Effects of duckling body condition on hunting vulnerability in juvenile and immature common eiders Somateria mollissima

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Condition related pre-breeding hunting vulnerability in the common eider *Somateria mollissima*, i.e. the relationship between body condition attained as a duckling and the probability of being shot, was analysed from recoveries of hunter-retrieved birds ringed in the Stavns Fjord colony in Denmark during 1991-1995. Mean duckling cohort condition showed significant variation between years, but the proportions of birds retrieved during the first three seasons were similar (4.9% ± 1.4 SD). The proportion of birds retrieved by hunters declined from 3.9% in the first year to 0.64% and 0.38% in the second and third year, respectively. A condition bias was found in first-year retrieved birds in the cohorts with the highest and poorest mean condition, but not in the cohorts of intermediate condition. In accordance with *a priori* predictions regarding condition related non-hunting mortality during the period between marking and the opening of the hunting season, the direction of the bias was negative (hunters retrieved poor individuals compared to cohort mean) in the cohort of high mean condition, and positive (hunters retrieved good individuals compared to cohort mean) in the cohort of poor mean condition. Despite significant variation in cohort condition, the duckling condition of individuals retrieved during their first season from the cohorts of high and poor mean condition was comparable. The condition of first-year retrieved birds was not significantly different from the condition of birds retrieved during their second and third year, when all years were pooled. As there is a significant positive relationship within cohorts between duckling condition and recruitment of (female) eiders, the present results suggest, 1) that hunting vulnerability in the eider is related to a specific (poor) level of body condition attained prior to fledging, and 2) that hunting tends to remove the poorest individuals present at the time when the hunting season opens.

Key words: body condition, duckling, eider, hunting, Somateria mollissima

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Weatherhead & Greenwood (1981) suggested that decoying attracted birds in poor rather than high condition due to a stronger response to decoys by food-stressed birds. Weatherhead & Ankney (1984) subsequently stressed that because most waterfowl hunters use decoys, food-stressed individuals should be more vulnerable to hunting, resulting in a disproportionately high hunting mortality of individuals in poor condition. Thus, under the condition bias hypothesis (*sensu* Weatherhead & Greenwood 1981), analyses of band-recovery data from hunting potentially rely on a biased subsample of a biased sample of banded birds, which may have important implications for estimates of population parameters such as hunting mortality

(Weatherhead & Ankney 1984, 1985, Burnham & Nichols 1985).

Several studies support the hypothesis that hunters of waterfowl tend to retrieve a condition biased segment of a population. Poorer condition or lower body mass in hunter retrieved ducks than in 'researcher collected' or in hunter retrieved ducks from marked populations has been shown for mallards *Anas platyrhynchos* (Greenwood, Clark & Weatherhead 1986, Hepp, Blohm, Reynolds, Hines & Nichols 1986, Reinecke & Shaiffer 1988, Dufour, Ankney & Weatherhead 1993, Heitmeyer, Fredrickson & Humburg 1993), canvasbacks *Aythya valisineria*, redheads *A. americana* (Bain 1980) and American black ducks *Anas rubripes* (Conroy, Constanzo & Stotts 1989). However, Sheeley & Smith (1989) found no indications of a condition bias among hunter-retrieved and 'researcher collected' northern pintails *Anas acuta*.

For juvenile birds, previous studies of the relationship between hunting vulnerability and body condition have been based on condition estimates obtained just prior to or during the hunting season (Greenwood, Clark & Weatherhead 1986, Conroy, Constanzo & Stotts 1989, Dufour, Ankney & Weatherhead 1993). Consequently, these studies focus on autumn populations and do not consider condition related non-hunting mortality between the time of hatching and the time of marking. Hence, the relative importance of hunting in specific cohorts, e.g. the effect of condition related hunting vulnerability on overall cohort survival in years of different growth and condition characteristics is presently unknown.

The aim of the present study is to analyse hunting vulnerability in juvenile common eiders *Somateria mollissima* from a Danish colony in relation to their body condition at pre-fledging. I compare duckling condition of: 1) individuals retrieved by hunters in relation to mean cohort condition in five different cohorts, 2) individuals retrieved from different cohorts and 3) individuals retrieved in their first season with individuals retrieved in their second and third season, respectively.

