Between-year variations in sex/age ratio bias in hunter wings of Eurasian Wigeon (*Anas penelope*) compared to field samples

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We compared age and sex ratios amongst Eurasian Wigeon (*Anas penelope*) derived from Danish field observations and hunter-based shot samples throughout an entire winter in two consecutive years. In the middle period of both winters, sex ratios did not differ significantly between the two samples. However, first-year males were more than three times more likely to be represented than adult males in the hunter sample compared to field samples and were 4–22 times overrepresented in the hunting sample at the beginning of both seasons. We found between and within-season differences in bias, confirming the need to account for such bias and its temporal variation when using the results of wing surveys to model population parameters. However, given the relative uniformity in bias in the middle part of both seasons, these results confirm that age ratios amongst wings voluntarily contributed by hunters provide an invaluable long term measure of reproductive success in dabbling duck populations as long as we can account for such bias.

1. Introduction

Modelling the population dynamics of huntable species requires an understanding of the relative contribution of annual reproductive success to year-on-year changes in overall abundance. This is especially important if we are ever to be able to demonstrate that levels of hunting are sustainable, in the sense that present hunting does not jeopardise continued favourable conservation status, as enshrined in international legislation such as the EU Birds Directive (Directive 2009/147/EC). Annual survival rates and reproductive success are therefore basic parameters to feed into models of the dynamics of closed quarry populations, yet for very few species do we have reliable annual as-

sessments of either of these parameters, despite the increasing urgency to derive these. The proportions of female and juvenile (1st winter) birds amongst hunter samples of Eurasian Wigeon (*Anas penelope*, hereafter Wigeon) wings contributed voluntarily by hunters declined during 1982–2010 (Christensen & Fox 2014), which could cause for concern if these ratios reflect those in the population as a whole. However, we need to be certain that these changes do not reflect changes in between-year hunting bias as has been established within a single season (Fox *et al.* 2015). In this analysis, we attempted to assess the degree of within and between season sex and age bias in the hunting kill relative to the population as a whole by comparing changes in ratios in the voluntary con-

tribution of wings from hunters with simultaneous field determinations within and between two hunting seasons in Denmark (see Mitchell *et al.* 2008, Clausen *et al.* 2013, Fox *et al.* 2015).

2. Methods

First winter Wigeon males exhibit grey forewings, whereas adult males have conspicuous white forewing coloration that is relatively easily and consistently determined in the field and the hand to generate age ratios amongst the male portion of the population (especially from mid-September onwards, Boyd *et al.* 1975). Test comparisons between observers in the field resulted in ratios within 1.3–3.6% of each other (Fox *et al.* 2015); earlier analysis suggested no consistent variation between age and sex ratios with respect to flock size, habitat type or geographical region (Clausen *et al.* 2013) and no significant difference between field ratios and samples of Wigeon caught for ringing (Mitchell *et al.* 2008). Hence, we combined all of our field observations (139 separate flocks, mean flock size 75.65 ± 6.4 SE range 12–447 birds from 47 sites in 2013/14 and 122 determinations, mean flock size 95.77 ± 7.29, 15–570 birds from 34 different sites in 2014/15) from all sites where we gathered age- and ratio data on Wigeon into one analysis using date as the continuous sampling variable for the two years of the study 2013/14 and 2014/15. We generated fortnightly proportions of males and females, adults and juveniles amongst wings submitted by hunters throughout the hunting seasons (1 September–31 January) of 2013/14 ($n = 1,674$) and 2014/15 ($n = 1,268$).

From both data sources, variations in the proportions of males amongst all birds (pM) and juveniles amongst males (pJ) were modelled as binomial outcomes using generalised linear models (GENMOD in SAS 6.1), based on a logit link function and binomial error distribution. The models were adjusted for variance inflation caused by over-dispersion of the residuals by taking the square root of their deviance divided by their degrees of freedom, using the DSCALE command in SAS (SAS 2008), where this ratio exceeded unity (Gelman & Hill 2007). We constructed models separately for the field and wing surveys and for the two samples combined.

