Research Article

Effect of Embedded Lead Shot on Body Condition of Common Eiders

FLEMMING R. MERKEL,[1,2] *Greenland Institute of Natural Resources, 3900, Nuuk, Greenland*

KNUD FALK, *Greenland Institute of Natural Resources, 3900, Nuuk, Greenland*

SARAH E. JAMIESON, *University of New Brunswick, Fredericton, NB E3B 6E1, Canada*

Abstract

*During waterfowl hunting a large number of birds are shot but not instantly killed. Some will die within a few days as a direct consequence of heavy injuries, whereas another proportion is only lightly injured and will survive for an extended period of time although their survival may still be affected. We predicted that embedded body shot (when not instantly lethal) will cause reduced body condition among common eiders (*Somateria mollissima*), as we assumed such birds to be physical disadvantaged (e.g., as to mobility and foraging) from their injuries. Among birds collected during 3 winters (2000–2002) by Inuit hunters and fishermen in Nuuk, southwest Greenland, we X-rayed and dissected 762 common eiders to extract information about embedded lead shot and body condition. After adjusting for structural body size, year and date of sampling, habitat, and sampling method, we found that embedded lead shot had a significant effect on juvenile body condition. Wounded juvenile birds carried on average 19% less fat than unwounded juveniles. In accordance with a priori predictions, we did not detect an impact of wounding on the body condition of immature and adult birds. For most of these older birds, the shooting incidence took place >1 year before they were collected, and the insignificant test results indicated the absence of a long-term effect on body condition once birds survived the initial effect of wounding. For juvenile birds, the wounding effect most likely added to other causes of mortality; however, additional knowledge about natural mortality is required to estimate the net consequence on population dynamic.* (JOURNAL OF WILDLIFE MANAGEMENT 70(6):1644–1649; 2006)

Key words

Arctic, body condition, condition bias, embedded lead shot, northern common eider, sea duck, Somateria mollissima borealis, *West Greenland.*

Apart from the direct mortality caused by hunting, hunting has a number of undesirable side effects that include disturbance (Madsen and Fox 1995), lead poisoning caused by the ingestion of spent shot pellets (Scheuhammer and Norris 1995), animals that are killed but not retrieved, and animals that die within a few days as a direct consequence of heavy injuries (Newton 1998). Another proportion of animals survives the injuries for an extended period of time and carries the lead pellets as embedded shot. Surveys of eiders at Canadian colonies suggest that up to approximately 50% of the adult females return to their breeding ground carrying embedded shot (Goudie et al. 2000). Depending on the extent of injury, shot pellet carriers may be expected to experience a reduced ability to move and forage for a period of time, and hence body condition might be reduced. Normally, eiders forage during daytime (Goudie et al. 2000), and the short Arctic winter days limit the available time for foraging. In midwinter, it may be difficult for inflicted birds to maintain adequate body-fat storage, and hence they are likely to experience reduced survival (Fournier and Hines 1994, Robertson and Gilchrist 1998). If nonlethal inflictions affect body condition over the winter, then reproductive success may also be at stake (Oosterhuis and van Dijk 2002). In waterfowl, body condition was positively correlated with various aspects of breeding performance (e.g., Ankney and MacInnes 1978, Pattenden and Boag 1989, Ebbinge and Spaans 1995, Blums et al. 1997). In 2 studies, birds carrying embedded shot had a lower annual survival rate than noncarriers (Madsen and Noer 1996, Tavecchia et al. 2001). In both cases, however, it is unknown whether low survival among wounded birds coincided with poor body condition.