Using body condition measures from pre-fledged ducklings, I hypothesised that the direction of condition biases of hunter-retrieved birds would be year-specific. I predicted that the duckling condition of retrieved birds should be better than the cohort mean in years of poor condition and below the mean in years of good condition. This pattern was expected due to effects of condition related non-hunting mortality in the period from marking to the opening of the hunting season. Eiders experience substantial juvenile mortality (Milne 1974, Coulson 1984, Swennen 1983), and mean cohort condition varies significantly between years (Christensen 1999). Thus, the proportion of eider ducklings susceptible to condition related non-hunting mortality before the hunting season is expected to be higher in years of poor mean cohort condition than in years of good cohort condition. Consequently, only very few ducklings of poor condition from poor condition cohorts are probably alive when the hunting season opens (Fig. 1). Increased post-fledging mortality of light-weight juveniles has been reported in studies of several species of birds (Patterson, Dunnet & Goodbody 1988, Owen & Black 1989, Sedinger, Flint & Lindberg 1995, van der Jeugd & Larsson 1998), and several studies have detected a threshold weight, above which survival is stable (Tinbergen & Boerlijst 1990, Magrath 1991, Brinkhof, Cavé & Perdeck 1997, van der Jeugd & Larsson 1998).

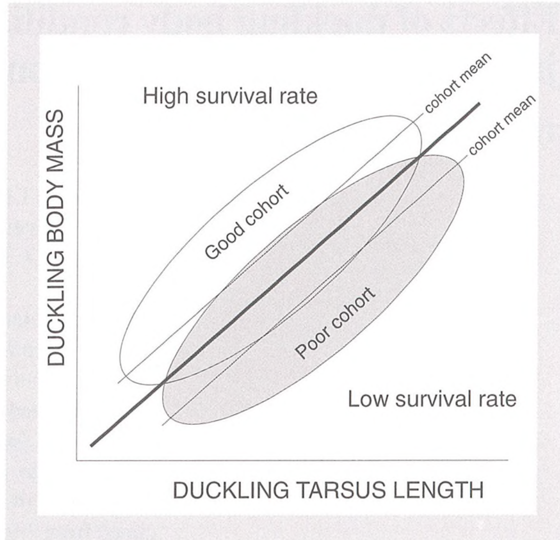

Figure 1. Hypothesised threshold model of the relationship between mean duckling body condition (expressed as the body mass/size relationship) and survival during the first months of life. The model predicts that the proportion of a year cohort that has a high probability of surviving (above the bold line) is larger and will posses much more variation in body condition in a year when the duckling cohort attains a good mean condition, than in a year when the duckling cohort attains a poor condition. The model assumes a relatively fixed threshold.

Study area and methods

Handling and marking of ducklings

During 1991-1995 eider ducklings were captured in the Stavns Fjord colony in Denmark (55°54'N; 11°39'E), by driving them into funnel traps. To avoid a condition bias in relation to the sampling method, all ducklings present in the searched area were captured on each drive. Mass drives were performed on 28-29 May and 17-18 June

1991, 9-12 June 1992, 11-13 June 1993, 24 June 1994 and 15-16 June 1995, producing annual captures of 331, 720, 343, 215 and 433 ducklings, respectively. At capture, ducklings ranged from a few days to approximately 5-6 weeks of age. Body mass (to the nearest 5 g) and tarsus length (to the nearest 0.1 mm of the total length of the bent leg including the intertarsal joints) were measured on all ducklings. To minimise measurement errors, the same person measured tarsus length on all ducklings in all years. All ducklings were ringed with a steel leg band, but were not sexed at the time of marking.

Data analyses

Estimates of mean body condition in each cohort was obtained from linear regression applied to plots of duckling weight on tarsus length (35-60 mm) cubed. Using this size interval, small ducklings which probably lose mass during the first days when using up the yolk sack (see Swennen 1989) were excluded, as were the largest ducklings in which tarsal growth probably decline when approaching adult size (mean tarsus length of breeding females: 62.4 mm ± 2.02 S.E.; (N = 75)). Given that duckling body mass shows less variation at the time of hatching than at the time of fledging (see Fig. 2), the slopes obtained from regression of body mass on tarsus length was assumed to be a reliable expression, or an index, of mean cohort condition.