Main effects of sampling date were modelled as third order polynomials. Interactive effects between date and sample type or date and season were modelled as second order polynomials ($x \times$ date $+ x \times$ date^2, where x denotes sample type or season). Comparisons between models were made on the basis of quasi-likelihood adjusted AIC values (QAIC, see Burnham & Anderson 2002 for full explanation).

From the best selected candidate models, we then generated a date specific hunter bias (HB$_d \pm$ 95% CI) from the differences in date-specific ($_d$) predictions (p_d) between the two logistic regression functions (HB$_d$ = logit(p_d)$_{fields}$–logit(p_d)$_{wings}$). The relative difference in probability of any category (e.g. females relative to males, juvenile males relative to adult males) is exp ($-$HB$_d$), which includes where HB$_d = 0$ (i.e. equal probability of the category being sampled) and HB$_d = -1$ which indicates the age or sex class was sampled 2.72 times as often by hunters as expected from field samples. We generated 95% CI about HB$_d$ estimates by means of the LSMEANS option in SAS (see Fox *et al.* 2015).

3. Results

Male field ratios in both years were relatively constant throughout both winters from October onwards (Figs. 1a and 1b). In both seasons, male sex ratios were high and declined in September (because of the relatively delayed arrival of females and juveniles to Denmark). The best fit pM model incorporated interactions between date and sampling method and between date and season (Table 1). For most of the mid-season, there was no bias in the bag (Fig. 1c) but males tended to be under-represented at the start and end of the period, especially in 2014/15. In the field samples from both years, it was evident that a wave of juveniles passed through Denmark in both years during October, after which age ratios remained relatively stable until the end of both seasons (Figs. 2a and 2b). Significant interaction terms between date and sample type, date and season and sample type and season (Table 1) reflected the over-representation of pJ in the wing sample at the very start and end of the season when they were up to 22 times more likely to be sampled by hunters than
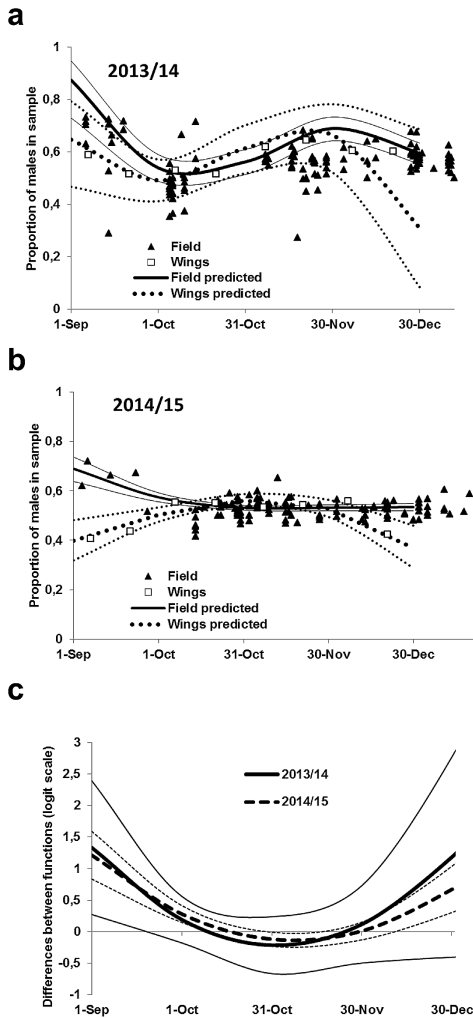
Fig. 1. Proportion of Wigeon males in wing samples from hunters (open squares) and field ratios (solid triangles) in Denmark, (a) September 2013–January 2014 and (b) September 2014–January 2015. Thick lines and dotted lines indicate fitted cubic logistic regression functions for each sample type, and thin lines indicate 95% confidence error bands. Wing samples from January were excluded because of small sample sizes. (c) Sampling bias functions for the years 2013/14 and 2014/15 estimated as the difference between the wing and field sex-ratio functions shown in (a) and (b) with 95% confidence bands.
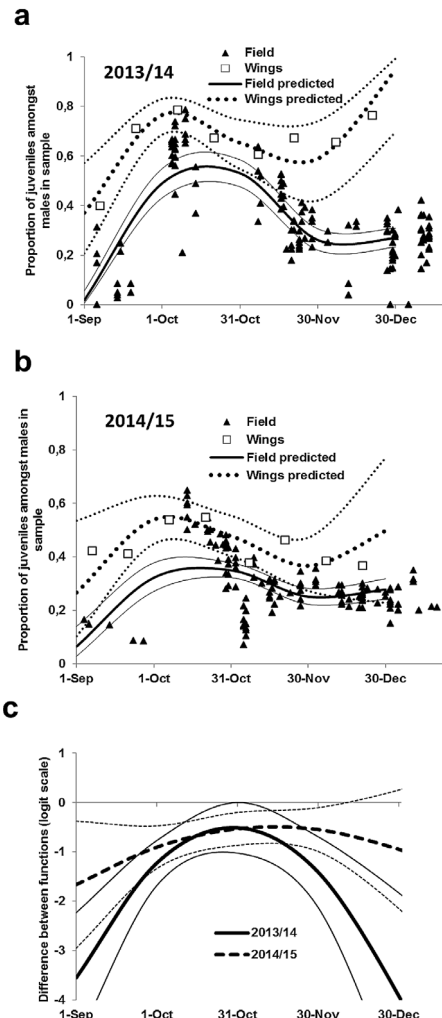
Fig. 2. Proportion of Wigeon males that were juveniles in wing samples from hunters (open squares) and field ratios (solid triangles) in Denmark, (a) September 2013–January 2014 and (b) September 2014–January 2015. Thick lines and dotted lines indicate fitted cubic logistic regression functions for each sample type, and thin lines indicate 95% confidence error bands. Wing samples from January were excluded because of small sample sizes. (c) Sampling bias functions for the years 2013/14 and 2014/15 estimated as the difference between the wing and field age-ratio functions shown in (a) and (b) with 95% confidence bands.