We focus on the winter population of northern common eiders in southwest Greenland. This population had an estimated 460,000 birds that originated from breeding areas in eastern Canada and western Greenland (Merkel et al. 2002, Lyngs 2003). Based on official bag records (raw figures reported by the hunters), it is estimated that at least 57,000 common eiders are killed annually in West Greenland (Greenland Home Rule Department of Hunting and Fishing, unpublished data). Any additional side effect of hunting induced by inflictions could add to the total mortality of common eiders in West Greenland. We analyzed winter body condition in relation to embedded body shot. Based on dissections of birds retrieved mainly as bycatch in fishing nets, we used estimates of total carcass lipids (TCL) to compare body condition between lead pellet carriers and noncarriers, as determined by X-ray examination. We hypothesized the following: 1) that birds with embedded shot pellets would show a poorer body condition because of likely physical consequences of being wounded, 2) that wounded birds would be more likely to suffer from consequences of nonlethal shot in the period immediately after the infliction, and 3) that once the wounds were healed

[1] *E-mail: fme@dmu.dk or flme@natur.gl*
[2] *Present address: National Environmental Research Institute, Department of Arctic Environment, DK-4000 Roskilde, Denmark.*

and the pellets embedded the effects might be negligible. For this reason, we analyzed body condition according to age: juveniles, immature birds, and adults.

Study Area

Our study area included the coastal zone and the fjord system surrounding Nuuk (45.3°N, 60.7°W), the capital city of Greenland (Fig. 1). This marine environment was part of the Greenland open water area, which is internationally important as winter quarter for seabirds, mainly from Arctic Canada, Greenland, and Svalbard (Boertmann et al. 2004). The Nuuk study area constituted key wintering areas for king eiders (*Somateria spectabilis*) and common eiders, with estimated numbers of 11,507 and 56,735 birds, respectively (Merkel et al. 2002). The municipality of Nuuk was inhabited by approximately 14,000 people, of which 2,486 persons were licensed as recreational hunters and 132 as commercial hunters. During fall, winter, and spring these hunters bagged on average 11,579 $\pm$ 1,071 (SE) eiders (both species; Greenland Home Rule Department of Hunting and Fishing, unpublished data). Common eiders were confined to coastal waters and the innermost fjord system (Merkel et al. 2002). Typically, eider hunting occurred at the coastal zone within a range of 30 km from the city (Merkel 2004). Until 2002, the hunting season was open from 1 October to 31 May.

Methods

Collections, X-rays and Dissections

Among eiders collected from November until May during 3 winters (2000–2002) in Nuuk, we X-rayed and dissected 762 common eiders. Birds were either retrieved from fishnets (mainly lumpsucker nets) where they were unintentionally caught as by-catch (86%) or were killed (4%) in collisions with ship lanterns (i.e., strong lights used by ships in winter to navigate). A small sample was shot (10%) as part of the traditional hunt; for the purpose of our study the birds were killed with large lead pellets (buckshots or similar), which are distinctly larger (diam: 5.2 or 6.0 mm) than shots normally used in bird hunting (diam: 2.7–3.9 mm) in Greenland (Falk et al. 2006), and thereby identifiable during X-ray inspections from older embedded shot.

We examined all birds for embedded lead pellets by either passing them (592 birds) through an airport security check X-ray device at Nuuk Airport (Schlumburger Controlix 2E) with parallel color and black-and-white monitors connected or by taking high resolution X-ray photographs (35 $\times$ 40 cm) at the local hospital in Nuuk (170 birds). We applied the first method to most drowned birds, and we used the latter method 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, we inspected a sample of 10 birds with lead pellets by both methods.

We aged ducks by plumage and length of the bursa of Fabricius (Baker 1993, Mather and Esler 1999) and in

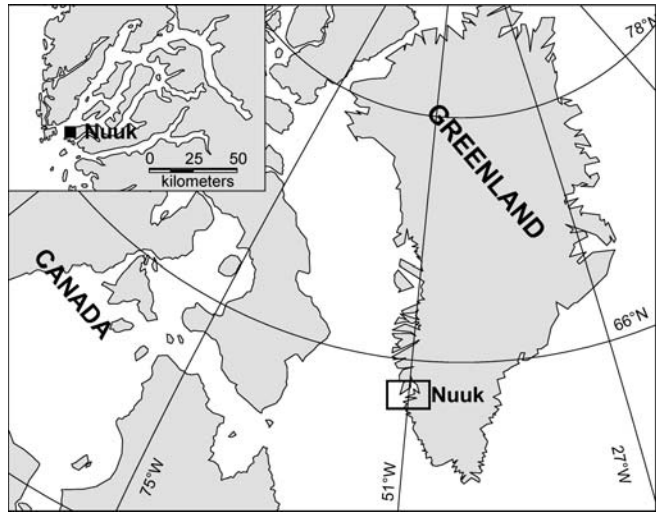

Figure 1. Geographical overview showing the winter sampling area (small box) for common eider around Nuuk in Southwest Greenland, 2000–2002.

