers. Adult common eiders collected in fjord areas were significantly less burdened (24.5%) than birds collected in the more heavily hunted coastal areas (35.0%). Among inflicted birds, 1W birds contained more pellets (mean 2.2) than AD (mean 1.7), despite the adults' longer time to accumulate pellets from multiple inflictions, which suggests that the most burdened juveniles die before entering the older age class. From the proportion of wounded 1W birds (13.2%) we modelled the infliction rates, i.e. the proportion of an age class that become pellet carriers each year, for older birds (IM+AD) to be at least 1.8-3%, assuming that annual survival of adult eiders falls within the range 0.8-0.9. Assuming that roughly 35% of the 463,000 common eiders estimated to winter in southwest Greenland are juveniles, 13% are immatures, and 52% adults (fourth winter and older), then each winter up to 30,000 eiders would become new carriers of embedded shot (21,000 juveniles, 1,200-1,800 immatures and 4,800-7,300 adults). As wounded birds may risk increased mortality in severe winters and reduced reproductive output, the infliction has implications for the demographic models used to assess sustainable eider harvest levels. There is a need for follow-up studies of regional variation in infliction, and to identify ways to possibly reduce the hunters' unintended impact on their game populations.

Key words: Arctic, eider, embedded shot, Greenland, hunting, Somateria mollissima, Somateria spectabilis

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The management of the seabird populations in West Greenland is controversial; hunting is culturally and economically important, but harvest levels are considered unsustainable, a discrepancy that has stirred local and international debate (Hansen 2001). The eider ducks *Somateria* sp. are among the most popular game species for subsistence hunting, and according to the officially reported bags a combined total of 64,000-90,000 (mean: 77,000) common eiders *Somateria mollissima* and king eiders *S. spectabilis* were shot annually during 1993-2000 (Piniarneq 2000, 2003).

In addition to direct hunting mortality, an unknown number of birds are wounded and not retrieved. An unknown proportion of the wounded individuals later die as a direct consequence of their wounds, but some survive and carry the non-lethal lead pellets as embedded shot. Studies of common eider colonies in eastern Canada, including samples of the northern common eider *S. m. borealis* migrating to Greenland, show that 16-53% of adult females returning to their breeding ground carry embedded shot (Barrow & Hicklin 2004); the samples also include the northern common eider wintering in Greenland. In pink-footed geese *Anser brachyrhynchus* it has been shown that birds carrying embedded shot had a lower annual survival rate than non-carriers (Madsen & Noer 1996). Depending on the type of injury, lead-pellet carriers may be expected to experience a reduced ability to move around and forage for a period of time after being hit, and hence their body condition may be reduced as a direct consequence of infliction (Van Dyke 1981). For common eiders in southwest Greenland, wounded juvenile birds (first-winter birds; 1W), i.e. the sample segment which was inflicted during the sampling season, had significantly lower body fat reserves than non-wounded individuals (Merkel et al. 2006). Since the size of nutrient reserves in common eiders has been shown to be positively correlated with different parameters determining reproductive output such as timing of breeding, clutch size, hatching success and brood care (Spurr & Milne 1976, Erikstad et al. 1993, Bustnes et al. 2002, Oosterhuis & van Dijk 2002, Hanssen et al. 2003), effects of embedded shot on body condition may influence breeding success and the demography of the populations wintering in southwest Greenland.

Recent surveys have confirmed that southwest Greenland constitutes an internationally very important wintering area for many seabird species, and the coastal waters are utilised by an estimated 463,000 common eiders and 153,000 king eiders. The waters around Nuuk and within the Julianehåb Bay area have been identified as seabird 'hot spots' (Mosbech & Johnson 1999, Merkel et al. 2002). Ringing recoveries suggest that most of the wintering common eiders originate from colonies in eastern arctic Canada (Reed & Erskine 1986, Lyngs 2003). Gilchrist et al. (2001) estimated that about 73% of the eastern Canadian population winter in southwest Greenland, and that only about 6.5% of the wintering birds in that area breed in Greenlandic colonies. This exchange of hunted species calls for international management cooperation as initiated under CAFF auspices (CAFF 1997).

