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ORIGINAL ARTICLE

Effects of neckbands on body condition of migratory geese

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Abstract Ringing and marking are widely used techniques in avian ecology to assist studies of migration, survival and behaviour, and often used to estimate population sizes. Only rarely, however, have the effects of these markings on bird viability been thoroughly tested. Using an abdominal profile index of marked geese and body mass of recaptured birds previously marked, this study investigated the effect of neckbands on body condition of Pink-footed Geese *Anser brachyrhynchus* at different temporal scales, and evaluated to what extent capture, handling and banding affected these birds on short, medium and longer terms. Our results indicated that body condition of geese were negatively affected in the days immediately succeeding capture, but that only a minor effect persisted on a seasonal scale. We found no support for a long-term effect of neckbands on the body mass of individual birds, indicating that the capture and handling event might be the main contributory cause to the transitory decline in body condition. Pink-footed Geese thus seemed to habituate almost completely to the presence of neckbands, and the effects on long-term body condition can be expected to be minor. However, neckbands might still influence important life-history traits such as reproduction and survival by means of, e.g., altering social interactions, increasing predation or interfering with mate acquisition.

Keywords Ringing · Abdominal profile · Capture–mark–recapture · Neck collars · Pink-footed Goose · *Anser brachyrhynchus*

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Zusammenfassung

Der Einfluss von Halsringen auf die Körperkondition ziehender Gänse

In der Ökologie der Vögel sind Beringung und Markierung vielfach genutzte Techniken bei der Erforschung des Vogelzuges sowie von Überlebensraten und Verhaltensweisen; außerdem werden sie oft zur Schätzung von Populationsgrößen eingesetzt. Trotzdem wird der Einfluss dieser Markierungen auf die Überlebensfähigkeit der Vögel nur selten sorgfältig überprüft. Mittels eines Abdominalprofil-Index markierter Gänse in Verbindung mit Körpermassedaten von zu einem früheren Zeitpunkt beringten Wiederfängen untersuchten wir in dieser Studie den Einfluss von Halsringen auf die Körperkondition von Kurzschnabelgänsen *Anser brachyrhynchus* über verschiedene Zeiträume und ermittelten, in welchem Ausmaß Fang, Bearbeitung und Beringung die Vögel kurz-, mittel- und langfristig beeinträchtigten. Unsere Ergebnisse weisen darauf hin, dass die Körperkondition der Gänse in den direkt auf den Fang folgenden Tagen negativ beeinflusst wurde, allerdings nur geringfügige Effekte die Saison über andauerten. Wir fanden keine Belege für einen Langzeiteffekt der Halsringe auf die Körpermasse einzelner Vögel, was dafür spricht, dass das Fang- und Bearbeitungsereignis die Hauptursache für die vorübergehende Abnahme der Körperkondition darstellen könnte. Kurzschnabelgänse scheinen sich somit fast vollständig an das Vorhandensein der Halsringe zu gewöhnen, und die langfristigen Auswirkungen auf die Körperkondition sind als gering anzunehmen. Allerdings könnten Halsringe dennoch wichtige biologische Größen wie zum Beispiel Reproduktion und Überlebensrate beeinflussen, indem sie beispielsweise soziale Interaktionen verändern, das Prädationsrisiko erhöhen oder in die Partnerwahl eingreifen.

Introduction

Capturing and marking animals is a widespread scientific approach to improve our understanding of species ecology and population dynamics (Sandercock 2006; Frederiksen et al. 2014). This practice has paved the way for assessments of population size, survival rates and migration, and is a prerequisite for the wide range of capture–mark–recapture (CMR) analyses increasingly used in population ecology (Schmidt et al. 2002; Fischhoff et al. 2007; Salewski et al. 2007; Geschke and Chilvers 2009). These approaches often assume that, from the point of capture, marked individuals act and behave similarly to non-marked individuals, but only rarely is this assumption thoroughly tested (Tuyttens et al. 2002; Juarez et al. 2011). However, individual performance may be affected by both handling stress during capture (e.g. changing hormone levels and reduced foraging opportunities) and subsequent effects of marking, that may potentially affect individual condition and survival by means of, e.g., increased grooming/preening activities, upset social signalling, elevated aggression levels, higher predation rates or reduced mobility. Clarifying to what extent these effects are expressed in marked natural populations, and understanding whether they are relatively transient or persist in longer terms is important to ensure reliable conclusions.