females by oviduct condition; we sexed ducks by syrinx morphology (Beer 1963). We classified birds in adult plumage as adults if they had no bursae and in females if they had a thick convoluted oviduct; otherwise we classified them as immature. Hence, we distinguish between first-winter birds (juveniles), immature birds (second- and third-winter), and adults. We measured head–bill length and tarsus-bone length to the nearest 0.1 mm using calipers. We measured flattened-wing length (WING) with a wing board and curved-keel length with a flexible ruler, both to the nearest mm. We recorded the total body mass (BM) to the nearest gram using an electronic scale and subsequently corrected for the degree of plumage wetness; we obtained the correction figures of the amount of water retained within the feathers of drowned birds by weighing dried feathers from a sample of plucked birds ($n = 92$). We dissected the abdominal fat pad (ABFAT) and the right side femoral fat pad (LGFAT) and weighed them to the nearest 0.1 gram.

Standardization and Data Analyses

We defined body condition as TCL, and we obtained estimates of TCL from the following equation:

$$\begin{aligned} TCL &= -246.84 + 0.04BM \\ &= 6.14ABFAT + 13.50LGFAT + 0.90WING \end{aligned}$$

This equation explained 93% of the variation in TCL (Jamieson 2003) according to a total carcass composition analysis of 92 common eiders (18 juv F, 28 second-year or older F, 15 juv M, 31 second-year or older M) and stepwise backwards multiple regressions that were based on 12 independent variables (including age and sex).

To test for effects of embedded shot on body condition we used analyses of covariance (ANCOVAs). We log-transformed the dependent variable (TCL) to meet the assumptions of normality (using the Andersen–Darling test) and homogeneity of variances (using Bartlett's test). Initially, we considered 7 independent factors as having

Table 1. ANCOVA test results concerning effects (∝ = 0.05) of structural body size (PC_1), age,[a] and wounding (yes or no) on common eider body condition (TCL_{ST})[b] after stepwise removal of highly insignificant sources of variation. Birds were collected during winters 2000–2002 in Southwest Greenland (Nuuk).

Dependent variable	Sources of variation	df	MS[c]	*F*	*P*
Body condition (TCL_{ST})	PC_1	1	0.681	37.11	0.000
	Age[a]	2	1.113	60.60	0.000
	Wound	1	0.045	2.45	0.118
	Age•Wound	2	0.075	4.08	0.017
	Error	722	0.018		
	Total	728			

[a] Juveniles, immatures, or adults.
[b] TCL_{ST} = standardized and log-transformed Total Carcass Lipids estimates.
[c] MS = mean squared deviation from the mean.

