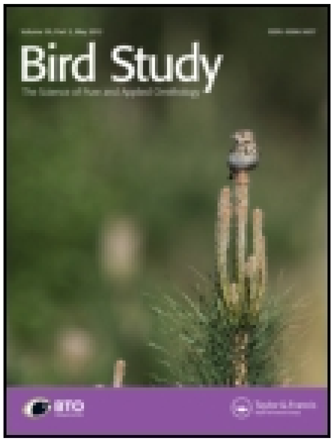

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Measuring neck collar loss of Pink-footed Geese Anser brachyrhynchus

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SHORT REPORT

Measuring neck collar loss of Pink-footed Geese *Anser brachyrhynchus*

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Capsule The ability to estimate mark loss of ringed animals is important to assess demographic parameters from mark-recapture studies correctly. Based on 23 years of neck collar recovery data from the Svalbard breeding population of Pink-footed Geese, we estimate an overall average annual loss rate of 3.2%. Neck collar loss was similar between males and females, and did not (based on currently available data) differ significantly between two types of collars used.

Ringing with plastic neck collars have become a widely used marking technique in waterbird ecology. Neck collars allow researchers to track the life history of individual birds (by continuous re-sightings of marked individuals). Tracking individuals is useful to studies of migration, survival, harvest, behaviour and population size (Pirkola & Kalinainen 1984, Nichols *et al.* 1992, Ganter & Madsen 2001, Alisauskas *et al.* 2009, Sanders & Trost 2013). While it is broadly acknowledged that collar loss can substantially bias the results of these studies by introducing false negatives in the encounter history of individual birds (Nelson *et al.* 1980, Conn *et al.* 2004), independent data to estimate retention rate of neck collars are very scarce. As a consequence, neck collar loss is often assumed to be negligible. However, to ensure confidence regarding the outcome of population studies using re-sightings of marked birds, quantitative estimates of collar loss are very important. This is particularly relevant in demographic studies because they often form the cornerstone of evidence-based management (Frederiksen *et al.* 2014). So far, very few studies report quantitative estimates of collar loss (see Nichols *et al.* 1992, Wiebe *et al.* 2000, Samuel *et al.* 2001), and none of them in a European context.

In this study we use 23 years of recovery data from the Svalbard breeding population of Pink-footed Geese *Anser brachyrhynchus* to derive estimates of collar loss. This population winters in Denmark, the Netherlands and Belgium and migrates via Norway in late spring to the Svalbard breeding areas (Madsen *et al.* 1999). This long-term ringing scheme started in the late 1980s and since 1990 individual birds have been fitted with neck collars at cannon-net captures in spring (Denmark) and round-ups of moulting family groups in summer (Svalbard). During 1990–2005 blue collars of the material Astralon were used, manufactured by Lindéns Industri & Affärsskyltar, Sweden. These collars were 44.5 mm high and 1.5 mm thick, with white engraving (3 digits) and engraving depth of 1 mm. During 2007–14 white collars of the material Gravoglas 2-Plex were used, manufactured by Pro-Touch Engraving, Canada. These collars were 43.5 mm high and 1.5 mm thick, with black engraving (3 digits) and engraving depth 1 mm. Both types of material are modified acrylic specified as flexible, break resistant and UV stable. All collars were carefully glued with Loctite® super glue and the collar diameter was adjusted to the size of the bird (width of the neck). The neck collars do not seem to have any long-term effect on the fitness of individual birds (Clausen & Madsen 2014).

Information on collar loss has been collected from 1992 to 2014 from either dead birds (shot by hunters or found dead) or recaptures of previously marked geese. We only used records where the presence or absence of a collar was definitely noted by the observer. These sources provided 111 recoveries of previously marked birds (83 with blue collars, 28 with

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white collars), of which 16 had lost their mark (12 blue collars, 4 white collars). Geese that had lost their collars were identified by identification of their metal rings. We observed no cases where the metal ring had been lost and the collar been retained. The probability of collar retention was modelled using a generalized linear model treating retention (whether the collar was present or not) as a binomially distributed response variable with a log link function. In the basic model, cumulative retention probability was modelled as a linear function of the number of years since the collar was added, implying constant loss rate. The intercept was set to 0 on the log scale (i.e. 1 on the real scale) to fix retention to 1 at the time of marking. In a step-up approach, we included further explanatory variables: a quadratic term to allow accelerating or decelerating loss rate, neck collar type to assess potential differences between blue and white collars from two different manufacturers and sex to investigate potential differences between males and females. The significance of additional terms was evaluated using χ^2 likelihood ratio tests, whereas the significance of the mean loss rate was evaluated with a z test (because this model had only one parameter, a χ^2 test was not possible). All models were fitted in R 3.0.2 (R Core Team 2013), and both raw data and model specifications are available in Supplementary Appendix 1.

The average annual retention rate was estimated at 0.968 (95% CI: 0.950–0.981), corresponding to an annual loss of 3.2% ($z = -4.0$, $P < 0.001$, Fig. 1). There was no support for a model with increasing loss rate with collar age ($\chi^2_1 = 0.8$, $P = 0.38$), indicating that the collars used were able to resist long-term wear over the period of this study. Neither neck collar type ($\chi^2_1 = 1.2$, $P = 0.27$) nor sex ($\chi^2_1 = 1.6$, $P = 0.20$) significantly influenced retention, but annual loss rate tended to be higher among males (4.1%, 95% CI: 1.7–6.5%) than among females (2.2%, 95% CI: 0.3–3.9%) and for white collars (5.4%, 95% CI: 0.0–10.6%) in comparison with blue collars (2.8%, 95% CI: 1.2–4.3%).