No other group of animals has been as intensively caught, handled and marked as birds. Ringing of migratory bird species with metal rings has long been a successful tool to describe longevity, flyway patterns and migratory movements (Bairlein 2001), and, more recently, advanced marking techniques has been used across many avian groups (Davis and Miller 1992; Osborne et al. 1997; McIntyre et al. 2009; Bowlin et al. 2010). The choice of marker is generally limited by body size (Fair et al. 2010), but in large-bodied conspicuous species such as waterfowl restrictions are few. Colour rings (e.g. Ebbinge et al. 1991), neckbands (e.g. Madsen et al. 2002) and satellite transmitters (e.g. Demers et al. 2003; Clausen et al. 2013) have thus all become increasingly more important tools in the field of waterbird ecology. While the development of new marking techniques has considerably improved the type and quality of data originating from ringing studies, the cost of carrying the associated devices has also increased. The size and weight of advanced markers have generally decreased in recent decades, but applying these devices often involves the use of additional attachments (elastic harnesses, plastic rings, glue, etc.) that prolong handling time and may entail further stress.

The use of neckbands (engraved colour plastic rings attached around the neck) has become a frequently used marking technique in goose and swan research across the world (Raveling et al. 1990; Nichols et al. 1992; Madsen et al. 2002). However, clarifying potential effects of neckbands on marked individuals, and how this might influence the data collected from these marking regimes, is still a largely unresolved issue. Early North American studies have failed to reach a clear consensus, and while some studies report no clear effects of ringing (Menu et al. 2000), others suggest negative impacts on clutch size (Reed et al. 2005) and survival (Castelli and Trost 1996). Although neckbands are widely used throughout Europe, no studies have investigated the effect on European flyway populations, and, in order to draw confident conclusions concerning the effect of neckbands on waterbird fitness, more studies are urgently needed. Moreover, potential impacts of neckbands are likely to be species-specific, and may vary greatly as a result of differences in body size, migration strategy, foraging technique, behaviour and social traits.

The effects of wearing neckbands may gradually fade due to habituation (Ely 1990; Guay and Mulder 2009; Legagneux et al. 2013), but might on the contrary also lead to long-term impairment as a result of cumulative impacts from lower energy intake, elevated energy expenditure or both. Reported effects of neckbands might therefore strongly depend on the temporal scale of analysis, and clarifying whether any negative effects are confined to a few days, a single season or a lifetime is of utmost importance.

Comprehensively assessing how capture and marking affect the viability of birds is often complicated by (1) small sample sizes because of relatively few marked birds, (2) infrequent recaptures to assess post-marking viability and (3) the lack of good fitness measures able to identify potential effects of handling and/or marking. In this study, we employ a 24-year dataset (1990–2013) of captures, re-sightings and fitness assessments from the Svalbard breeding population of Pink-footed Geese *Anser brachyrhynchus* to determine whether captures and neckbands may affect short-, medium- and long-term body condition of marked birds.

Methods

The focal species of this study was the Svalbard breeding population of Pink-footed Geese, which migrates via stopover sites in Norway to wintering grounds in Denmark, The Netherlands and Belgium. During spring, the geese concentrate in western Jutland, Denmark, and in April the population migrates to stopover sites in Trøndelag (mid-Norway) and Vesterålen (northern Norway) before the final migration to Svalbard around the middle of May (Madsen et al. 1999; Tombre et al. 2008).

The population has been subject to a long-term study of population dynamics and migration ecology using neckbands. Ringing of Pink-footed Geese with neckbands was initiated in 1990, and since then a total of >3,700 individual geese have been captured and marked. Most birds have been captured by cannon-netting in spring (March–May) in western Jutland, Denmark, but a minority (<500) have been caught and marked by rounding up geese during wing moult on the Svalbard breeding grounds. At capture, geese were ringed with metal rings and plastic neckbands, sexed by cloacal examination and aged by feather characteristics. They were also measured (head and wing length) and weighed, providing morphological data and body condition of all birds included in the ringing program. In the majority of captures in Denmark, geese were X-rayed as part of a campaign to reveal the prevalence of shotgun pellets, and since 2005, blood samples have been taken for DNA analyses. Captures included between 35 and 500 individuals, and, after being taken out of the net, geese were kept in a tent with compartments holding 15–20 birds. Geese were processed individually for marking and handling, and subsequently put back into the tent. In captures with up to c. 200 individuals, all geese were released collectively from the tent following the marking session. In larger captures, groups of marked geese (50–100) were released gradually during the course of processing. The length of the handling period (from capture to release) varied between c. 5 and 12 h. While kept in the tent, geese were generally calm and resting, and, to avoid dehydration during handling, geese were given water orally using a syringe.