Information on the combined effects of hunting is important for management and conservation of the harvested populations. Gilchist et al. (2001) estimated that the sustainable annual yield would be around 36,000 birds based on current knowledge on population sizes and migration patterns, which is about half of the officially reported bag for 1993-2000. Any additional mortality or reduced reproductive capacity induced by infliction will add to the total effects of hunting on the involved populations. This paper provides the first appraisal of the shotgun pellet loads and infliction rates of the eiders wintering in southwest Greenland.

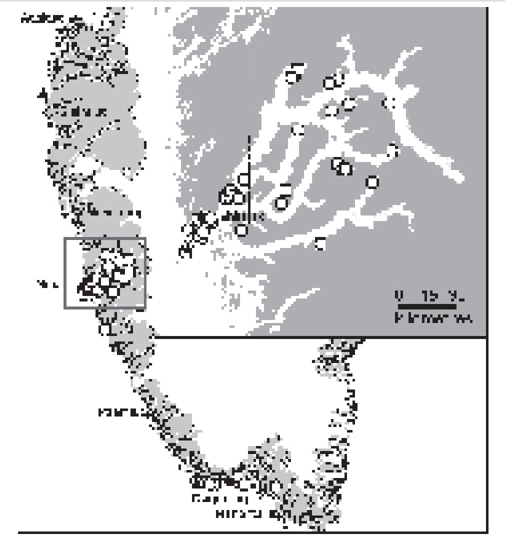

Figure 1. Areas of West Greenland where common eider (○) or king eiders (▲) were collected during 2000, 2001 and 2002; on the insert showing the Nuuk region, the border between the coast and fjord habitat is marked (- - -).

Methods

Study area

Our study was conducted in southwest Greenland with sampling ranging from Lichtenau Fjord (60°40'N) to the mouth of Nordre Strømfjord (67°30'N). However, sampling coverage was uneven, and most birds derived from the coastal and fjord areas within 30 km of Nuuk (Fig. 1), the capital of Greenland with a human population of ca 15,000. The open season for eiders was 1 October - 31 May in the winters of 1999/2000 and 2000/01, and 1 October-15 February in the 2001/02 hunting season. Most hunting takes place from dinghies and other small boats while navigating straits and coastlines in the coastal archipelago; see further descriptions of eider hunting methods in Merkel (2004a) and Merkel et al. (2006). Only shotguns with a maximum capacity of two cartridges are allowed, and there are as yet no restrictions in the use of lead shot in Greenland.

Sampling

Eiders of both species were collected during the hunting seasons of the three winters: January-April 2000, November 2000-April 2001, and December 2001-April 2002. Samples came from various sources: A) birds drowned in fishing gear (N = 788), mainly in lumpsucker gillnets, but also in some cod traps and a few seal nets, B) birds killed in collisions with ship lanterns (strong lights applied in winter to locate icebergs; N = 93), and C) birds shot with large lead pellets ('buckshot' or similar; N = 112) distinctly larger (5.2-6.02 mm in diameter) than shot normally used in bird hunting (2.7-3.9 mm in diameter) in Greenland and therefore identifiable during X-ray inspections. For birds collected at the same location and within the same period of time there was no difference in body condition for drowned and shot birds (Merkel et al. 2006), indicating that none of these sampling methods singled out particularly weak individuals. A similar comparison could not be made for the birds killed in collision with ship lanterns.

X-ray examination

A total of 993 birds, i.e. 879 common and 114 king eiders, were examined for embedded lead shot by either passing them (N = 764 birds) through an airport security check X-ray device (Schlumburger Controlix 2E) at Nuuk Airport with parallel colour and B/W monitors connected, or by taking high resolution X-ray photographs (35 × 40 cm) at the local hospital in Nuuk (N = 229). The first method was applied to most drowned birds, whereas the latter method was used to safely distinguish between embedded shot and the larger pellets used to collect some samples. To verify the ability of the airport X-ray equipment to detect pellets, a sample of 10 birds with lead shot was inspected using both methods. The number of pellets in each carrier was counted, and in case more than one size of lead pellets could be identified (disregarding the large pellets used in sampling some of the birds) the number of each pellet size was recorded. For the wounded birds, notes were taken on the approximate position of the pellet(s), i.e. in the body, head, wings, legs or rump (Fig. 2).