adults in 2013/14, and up to 6 times in 2014/15 when numbers of young were proportionately less in the autumn flight. Overall, first-year males were more than three times more likely to be represented than adult males in the hunter sample compared to field samples. However, in October and November, there were relatively little differences between years when juveniles were 1.2–2.3 times more likely to be represented in the wing survey compared to the field.

Table 1. Comparison of six candidate models comparing within and between year variation in proportions of males and proportions of juveniles amongst males in wing and field samples. Explanatory variables were D = Date; T = Type of data (wing/field) and S = hunting season, and k is number of estimated parameters. ΔQAIC values show differences in quasi-AIC relative to the best fit model and w_i the relative proportional support to each model. Values are shown in bold type for the parsimonious models.

Model structure	k	Proportion of males		Proportion of juveniles amongst males	
		ΔQAIC	w_i	ΔQAIC	w_i
D*T	7	64.54	0.00	86.09	0.00
D*T + S	8	8.36	0.01	38.54	0.00
D*T + D*S	10	**0.00**	**0.60**	3.52	0.09
D*T + S*T	9	9.39	0.01	26.19	0.00
D*T + D*S + S*T	11	1.99	0.22	**0.00**	**0.53**
D*T*S	13	2.53	0.17	0.63	0.38

4. Discussion

It is well known that moult migrant males, that have left the nesting areas very soon after the start of incubation, arrive first to wetlands along the flyway in autumn, including Denmark (Salomonsen 1968). This explains the 60–80% pM detected in field ratios in September, in advance of the arrival of breeding females and young of the year that arrive in very late September and early October (Figs. 1a and 1b). There follows a wave of first winter Wigeon which results in peaks in pJ in early to mid-October, falling through that month to stabilise through November, December and January (Figs. 2a and 2b). This pattern was consistent in both years, presumably the result of this pulse of birds passing westwards through Denmark to their ultimate wintering areas in the United Kingdom and the Netherlands (Bønløkke *et al*. 2006).