The present analyses focus on the effects of differences in body condition and do not take into account variation in growth rates existing between cohorts and individual ducklings. Thus, a cohort in good condition, expressed by a large slope value, may, theoretically, be a cohort possessing slow tarsal growth in relation to body mass gain. But, as variation in condition between early and late hatched ducklings, including those from different catching locations, have been shown to be much less than the variation between cohorts (Christensen in press), no bias arising from the difference in time of capture was expected as long as all size classes were substantially represented. However, because the late time of capture in 1994 (24 June) strongly influenced the size distribution of captured ducklings (few small and many large ducklings), probably resulting in a biased slope-value (see Fig. 2), the data from the 1994 cohort were omitted from the analyses of variation in condition between cohorts. Homogeneity tests of slopes (slope values), ANCOVA (slope levels; SAS Institute Inc.1988) and sequential Bonferroni-test (Sokal & Rohlf 1995) were used to test for differences in condition between cohorts and differences between birds shot.

From plots of body mass on tarsus length of each cohort (including all ducklings), numbers of individuals placed above and below the regression lines of those retrieved during their first season and those retrieved during their second or third season, were counted. To test the assumption that the condition of hunter-killed individuals was conditionally biased in relation to mean cohort condition, one-tailed sign-tests (~binomial test when $N < 12$; ~t-test when $N > 12$; Sokal & Rohlf 1981) were applied to retrieved birds. Frequency analyses were performed using the SAS statistical package (χ^2-test, Fisher's exact test; SAS Institute Inc. 1988).

Analyses based on recoveries of marked individuals in relation to condition generally suffer from small sample sizes and thus provide statistical tests of low power (Dufour, Ankney & Weatherhead 1993, see also Krementz, Hines, Corr & Owen 1989). In the present study, small sample sizes of hunter-retrieved birds resulted from segregation of data into separate cohorts and into season of retrieval. Given the small sample sizes, the level of significance was set at 0.10 in analyses including retrieved birds only. In analyses of overall cohort differences and in frequency analyses, the level of significance was set at 0.05.

Results

Proportion retrieved

Of 2,042 eiders ringed as ducklings, 105 were subsequently retrieved and voluntarily reported by hunters. Of these, 85 were retrieved during their first season after ringing whereas 20 were retrieved during their second or third season after ringing. Hunters retrieved similar proportions of the marked eider ducklings from each

Table 1. Number of marked and first-year hunter-retrieved ducklings from five seasons (1991-1995) in relation to size at capture expressed as tarsus length. P-values of Fisher's exact tests are shown.

	1991		1992		1993		1994		1995	
Tarsus length (mm)	Marked	Shot	Marked	Shot	Marked	Shot	Marked	Shot	Marked	Shot
<40	105	2	91	2	117	6	1	0	22	0
40-50	109	7	288	21	112	2	20	2	116	4
>50	117	7	341	18	114	2	194	6	295	6
	P = 0.21		P = 0.16		P = 0.34		P = 0.20		P = 0.69	