Other studies of waterbirds have found considerable variation in collar retention rate. Samuel *et al.* (2001) found annual retention rates between 0.756 and 0.958 for Lesser Snow Geese *Anser caerulescens caerulescens*, and Nichols *et al.* (1992) showed that retention rate varied greatly between sex and age classes in Tundra Swans *Cygnus columbianus* (adult males: 0.50, juveniles and females: 0.96). Among White-fronted Geese *Anser albifrons*, Wiebe *et al.* (2000) reported very high retention rates of 0.982 and 1.000 for males and females, respectively. In comparison with these findings, our estimate of 0.968 for Pink-footed Geese

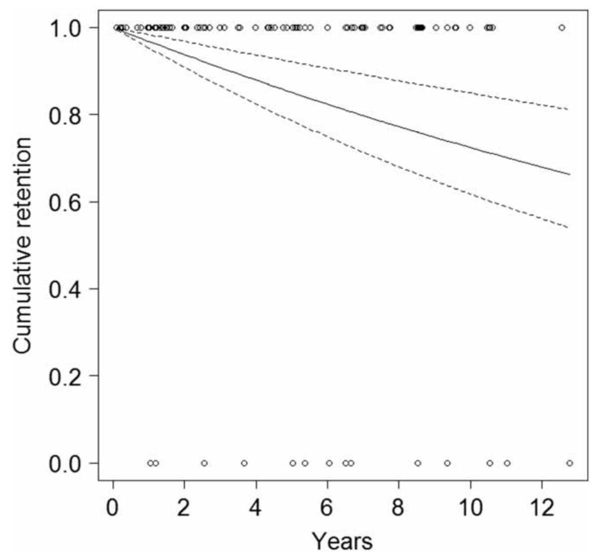

Figure 1. Predicted cumulative retention of neck collars among Pink-footed Geese as a function of years after marking. Dashed lines indicate the 95% confidence limits. The relationship represents the best supported model with constant loss rate and no effect of sex or type of neck collar. Symbols indicate birds reported with or without neck collars.

seems to be a reasonable mid-range result. While some studies have found clearly different retention rates between the two sexes (Nichols *et al.* 1992, Coluccy *et al.* 2002), others report similar loss rates for male and female geese (Zicus & Pace 1986). Although our current data do not indicate significant sex-specific retention rates among Pink-footed Geese, non-significance might be related to sample size. The tendency for higher loss rate among males suggested in some studies is also indicated here, with males having almost twice the probability of losing their collar as compared to females.

The causes of collar loss are difficult to verify, but may relate to a wide array of potential mechanisms such as aggressive behaviour, shotgun pellets causing cracks as well as plastic fatigue. There are currently no data available to clarify which of these mechanisms are most important, but it seems likely that the cumulative effects of such damage will have an impact on collar retention.

Retention rate of all colour marks and neck collars may be heavily influenced by mark type, material and procedures applied at the marking event. Wiebe *et al.* (2000) highlighted that durability of neck collars might differ widely as a result of differences in collar type and thickness, and showed that retention rates among Canada Geese *Branta canadensis* were highly dependent on the manufacturer used. Type and depth of engraving, collar size and attachment method (glue or solvent cement) can also affect longevity of collars and render generalizations difficult. No significant difference between the two types of collars used on Pink-footed Geese was found in this study, although loss rate was approximately twice as high for white collars as compared to blue collars. The non-significant result may partly be due to differences in sample size between the two collar types. White collars have only been used since 2007, and the number of recoveries from these birds is still relatively low. The wide associated confidence limits may mask real differences in retention that could become apparent as data accumulate. Besides the importance of different types of marks and attachment methods, retention rates are likely to be influenced by bird morphology and ecology (body size, vigilance behaviour, habitat use, migration patterns, etc.) that could trigger species-specific differences. As a consequence, knowledge of collar loss rates at the population level is vital to effectively estimate demographic parameters in mark-resight studies, because even minor biases will add up if used to predict future population size in, for example, population viability analyses or adaptive harvest management. Disregarding mark loss when estimating survival would result in underestimation of true survival, and in line with Conn *et al.* (2004), we recommend that mark loss should be specifically accounted for when estimating life-history traits of marked birds. In the case of Pink-footed Geese where mean annual survival is approx. 0.8 (Kéry *et al.* 2006), an underestimation of survival by 3% would correspond to a difference in mean expected life span of nearly one year (4.5 vs. 5.4 y).

Advanced models to precisely estimate survival and other demographic rates are increasingly used in ecological studies (Besbeas *et al.* 2005, Frederiksen *et al.* 2014). However, to fully utilize the potential of these models it is essential to identify and account for possible biases in available data, which may be more important than the choice of statistical approach. Among ornithological studies mark loss is an important issue, and systematically addressing this subject would greatly advance the field of avian ecology. Multi-state capture-mark-recapture models offer a useful framework for such analyses (Juillet *et al.* 2011), particularly if data on birds ringed only with metal rings exist to allow estimation of reporting probability of dead individuals without neck collars. Recent studies indicate that differentiation between sexes and types of markers may have to be incorporated in the analytical framework to give the full picture (Nichols *et al.* 1992, Wiebe *et al.* 2000, Coluccy *et al.* 2002), but analytical complexity can be minimized by consistency between captures (marking type, attachment method, etc.).

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SUPPLEMENTAL MATERIAL

Raw data and model specification can be accessed at 10.1080/00063657.2014.992858.

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