potential influence on body condition: age, sex, wound (yes or no), habitat (coast or fjord), year, Julian date of sampling, and sampling method. As a first step, we disregarded sex based on a previous year-by-year, multifactor ANCOVA that showed that there were no significant differences between the amount of lipid stored by males and females and that sex did not interact significantly with any other variable (Jamieson 2003). Subsequently, we standardized the dependent variable (*log*[TCL]) to eliminate potential variance from year, date, habitat, and sampling method. We compared body condition at the sample level; for each sample of birds (collected at a particular date and location, with the same sampling method) we compared the body condition of each individual bird to (subtracted from) the sample mean, returning either a positive or a negative value (sample residuals). Thus, within each sample, we quantified whether the body condition of a wounded or unwounded bird was superior or inferior (and how much) to the average bird in the sample. We pooled samples ahead of the residual procedure if they consisted of <15 birds, were collected <10 days apart with the same method, and were from the same habitat. Afterwards, some samples still consisted of only few birds (<6), and we excluded these along with samples that did not include wounded birds. The resulting material consisted of 39 samples of unequal size, totalling 729 birds. The final ANCOVA included age and wound as independent fixed factors, a covariate for structural body size (PC_1), and body condition (standardized *log*[TCL] scores) as the dependent variable. We used the generalized linear model procedure to allow an unbalanced design. Consequently, we used least square means for multiple comparisons with the Tukey–Kramer test (at the 0.05 significance level) that also accounted for unequal sample size (Day and Quinn 1989, Zar 1999). We derived PC_1 scores from principal component analyses based on the length of head–bill, tarsus bone, and keel. The variables had an equal factor loading (0.56–0.60) on the first principal component (PC_1) and explained 72% of the total variance. We included the covariate because of a weak, but highly significant, correlation between PC_1 and TCL (Pearson, $r = 0.20$, $P < 0.001$). When expressing mean body condition of wounded and unwounded age classes as TCL (in grams) we adjusted for structural size (PC_1). Regression of TCL on PC_1 scores yielded the equation $TCL = 188.0 + 10.7\ PC_1$ ($r^2 = 0.042$, $P < 0.001$), and we calculated the adjusted values (TCL_A) as $TCL_A = TCL - 10.7\ PC_1$.

Results

Among the 729 common eiders included in the ANCOVA, 396 were adult, 114 were immature, and 219 were juvenile birds. Among these 29%, 18%, and 15%, respectively, were embedded with lead shot. Males and females were equally burdened ($G_{adj} = 0.26$, df = 1, $P > 0.05$). Embedded birds carried 1–7 pellets, and juveniles carried on average significantly more pellets (2.2 ± 1.4 [SD]) than birds older than 1 yr (1.7 ± 1.1 [SD], $t = 2.13$, df = 194, $P = 0.03$). For detailed information regarding shotgun pellet loads, pellet distribution, and infliction rates of eiders wintering in southwest Greenland see Falk et al. (2006).

For the analysis on body condition, we initially included 2-way and 3-way interaction terms in the model, between PC_1 and the age and wound factor, to ensure that there were no conflicting interactions between the covariate and the fixed factors. This assumption was met in all cases. The final ANCOVA (Table 1) showed that structural body size (PC_1) had a significant effect on common eider body condition, as larger birds had larger total fat deposits. Adjusted for body size, age still explained a large and significant proportion of the variation in body condition, whereas wound, as a main effect, was only significant at the 0.12 level. Because a significant interaction existed between age and wound, we explored the effect of wounding by post hoc mean comparison between these 6 groups (Fig. 2). Both wounded and unwounded adults had a significantly better body condition than younger age groups. However, we could not detect a difference in body condition between wounded and unwounded adults. This was also the case for immature birds. In contrast, juvenile wounded birds were significantly leaner than unwounded juveniles (Fig. 2). Expressed as total carcass lipids (TCL_A) unwounded juveniles carried on average 19% more fat (approx. 24.0 g) than wounded birds of the same age. Otherwise, immature and juvenile unwounded birds were equal in body condition.

Within 2 10-day sampling periods, a small number of TCL_A estimates were available for drowned and hunted birds collected at the same location. In both instances mean TCL_A were practically identical for drowned and hunted birds (179.4 ± 20.0 [SE] vs. 179.4 ± 30.0 and 176.2 ± 15.0 vs. 178.9 ± 7.4, df = 14 and 14, $t = 0.00$ and 0.08, $P = 1.00$ and 0.94, respectively), indicating that body condition was not biased as a result of different sampling methods.