Although the wings pM deviated slightly from field pM in September and late December, there was no evidence of major sex bias in the kill relative to the field, especially in the middle part of the hunting season (Fig. 1c). In contrast, models showed significant within- and between season pJ differences amongst wings compared to field ratios, with young birds heavily over-represented in the wing samples compared to the field throughout both hunting seasons, but with signs of between year differences in these patterns (Fig. 2c). In both seasons, young birds were more over-represented in the wing surveys than the field, but during the peak period of migration through October these differed little between years, when juveniles were

1.6–2.7 times more likely to be represented in the hunting bag than in the field. However, in the early and late parts of the season, poor reproductive success in 2014 compared to that in 2013 resulted in lower over-representation of young in the hunting bag at the start and end in 2014 compared to the previous year. Wigeon age ratios in the autumn of 2013 (7.48 juveniles for every adult female) were the highest recorded in the wing surveys since 1991 (10.23 juveniles per adult female), whereas those in 2014 (2.64) were the second lowest since records began in 1982 (mean 5.36 ± 0.375, range 1.46–10.29 from 1982–2014 inclusive, unpublished data).

These results confirm that there is an age bias in the wing sample compared to the field ratios which suggests that hunting selects in some way for first winter birds, which does not appear to affect sex ratios in both surveys. The data from two hunting seasons show consistent overall changes in that bias through the season, but some between-season differences as well. In particular, inferences from age ratio data based on hunter shot samples of Wigeon collected very early or late in the hunting season (when the age ratio bias seems most pronounced and variable) should be avoided. This is likely because of the recognised difficulties in correctly discriminating all age and sex classes, especially in early September and the relatively small samples of wings later in the season when fewer Wigeon remain in Denmark to be shot. Although we cannot exclude systematic error in ageing and sexing, tests between observers sampling the same flocks suggest high repeatability (Fox *et*

al. 2015). Any bias is likely to inflate the proportion of young because of missed white forewing determinations on adult drakes, which may also be more likely to occur in September/October, although we believe that among experienced observers this source of error is minimal. For these reasons, we are still not in a position to fully calibrate the historical archive of age ratios in the wing samples of Wigeon that stretch back to 1982 in Denmark (e.g., Clausager 2004) to account for the effects of hunting bias. However, from the evidence presented here, we remain convinced that the ratio of first winter Wigeon in the wing surveys provide an invaluable source of historical reproductive success in those years. It is clearly important to take account for within- and between-year variation in demographic measures over a longer span of hunting seasons to calibrate bias in the hunted samples for age ratios. Nonetheless, we urge continued compilation of these data from Wigeon and other quarry duck species, not just from Denmark but from hunting states throughout their annual flyways, to enable the use of long runs of hunter wing sample data to improve the monitoring basis for understanding the population dynamics and management of such species.

Sukupuoli- ja ikäluokkien lukusuhteiden vertailu metsästyssaaliin ja maastohavaintojen välillä haapanalla

Työssä tarkastellaan mahdollista harhaa metsästyssaaliin (tanskalaisten metsästäjien toimittamat siipinäytteet) antamissa sukupuoli- ja ikäluokkien lukusuhteissa vertaamalla näitä maastolaskennoissa havaittuihin lukusuhteisiin kahtena metsästyskautena syyskuusta tammikuuhun. Kauden puolivälissä saaliista laskettu sukupuolten lukusuhde ei poikennut maastolaskennoissa havaitusta lukusuhteesta kumpanakaan vuotena. Maastolaskentoihin verrattuna, nuoria koiraita kuitenkin esiintyi saaliissa kolme kertaa runsaammin kuin vanhoja koiraita ja kauden alussa nuorten

koiraiden yliedustus oli jopa 4–22-kertainen. Saaliista laskettu ikäluokkien lukusuhteen harha vaihteli sekä metsästyskauden sisällä että kausien välillä. Koska harhan suuruus metsästyskauden puolivälissä oli samaa luokkaa kumpanakin vuotena, metsästyssaaliista saatavaa ikäluokkien lukusuhdetta voitaisiin käyttää puolisukeltajasorsilla lisääntymistuloksen mittarina. Tämä kuitenkin edellyttää, että saaliissa esiintyvän harhan suuruus tunnetaan ja otetaan laskelmissa huomioon.

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