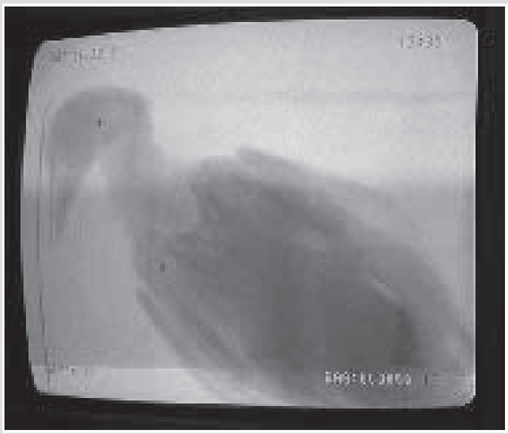

Figure 2. Standard airport security X-ray equipment was used to identify embedded shot. This common eider carries one pellet in the head and one in the breast muscle.

Laboratory inspections

All birds were identified to species, aged and sexed by plumage characteristics (Baker 1993). At subsequent dissection, the sex of first winter birds was confirmed by syrinx morphology (Beer 1963) and/or gonads; birds in adult plumage were classified as adults if they had no bursae, and, in the case of females, had a thick convoluted oviduct; otherwise they were classified as immature. Hence, for this study we distinguish between the age categories first-winter birds (1W), immatures (second and third winter; IM), and adults (AD). During dissection, many of the embedded shot were found, and their position and size were recorded; in particular, a few cases where X-ray results suggested pellets in the gizzard, we verified if the pellet was ingested or shot into the bird.

Data analysis

When comparing differences in proportions of pellet carriers during the winter hunt, we defined three periods: 'early', 'mid' and 'late' winter corresponding to the periods November-December, January-February and March-April, respectively. The majority of birds were derived from the Nuuk area, and most analyses are based on this subsample, but with comparisons to the other areas; unless specified otherwise, we refer to the Nuuk area only. Wintering eiders utilise the outer coastal areas as well as the inner Nuuk Fjord, ice conditions permitting. Flocks of eiders may winter more or less separated in the fjord and the coastal areas, respectively, and the risk of infliction may differ. We define the 'coastal' collection area in Nuuk as west of 51°32'W (Merkel 2004a), while the areas east of that are considered 'fjord' habitat (see Fig. 1).

Males and females were equally burdened ($G_{adj} = 0.26$, df = 1; ns), so we combine sexes in further analyses. The effects of age, species, sampling area and collection date on the frequency of wounded birds were tested by logistic regression using the SAS 'proc probit' procedure (SAS 1989) with the dichotomous variable WOUND (yes/no) as the dependant variable. As independent class variables we defined: AGE (1W, IM, AD), YEAR (the three sampling winters), and sampling HABITAT (coast or fjord). As continuous independent variable (covariate) we defined DAYNUMBER (collection date, numbered as days since hunting season opened, i.e. 1. October = day 1). We used a stepwise reduction, successively removing the variable with the highest P-value if larger than 0.2, and as long as the removal did not significantly change the fit of the log-likelihood model. Including meaningful interactions between parameters caused subgroups to be too small, so interactions were not considered.

Infliction rate estimates

In long-lived species, such as the eider, the observed proportions of adult pellet carriers are the accumulated result of a relatively low annual number of inflictions over many years (Noer & Madsen 1996). The annual infliction rates can be estimated by a simplified model using only three parameters: s, the annual survival of birds older than one year (IM and AD categories in this paper); x, the annual infliction rate of 1W birds, and y, the annual infliction rate of IM and AD. As defined here, the infliction rate is the number of birds in a given age class that are wounded but survive until entering the next age class, relative to the total number of survivors of the same age.

By definition, a proportion $C_{1W} = x$ of the 1W survivors will carry pellets. During the second hunting season, a fraction y of the birds will become new carriers, adding to those inflicted in the first season, so the proportion of pellet carriers will have increased to $Q_2 = x + (1-x)y$ at the age of two years. At the age of three, the proportion becomes $Q_3 = Q_2 + (1-Q_2)y$, and so forth.

Generally, the proportion of pellet carriers among birds aged n years will be $Q_n = Q_n\text{-}1 + (1- Q_{n-1})y$ for $n \geq 2$, and with $Q_1 = x$.

The mean proportion of carriers among IM birds, C_{IM} (birds in their second and third year combined) is obtained by averaging over the two groups, weighted according to the number of birds in each: $C_{IM} = w_2Q_2 + w_3Q_3$, where $w_2 = 1/(1+s)$ and $w_3 = s/(1+s)$.