Discussion

Impact of Embedded Shot Pellets on Body Condition

A critical assumption for the conclusion that juvenile wounded birds were leaner than unwounded birds as a consequence of previous wounding incidences is that they

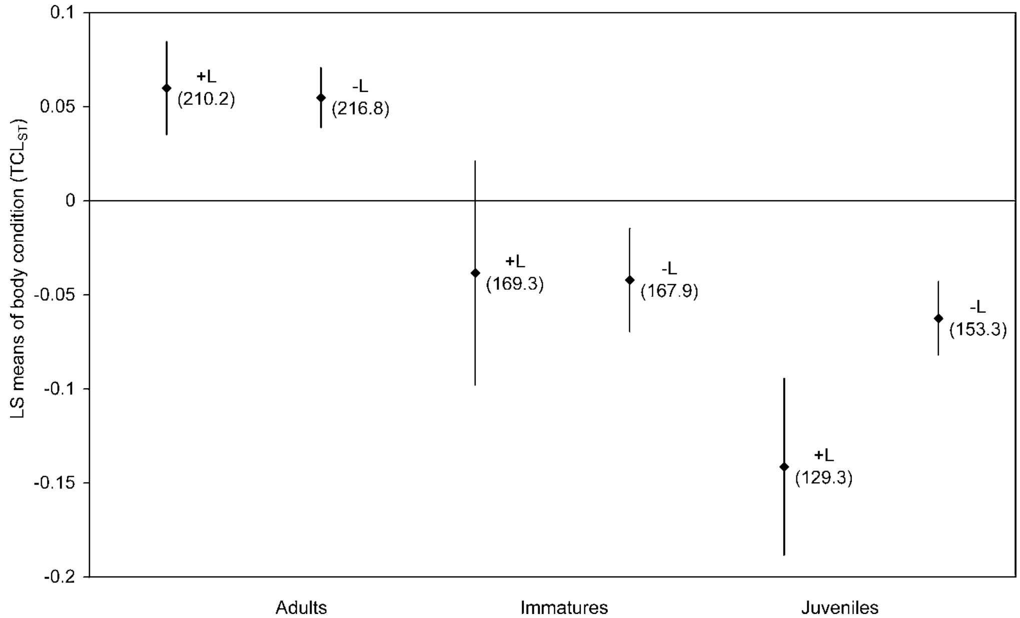

Figure 2. Comparison intervals (95%) by the Tukey–Kramer method for the least squares (LS) means of body condition (TCL_{ST}) in relation to age and embedded lead shot for common eiders collected in southwest Greenland (Nuuk) 2000–2002. Means whose intervals do not overlap are significantly different ($P < 0.05$). Numbers in brackets show raw TCL means corrected for structural body size. +L = embedded with lead shot, and -L = no lead.

were true representatives of the target population when they became wounded. This would not be the case if poor condition birds were more vulnerable to hunting (and thus wounding) than were birds in superior condition. This is referred to as the condition bias hypothesis (Weatherhead and Greenwood 1981). In our case, such a scenario implies that juvenile wounded birds were lean from the beginning (before they were wounded). Obviously, being wounded would not have improved the situation, but wounding would not have been the ultimate reason for the poor condition state. However, condition bias is usually related to hunting that involves decoys that lure food-stressed individuals within gunshot range (e.g., Weatherhead and Greenwood 1981, Greenwood et al. 1986, Reinecke and Shaiffer 1988, Sheeley and Smith 1989, Dufour et al. 1993, McCracken et al. 2000). Decoys are never used for seabird hunting in Greenland. Usually hunters practice jump shooting, where they rely on fast-moving boats and their knowledge about typical eider flight behavior (e.g., that they seldom cross land during flight and usually take off in the headwind). Some hunters also practice a traditional hunting technique, pass shooting, where hunters position themselves at known flight corridors between roosting and feeding areas (Müller 1906). Pass shooting and jump shooting were used as the random sampling method in several studies testing for condition bias, and were found to sample birds in superior condition compared to decoy-trapped birds (Greenwood et al. 1986, Sheeley and Smith 1989, McCracken et al. 2000). Furthermore, our data indicated that condition bias was not an issue in our study. For birds collected at the same location and within the same 10-day sampling period, we found no difference in body condition between drowned and hunted birds. Thus, we believe that the wounded birds collected did represent the target population at the time of wounding, and we conclude that wounded juvenile birds were significantly leaner than unwounded juveniles as a direct consequence of being wounded earlier in the hunting season.