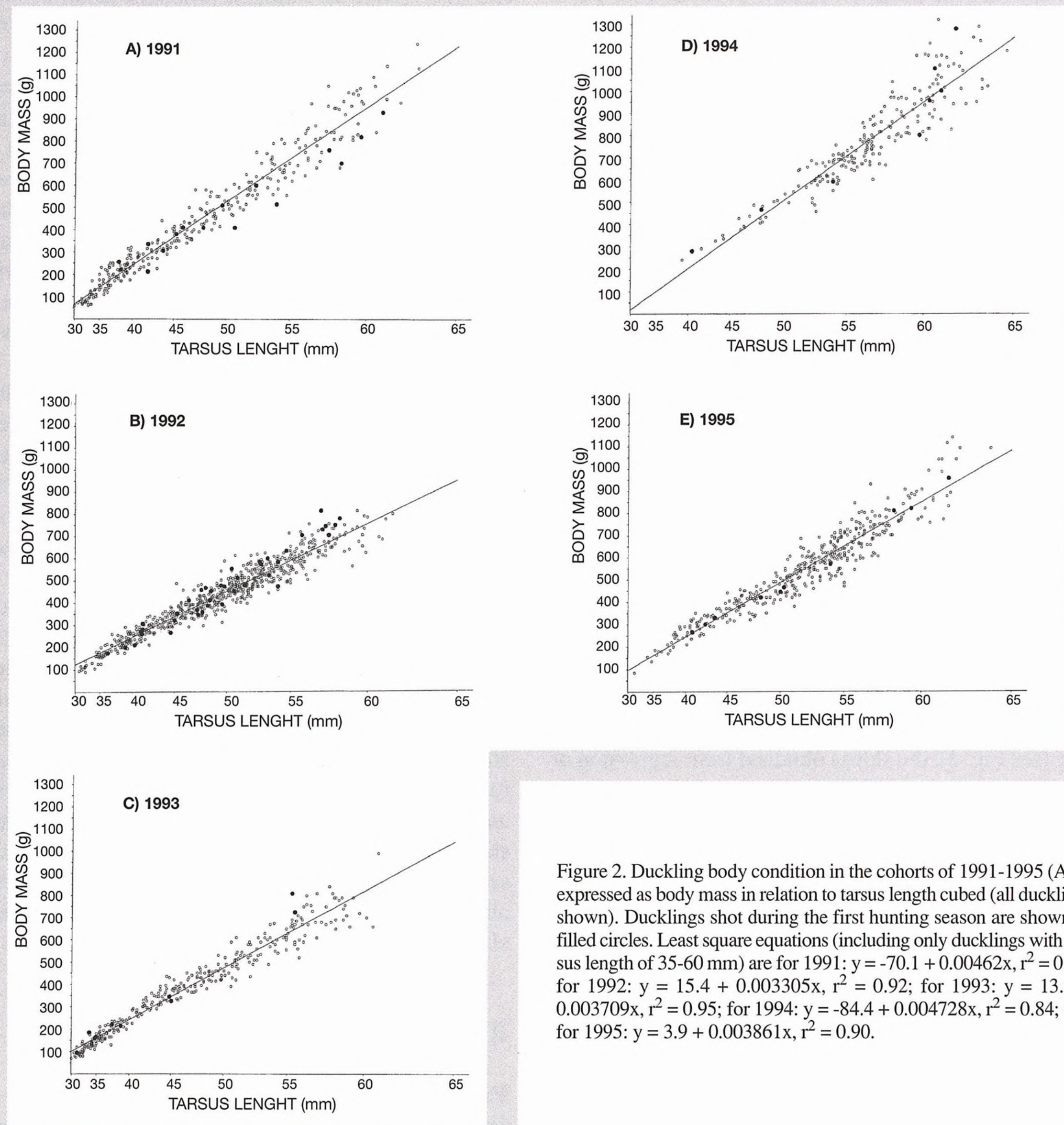

Figure 2. Duckling body condition in the cohorts of 1991-1995 (A-E) expressed as body mass in relation to tarsus length cubed (all ducklings shown). Ducklings shot during the first hunting season are shown as filled circles. Least square equations (including only ducklings with tarsus length of 35-60 mm) are for 1991: $y = -70.1 + 0.00462x$, $r^2 = 0.94$; for 1992: $y = 15.4 + 0.003305x$, $r^2 = 0.92$; for 1993: $y = 13.6 + 0.003709x$, $r^2 = 0.95$; for 1994: $y = -84.4 + 0.004728x$, $r^2 = 0.84$; and for 1995: $y = 3.9 + 0.003861x$, $r^2 = 0.90$.

cohort during the first three hunting seasons ($\chi^2 = 8.17$, df = 4, P > 0.05) averaging 4.9% ± 1.4 (SD). On average 3.9% ± 1.38 (SD) were retrieved during the first hunting season and 0.64% ± 0.54 (SD) and 0.38% ± 0.41 (SD) during the second and third seasons, respectively.

To assess whether size at capture, or time of hatching, affected the individuals' probability of surviving until the opening of the hunting season and of being retrieved, the number of birds retrieved in their first season was related to the numbers marked within size intervals of three different tarsus lengths (< 40 mm, 40-50 mm and >50 mm) at the time of capture. The proportions shot did not vary among size intervals within years (Table 1). Consequently, the probability of surviving and being retrieved by hunters was independent of the size at capture.

Cohort condition and hunting vulnerability

Mean duckling body condition differed significantly between cohorts. Pair-wise comparison revealed significant differences in the slopes or in the slope levels

Table 2. Number of ducklings with a body condition above and below mean cohort condition in the cohorts of 1991-1995 for individuals retrieved during their first season. Test statistics are shown (s = sign test; b = binomial test) for each cohort and pooled data.