Similarly, the mean proportion of carriers among the adults, C_{AD}, is obtained by $C_{AD} = \Sigma_k w_kQ_k$ where $w_k = s^k/(\Sigma s^k)$, and k goes from four to infinity (or to the maximum age of eiders); we used k up to 50 years, i.e. with the denominator for each value of w_k (for $k \geq 4$) then being ($s^4+s^5+s^6+ \dots s^{50}$). Guessing an initial value for y, the resulting C_{IM} and C_{AD} can be compared to the observed proportions, and the solution optimised for y by iteration.

Results

On average, 22% of all common eiders in the Nuuk area carried embedded shot, but the proportions differed considerably among age groups and periods (Table 1). First-winter (1W) birds, which in early autumn had only experienced one short hunting season, carried the lowest proportion (9.5%) while immatures (IM) had slightly higher burdens, and particularly high shares (35.6%) occurred in adults (AD) in mid-winter.

The small sample from South Greenland only covered

Table 1. Number of lead pellet carriers (+ shot), non-carriers (- shot), and proportion inflicted (% +) among common eiders wintering in the Nuuk area in West Greenland. Data are categorised according to age group and winter period (see 'Methods' for definitions). In the lower panel, data are grouped by habitat.

	Age group											
	1st winter			Immature (2nd & 3rd winter)			Adult (≥ 4th winter)			Ages pooled		
	+ shot	- shot	% +	+ shot	- shot	% +	+ shot	- shot	% +	+ shot	- shot	% +
Winter period												
Early	6	57	9.5	3	16	15.8	7	20	25.9	16	93	14.7
Mid	15	74	16.8	4	21	16	19	34	35.6	38	129	22.8
Late	13	92	12.4	14	70	16.7	95	241	28.3	122	403	25.2
Total	34	223	13.2	21	107	16.4	121	295	29.1	176	625	22.0
Habitats												
Coast	27	188	12.6	13	59	18.1	64	119	35.0	104	366	22.1
Fjord	7	35	16.7	8	48	14.3	57	176	24.5	72	259	21.8

mid and late winter, and the number and proportions of wounded birds were comparable to the levels in Nuuk: of AD, 19 were wounded and 43 were not wounded (31%; insignificantly different from proportions in Nuuk, $G_{adj} = 0.06$, df = 1; ns); of 1W one was wounded and 12 were not wounded (8%; $G_{adj} = 0.37$, df = 1; ns); of IM, three were not wounded.

In the logistic regression analysis of factors contributing to the risk of an eider being wounded only AGE was significant in the full model although HABITAT also had a low P-value (0.06), while DAYNUMBER was the first variable to fall out (P = 0.50). After stepwise reduction, AGE remained highly significant (P < 0.0001), and HABITAT was close to being significant at the 5% level (P = 0.053). The difference between habitats stems mainly from the marked difference among AD, where birds sampled in the fjord areas were significantly less burdened with lead shot than birds sampled in coastal areas ($G_{adj} = 5.44$, df = 1, P < 0.05; see Table 1).

King eider

The small sample of king eiders only permits an estimate covering all winter (Table 2). Direct pair-wise comparisons, using coastal habitat samples for common eider only since the king eider exclusively resides there (Merkel et al. 2002), do suggest that more AD common eiders are carriers ($G_{adj} = 4.27$, df = 1, P < 0.05).

Infliction rates

The observed proportion of pellet carriers in the total sample from Nuuk (from Table 1) was 0.1323 (SE ± 0.0211) for 1W birds (= x), 0.1641 (± 0.0327) for IM, and 0.2909 (± 0.0223) for AD; the standard errors were estimated using the binomial distribution. Using an annual survival, s, of 0.80 these values are reproduced almost exactly by y = 0.0296 (giving $C_{AD} = 0.2910$ and $C_{IM} = 0.1691$).

Most estimates of annual survival of eiders fall within the range of 0.80-0.90 (Goudie et al. 2000). Repeating the calculation using the upper value (s = 0.90) gives the following optimum values of the infliction rates: y = 0.0181 ($C_{AD} = 0.2910$ and $C_{IM} = 0.1553$).