The fact that no effect of wounding could be detected for immature and adult birds is probably related to age. Eiders are long-lived, and high frequencies of pellet carriers among adult birds are not necessarily evidence that pellets are inflicted upon large numbers of eiders within any single hunting season (Noer and Madsen 1996). For juvenile birds in our study area, the infliction rate (proportion of age class becoming lead carriers each year) was estimated to 13.2%, whereas it was only estimated between 2% and 3% per year for immature and adult birds (Falk et al. 2006). This rather large difference makes sense knowing that juveniles make up approximately 60–70% of the winter harvest of common eiders in Nuuk (Frich and Falk 1997, Merkel 2004). Thus, for most immature and adult birds, the wounding incidence took place one or several years before they were collected for this study, so only birds that were able to recover from the injuries would still be alive. The fact that wounded juvenile birds carried significantly more pellets than older wounded birds (mean 2.2 vs. 1.7, respectively) indicated that some wounded juveniles (i.e., those carrying the largest number of pellets) died before entering the older age classes. Based on the estimated infliction rate for older birds (2–3%), we were likely to sample only a small number of recently wounded old birds (i.e., wounded and sampled within the same hunting season). Since we were not able to distinguish between recent inflictions and old ones, a potential effect on recently wounded birds could easily go undetected for immature and adult birds. Thus, when testing for an effect of wounding on immature and adult body condition we mainly addressed whether there had been a long-term effect on body condition on eiders inflicted one or several years previously. Apparently, this was not the case.

Several studies have shown that ducks and geese in better body condition have a higher annual survival probability than do birds in poor condition (Haramis et al. 1986, Conroy et al. 1989, Hohman et al. 1995, Christensen 1999, Schmutz and Ely 1999). This was probably also the case for unwounded juvenile eiders from out study area. Based on information that 1 g of fat will release 9.284 kcal (Parker and Holm 1990), and according to a daily energy expenditure estimate of 442 kcal for eiders (Drent et al. 1979), an unwounded juvenile eider carrying on average 153.3 g of fat (Fig. 2) would be able to stave off starvation for 3.22 days by metabolizing available fat. This is a period 12–13 hours longer than for the average wounded juvenile bird (2.72 d). Under severe winter conditions this may be a critical reduction in the buffering capacity for birds in the low end of the range, and many of the inflicted juveniles should probably be added to the official bag records. Consequently, there is a possibility that sustainable take of northern common eiders is less than previously modeled (Gilchrist et al. 2001, Canadian Wildlife Service, unpublished report). Because we argued that wounding in our study area is inflicted upon a condition-unbiased subsample of the juvenile eiders, we presume that any related mortality effect is partly or entirely additive to nonhunting mortality, instead of compensatory (Newton 1998).

In addition, the effect of wounding on juvenile birds might have been slightly underestimated because of uncertainties about when birds were wounded. If birds were wounded early in the hunting season (Oct–Nov), but not collected until late in the season (Apr–May), they may have had sufficient time to recover from the wounding incidence. For immature and adult birds, the exact time of wounding is not equally important. Since most birds were wounded one or several years before they were collected for this study, we expect that all survivors had sufficient time to recover from the initial effect of wounding. For all age classes, there is a possibility that some birds detected as noncarriers may also have been wounded, if all pellets passed through the bird. The probability of this happening is likely small but unknown.

Management Implications

To accurately estimate the net consequence on population dynamic we need additional knowledge about natural mortality among juvenile eiders in southwest Greenland (e.g., only if natural loss is density dependent can hunting be offset by reduced natural loss [Newton 1998]). We recommend future modeling of the harvest impact to deal with the possibility that, for more heavily injured eiders, the proportion of inflicted birds is even higher than we detected. The most heavily injured birds are sometimes referred to as divers or cripples (Noer et al. 1999, Tavecchia et al. 2001), and these are birds that are not likely to turn up when collecting random samples, as in our study, because of a quick death (within hours or few days) or abnormal behavior. For common eiders wintering in Denmark, 71% of the birds collected as divers carried embedded shot pellets, which was twice as high as in the target population (Noer et al. 1999).

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