		Year of marking					
Shot in:		1991	1992	1993	1994	1995	Sum
First season	Above	5	25	7	4	5	46
	Below	11	16	3	4	5	39
	t-values	1.5	1.41				0.76
	P-values	0.067[s]	0.079[s]	0.172[b]	0.637[b]	0.623[b]	0.224[s]

between all cohorts (test of homogeneity of slopes: 1991 > 1995: t = 8.13, df = 669, P < 0.001; 1995 > 1993: t = 1.79, df = 695, P > 0.05; 1993 > 1992: t = 6.26, df = 974, P < 0.001; P-values were Bonferroni corrected; ANCOVA (1993 vs 1995): t = 2.36, df = 693, P < 0.05; the 1994 cohort was excluded due to the late time of capture).

The duckling condition of individuals shot during their first season deviated significantly from the cohort mean in the cohorts with the best and poorest mean condition, i.e. 1991 and 1992, respectively (Fig. 2 and Table 2). The proportions of retrieved individuals below the cohort mean in 1991 (68.8%; N = 16) and 1992 (39.0%; N = 41) was significantly different ($\chi^2 = 4.08$, df = 1, P < 0.05), showing a 'negative' condition bias in the 1991 cohort and a 'positive' condition bias in the 1992 cohort. Sign-test analyses of the condition of first year retrieved birds from the 1993, 1994 and 1995 cohorts revealed no deviation from cohort means (see Fig. 2 and Table 2).

When the condition of first year retrieved individuals from the 1991 and 1992 cohorts were compared by regression, no significant differences in mean duckling condition were found (test of homogeneity of slopes: t = -0.64, df = 53, P > 0.10; ANCOVA: t = 0.95, df = 54, P > 0.10). Thus, despite significant differences in mean cohort condition, individuals from these two cohorts, which were shot during their first hunting season, had comparable duckling condition, i.e. sizes and weights.

Comparison of mean duckling condition of all individuals shot during their first season (least square equation: $y = -28.3 + 0.00391x$; $r^2 = 0.93$; N = 75) and of the condition of all individuals shot during their second and third season (least square equation: $y = -26.8 + 0.00405x$; $r^2 = 0.93$; N = 17), showed no significant difference (test of homogeneity of slopes: t = -0.45, df = 88, P > 0.10; ANCOVA: t = 1.30, P > 0.10). Thus, the duckling condition of individuals retrieved during their first season was comparable to that of individuals retrieved during their second and third season.

Discussion

I found a condition bias in eiders retrieved by hunters in their first year in two out of five cohorts, though the condition bias was only evident in the cohorts with the best and poorest mean duckling condition, but not in cohorts of intermediate condition. In accordance with the *a prior* predictions, eiders retrieved from the cohort of the highest mean duckling condition were in poor condition relative to the cohort mean, whereas eiders retrieved from the cohort of poor mean duckling condition were in good condition relative to the cohort mean. This finding is consistent with the results of other studies showing a negative relationship between body mass or condition and hunting vulnerability (Greenwood, Clark & Weatherhead 1986, Hepp, Blohm, Reynolds, Hines & Nichols 1986, Reinecke & Shaiffer 1988, Conroy, Constanzo & Stotts 1989, Dufour, Ankney & Weatherhead 1993). Despite significant differences in mean cohort duckling condition, birds retrieved in their first year from both the highest and poorest cohorts had comparable body condition as ducklings. Likewise, comparable duckling condition was found in birds retrieved during their first year and birds retrieved during their second and third year.

In the cohort of poorest mean condition, however, the relationship between condition and hunting vulnerability tended to be positive, as the duckling condition of most of the birds retrieved was above the cohort mean. This result was as expected when assuming that a larger proportion of ducklings with a condition below the cohort mean may have died before the opening of the hunting season in poor years than in good years. Van der Jeugd & Larsson (1998) found that in the barnacle goose *Branta leucopsis* survival rates increased between the post-fledging period and the subsequent period after the first winter in cohorts of low mean body weight, whereas no change in survival rates occurred in cohorts of high mean body condition. Their results suggest that light-weight juveniles in cohorts of low mean body weights suffered higher non-hunting mortality rates during their first month of life than light-weight juveniles from cohorts of higher mean weight.

That duckling condition of birds retrieved during their first year from both the highest and poorest cohorts was similar, despite significant differences in mean cohort condition, supports the suggestion that a higher rate of condition related non-hunting mortality occurred before the opening of the hunting season among the poorest ducklings in the poorest cohort.