Hence, 1.8-3.0% of IM and AD birds must become new carriers each year to maintain the carrier proportions in Table 1. The range of values of y for which the model predicts values of proportion pellet carriers within a given range will depend on x. If we want to keep the proportions within one standard error from the observed values, the 'area of uncertainty' takes the shape of a par-

Table 2. Number of lead pellet carriers (+ shot), non-carriers (- shot), and proportion inflicted (% +) among king eiders sampled in the three coastal areas of West Greenland: Sisimiut, Nuuk and South Greenland. Data are categorised according to age group.

	Age group											
	1st winter			Immature			Adult			Ages pooled		
Area	+ shot	- shot	% +	+ shot	- shot	% +	+ shot	- shot	% +	+ shot	- shot	% +
Sisimiut				0	1	0	2	22	8.3	2	23	8.0
Nuuk	6	44	12.0	1	4	20.0	8	7	53.0	15	55	27.3
South Greenland	0	3	0	0	5	0	0	11	0	0	19	0
Total	6	47	11.3	1	10	10.0	10	40	20.0	17	97	14.9

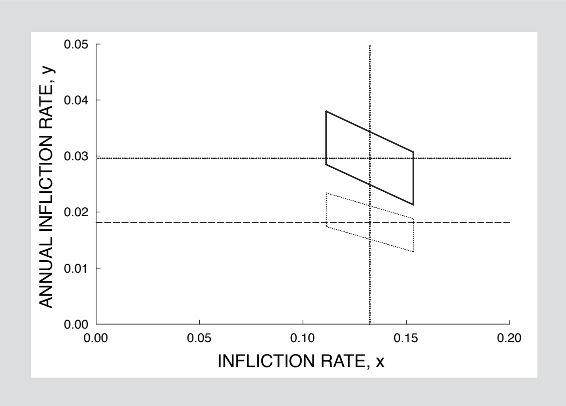

Figure 3. Infliction rate of older birds (IM + AD), y, versus the infliction rate of juvenile (1W) birds, x. The observed carrier proportions (± 1 SD) in Table 1 are compatible with x and y combinations within the shown parallelograms, with best fits obtained at the centres. The infliction rates are calculated using an adult survival s = 0.8 (———, centre at (x,y) = (0.132, 0.0296)) and s = 0.9 (··········, centre at (x,y) = (0.132, 0.0181)).

allelogram in an x-y plot (Fig. 3). The parallelogram is determined by C_{1W} and C_{AD} alone, owing to the relatively large standard error of C_{IM}.

Lead pellet distribution in the wounded birds

Wounded common eiders carried 1-7 lead pellets; 1W birds carried on average 2.2 pellets (SD = 1.4, N = 35), which is significantly more than birds older than one year (average 1.7, SD = 1.1, N = 161, t = 2.13, df = 194, P = 0.03). For comparison, a sample of eiders killed during the normal hunt (obtained from local hunters in Nuuk) contained 1-42 pellets (average 9.7; SD = 8.5, N = 30).

The X-ray photographs of birds (N = 229) analysed at the local hospital allowed identification of different lead pellet sizes. Among the 92 wounded common eiders in this subsample, five (5.4%) carried lead pellets of different sizes, indicating that they had been inflicted more than once. Undoubtedly, of course, multiple inflictions will apply to more birds, but with same-size pellets. During dissections, 28 pellets were extracted (mean size of 3.2 mm in diameter, SD = 0.3, range: 2.7-3.8); all of these were lead shot as used in Greenland, not steel shot, which has been mandatory for waterfowl hunting in Canada (including Nunavut) since 1999.

Among 191 wounded common eiders the approximate position of the lead pellets in the carcass could be recorded (see Fig. 2). Since most birds carried more than one pellet, each bird may contribute to several of the following categories: lead pellets were carried in a) the limbs (54 birds with lead shot in a wing or leg/thigh), b) the head/bill (31 birds, one of them had an old, healed wound of a shot into the brain), c) neck (30 birds), d) rump/tail (10), and e) body (128, one of them with a pellet encapsulated at the surface of the heart). Apart from the 'lucky' exceptions of shot into the heart or brain, most retrieved pellets were found just under the skin or in the body fat depots. In two instances the pellets were found in the gizzard, but in one case a fresh wound in the gizzard verified that the pellet was shot into the bird; in the other case (a king eider) the pellet may have been ingested as grit.