Evidence of condition related pre-fledging and post-fledging mortality in the eider is scarce, although small eider ducklings, weakened by poor foraging conditions, are more vulnerable to predation by gulls (Swennen 1989). Low body weight and small tarsus length in juvenile birds have, however, been shown to be significantly related to low post-fledging survival in several bird studies (e.g. Owen & Black 1989, Schmutz 1993, Brinkhof, Cavé & Perdeck 1997, Sedinger, Flint & Lindberg 1995). In the Stavns Fjord colony, the proportion of marked ducklings surviving to first breeding at the age of three, was not affected by differences in cohort conditions (ca 18% being recruited from the 1991, 1992 and 1993 cohorts; Christensen 1999), and individuals surviving until breeding age had an average duckling condition above the cohort mean, irrespective of their size at capture (1991-1993 cohorts; Christensen 1999). It is therefore assumed that condition related non-hunting mortality in both the pre- and post-fledging periods and among early and late hatched ducklings did not act differently, but in general removed ducklings in poor condition within cohorts.

The tendency of a positive condition bias in the poor year does, however, not contradict the evidence of a negative condition bias in hunter-retrieved waterfowl measured in the autumn, but indicates that relatively poor individuals retrieved by hunters do not necessarily represent the poorest fraction of a present year class. Birds from poor cohorts retrieved in their first year may actually be potential breeders, as hunters seemingly harvested from the part of the cohort which had the highest probability of recruitment (see Christensen 1999). Because condition related non-hunting mortality will tend to reduce the variability in cohort condition in poor cohorts at the opening of the hunting season more strongly than in cohorts of good condition, the difference in condition between hunter-shot and surviving individuals will be smaller in years of positive condition bias (poor cohorts) than in years of negative condition bias (good cohorts). Thus, annual variation in mean cohort condition may result in variable magnitudes of condition biases when condition is measured in autumn populations, as has also been reported from previous studies (e.g. Greenwood, Clark & Weatherhead 1986, Conroy, Constanzo & Stotts 1989).

In general, juvenile ducks are more vulnerable to hunting than adults (e.g. Krementz, Conroy, Hines & Percival 1987, Nichols, Williams & Caithness 1990, Caithness, Williams & Nichols 1991), but evidence of a relationship between juvenile autumn body mass or condition and hunting vulnerability has been less clear than for adult ducks. Conroy, Constanzo & Stotts (1989) found a significant negative relationship between condition and probability of being shot in adults, but not in juvenile American black ducks. Greenwood, Clark & Weatherhead (1986) found lower body mass in hunter-shot than in randomly collected juvenile mallards only in one of three samples. They also found that the difference for juvenile samples (both sexes) was less significant than for adult samples. Dufour, Ankney & Weatherhead (1993) found, however, a negative relationship between juvenile mallard condition and subsequent recovery probability (by hunters) in four comparisons (by year and sex).

It is likely, that the lack of significance at the 5% level in my study may have been influenced by the small sample size, representing a recovery rate of only 2.3-5.7%. In fact, addition of only one individual of below and above mean condition to the 1991 and 1992 cohort, respectively, makes the test significant at the 5% level. Therefore, the significant deviation ($P < 0.10$) from the cohort mean condition in individuals retrieved by hunters in these cohorts is believed to reflect that condition biases exist in years of extreme (high and low) mean cohort condition, but not in years of intermediate cohort condition.

The fact that the mean duckling condition of hunter-retrieved birds from the first season and second/third seasons were comparable supports the existence of a positive relationship between the absolute condition attained as ducklings and the probability of survival and recruitment (see Christensen 1999). This result also indicates, that hunting of young and immature birds present at the opening of the hunting season, mainly affects the poorest individuals. Considering that hunting with decoys, which potentially attract individuals in poor condition more frequently than individuals in good condition, is not the dominant type of eider hunting in Denmark (ca 25% of hunters use decoys; Madsen, Asferg, Clausager & Noer 1996), the relationship between duckling condition and hunting vulnerability may not be related to a specific type of hunting, but may prove to be a more general pattern. Because the rates of recruitment to the Stavns Fjord population were unaffected by the observed variation in cohort condition, whereas individual recruitment was positively related to duckling condition, I argue that the probability of surviving from hatching to breeding age was related to the relative rather than the absolute condition attained as a duckling (Christensen 1999). Hunting vulnerability and mortality, on the other hand, seem to be more related to the absolute condition attained as a duckling, as hunters seem to retrieve the poorest individuals within specific cohorts present at the time when the hunting season opens.

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