Discussion

Our study revealed high proportions of lead carriers of both eider species wintering in southwest Greenland. The proportions of adult common eiders being carriers (see Table 1) are within the ranges observed in other studies, including the proportion recorded for live birds X-rayed at colonies in Nunavut (24%; Barrow & Hicklin 2004) where most of the birds wintering in Greenland return to breed. The highest share recorded in our study was 35.6% (AD, mid-winter), which is similar to the 34% recorded for adult common eiders in Denmark (Noer et al. 1999) where the sizes of the annual bag (100,000) as well as the wintering population (~ 500,000) are comparable to those in southwest Greenland (Asferg 2002, Meltofte & Fjeldså 2002).

For king eiders our sample of AD includes 24 birds (of which 8% were carriers) from an offshore bank area (10-60 km from the coast and > 55 km from the nearest settlement) where the highest densities of king eiders are known to winter (Mosbech & Johnson 1999, Merkel et al. 2002), and which is out of reach for most hunters. If the king eiders winter in the same area in successive winters they would accumulate fewer pellets than common eiders in the coastal zone near towns.

The observed proportions of carriers provide minimum estimates only of the frequency of infliction in the study population for a number of reasons: A proportion of birds are wounded more than once, but this is 'hidden' in the sample of carriers apart from the few cases where different pellet sizes can be identified (in our study 5.4%). In addition, some shot pass through the birds (if hit in the neck or feet) especially if hunters use relatively large lead shot, causing wounded birds to be classified as non-carriers at X-ray inspections. Finally, the sampling only includes birds that survive to become 'carriers' in the next season, and a still unknown number of birds are wounded and die without being recorded by the hunter or identified in studies such as ours. In a study of eider infliction in Denmark researchers made an effort to collect such heavily wounded eiders that would hug the coastline instead of flying off, referred to as 'divers', and found that 71% of these birds carried embedded lead shot, twice as many as flying eiders sampled using large lead pellets (Noer et al. 1999). The fact that the wounded 1W birds in our study on average contained more pellets (mean 2.2) than adults (mean 1.7), despite the adults' longer time to accumulate pellets from multiple inflictions, suggests that the most heavily burdened 1W birds would be gone before entering the IM age class. This would cause our effective infliction rate, x, for 1W birds to bee too high (i.e. the 13% 1W birds wounded would be subject to more than 'normal' age-dependent mortality, so a smaller proportion would enter the next age class as pellet carriers), and the rate for older birds, y, would be too low. Finally, the calculations are based on the assumption that once the non-lethally wounded birds have recovered, their survival rates are the same as non-carriers; if carrying a lead pellet would induce any long-term change in the AD survival rate, it will further contribute to underestimating the annual infliction rates of IM and AD.

The stepwise reduced logistic regression model confirmed a highly significant effect of age class on the risk of being a carrier, and suggested, although not significantly, that coastal eiders were more prone to being inflicted than birds from the fjord habitat. It appears that the adults wintering in the fjords, as well as king eiders wintering on offshore banks, are sufficiently sedentary to experience less hunting, despite the birds' annual movements through the coastal zone with its higher hunting pressure. Although foraging conditions may be suboptimal in the fjords (F. Merkel, unpubl. data), the lower hunting pressure may be adequate compensation for a group of the adults to uphold the segregation during successive winters. While the proportion of pellet carriers differed between coast and fjord birds, the regional differences (South Greenland vs the Nuuk area) were not significant, suggesting that eiders face a similar hunting pressure along the coastline. However, our sample is small, and there is a need for further studies of possible regional differences.

We had expected the proportion of carriers among 1W to increase during the winter, but in 1W as well as in AD birds the proportion was highest in mid-winter (see Table 1). This observation may have several causes. First, the sampling in different habitats was uneven during the winter, with fjord birds making up a larger proportion of the total sample in late winter than in early and mid-winter. Secondly, especially for the 1W birds that were wounded the same winter they were studied, post-wounding mortality may contribute to the observed decreased proportion of pellet carries (and affect infliction rates x and y, as mentioned above). To a small extent this could also be the case for IM and AD birds.

None of the pellets found in the birds were steel shot, which is now almost exclusively used by hunters in the main 'source area' of the eiders, Baffin Island and Hudson Strait in Nunavut (M. Mallory, Canadian Wildlife Service (CWS), pers. comm.), suggesting that the wounding takes place mainly in Greenland. The eider hunt in Nunavut is moderate compared to the Greenland hunt; Gilchrist et al. (2001) cite the Nunavut Wildlife Management Board for about 2,400 adult eiders being killed mainly in an early spring hunt. With such a low hunting pressure very few of the adults moving to their wintering grounds in Greenland would carry embedded shot from Canadian hunters. The autumn hunt in the main 'source area' is very limited (M. Mallory, CWS, pers. comm.), so almost no juvenile (1W) birds will arrive to Greenland with embedded shot.

We constructed a simple model to assess the wounding rate of adults. The estimates can be improved if better survival parameters can be identified, but at present, little appears to be gained by refining the model, even though it may be questioned whether survival and infliction rates are equal for immatures and adults. If our proportion of inflicted 1W birds, x, overestimates the number of pellet carriers surviving to enter the next age class because newly hit and fatally wounded birds were included in the sample (which was not checked in this study), it would lead to an underestimate of the infliction rate for older birds. It may be noted that the infliction rate for first-year birds, x, divided by the infliction rate for older birds, y, should constitute an estimate of the vulnerability to hunting of first-year birds relative to older birds, assuming that the number of wounded birds relative to the number of shot birds is independent of age. This relative vulnerability amounts to 4.47 for $s = 0.8$ in our model.

According to our model, the 29% adults carrying pellets in our study resulted from the wounding of ca 13% of 1W birds, and subsequent annual infliction rates of 2-3% for birds > 1 year old (IM and AD). If we assume (based on the standard demographic parameters) that roughly 35% of the 463,000 common eiders estimated to winter in southwest Greenland (Merkel et al. 2002) are 1W birds, 13% are immatures, and 52% are adults (fourth winter and older), it would mean that each winter roughly 30,000 eiders would become new carriers of embedded shot (21,000 juveniles, 1,200-1,800 immatures and 4,800-7,300 adults). These crude estimates rely on the assumption that the proportion of wounded eiders is roughly similar across the wintering area in southwest

Greenland, an assumption supported by the fact that we did not find significant differences in the proportion of wounded birds between the main survey area around Nuuk and South Greenland. However, data are limited, and our study is only a first assessment of infliction rates of eiders wintering in Greenland, and further studies are needed to clarify regional and annual variation in infliction rates.

The infliction of many thousands of eiders annually has direct management implications. Non-lethal injuries may have a negative population effect since a large share of these birds may suffer from reduced body condition for a period after the wounding incident (Merkel et al. in press, Van Dyke 1981). In severe winters, infliction is likely to cause the wounded birds to die due to inadequate body reserves, implying that the wounded birds should in some years be considered additional to the officially recorded hunters' bag. Furthermore, as the size of nutrient reserves affects reproductive output (see details and references in the introduction), infliction may reduce breeding success. Using our estimates of adults wounded, up to 3,600 adult females annually might be unable to breed, equal to the loss of one very large Canadian colony or approximately equal to the breeding population in all 106 colonies (~ 4,100 breeding pairs) in the central part of West Greenland (Merkel 2004b). Hence, the demography of the populations wintering in southwest Greenland is influenced by a possible unrecorded mortality in some years as well as by reduced reproduction, factors that are important when modelling sustainable harvest levels (see Gilchrist et al. 2001). Details in hunting methods, e.g. shooting distance, type of hunting platform, weather, hunters' marksmanship, and weapons and ammunition, influence the likelihood of inflictions during eider hunt (Noer et al. 1999). In a Danish study of the outcome of experienced eider hunters' shooting in a controlled experiment (shooting within 35 m only), 31% of all cartridges fired missed the target birds; and among the remaining 'hits', 56% killed the birds right away, 9% wounded the eiders lightly (probably making the birds pellet carriers), and 35% severely wounded the birds, many of which (73%) could later be retrieved through intensive searching (Noer et al. 1999). If these results from eider hunting under ideal and controlled conditions would also be applicable to the Greenlandic hunt, then the official bag statistics would only record up to 81% of all eiders hit, and the total number of inflictions annually would be half of the figures found in our study. There is a need for studies of the practical behaviour of eider hunters in Greenland to identify possible ways to reduce infliction rates during the seabird hunt in Greenland.

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