Continuous assessments of body condition after birds were released back to the wild required a different approach. Although the most accurate assessments of avian body condition are internal measures or body mass (Brown 1996; Jakob et al. 1996), these procedures are often time consuming, very expensive and associated with either handling or death of individual birds. As a consequence, these techniques are not feasible for large-scale assessments of many individuals—even less so when the aim is to evaluate the effect of capturing and handling, as continuously exposing geese to these procedures would severely hamper interpretation. As an alternative measure of body condition, Owen (1981) developed the concept of an abdominal profile index (API), a proxy assuming that body condition of individual birds is well reflected in the appearance ("sagginess") of their abdomen. APIs have been shown to correlate nicely with body mass and fat stores (Feret et al. 2005; Madsen and Klaassen 2006), and are widely accepted as good proxies of body condition among waterfowl (Zillich and Black 2002; Drent et al. 2003). However, accurately assessing API scores relies heavily on standard procedures and experienced observers to eliminate potential biases associated with observer effects.

The abdominal profile index for Pink-footed Geese used in this study categorises abdominal profiles on a 1–7 scale, and is linearly related to both body mass and total energy content of individual birds (Madsen and Klaassen 2006). All APIs included in this study was scored by a few intercalibrated observers with extensive experience of assessing abdominal profiles in the field, and Madsen and Klaassen (2006) give a detailed description of the protocol used for assessing body condition. Over the years, this programme has collected a total of 33,046 abdominal profile scores of 3,350 different Pink-footed Geese in the spring staging areas of Denmark and Norway, spanning a post-marking period of individual birds from a few hours to more than 22 years. In the following analyses, we confined the use of API data to adult birds (individuals hatched earlier than the calendar year preceding the year of banding), ensuring that potential morphological differences between age classes did not affect the results. Statistical analysis and graphical representations were conducted using JMP 10.0 (SAS Institute) and R 3.0.2 (R Core Development Team).

Short-term effects

To assess the immediate handling effect of capture and ringing on goose body condition, we used API data from years with exceptional good coverage of fitness assessments in the days just after capture. We defined short-term effects as the difference in API between newly ringed individuals (until 2 weeks after capture) and individuals ringed in previous years with API data from the same 2-week period. This analysis should therefore primarily reveal any immediate effect of capturing and handling birds, as well as initial discomfort of carrying the neckband. The 2-week window was further subdivided into five 3-day periods, and only periods with more than ten independent abdominal profile scores were used in the analysis.

Only 2 years with comprehensive field work (1992 and 1995) satisfied this criterion. These two study years contained more than three times the number of API assessments in the 2-week period compared to an average year, and allowed for analyses in time periods of few days. The effect of capture and handling on API was investigated by controlling for confounding variables with a linear mixed model incorporating "Year" and "Bird ID" as random effects and "Sex", "Period" and "Ringing" as fixed effects. "Period" described the 3-day periods mentioned above, and the "Ringing" variable was defined as a discrete variable with two levels indicating whether the API score of any given bird was assessed in the year of ringing or in succeeding years. The interaction “Ringing × Period” was included to assess any temporal changes in the effect of ringing, and the interaction “Ringing × Sex” to look for gender-specific responses. The magnitude of short-term effects were evaluated by post hoc tests of differences between the least square means of newly and previously ringed birds for each 3-day period.

Medium-term effects

Pink-footed Geese were marked with neckbands in the Danish non-breeding areas during spring (March–May), and we defined medium-term effects as the impact of a preceding capture and ringing event on body condition during the subsequent spring migration. As above, we compared API scores between newly caught birds and birds caught in previous years, and investigated whether any effect on body condition from the capture/ringing event persisted at three major stopover sites (Denmark, Trøndelag and Vesterålen) during spring migration. This analysis incorporated all available spring observations from the 24-year period in a linear mixed model with “Year”, and “Bird ID” as random effects and “Sex”, “Day of year” and “Ringing” as fixed effects for each of the three stopover sites. The interaction “Ringing × Sex” was included to reveal potential gender-specific effects, and the interaction “Ringing × Day of year” was incorporated to assess whether/when potential effects of ringing would ease off. Again, we assessed the magnitude of potential differences between newly and previously ringed birds by comparison of least square means.

Long-term effects

To evaluate the long-term effect of wearing neckbands on body condition, we relied on recaptured Pink-footed Geese that had completed at least one annual cycle since the time of first capture. By comparing body mass of birds caught for the first time with recaptured individuals fitted with neckbands in previous years, any differences in body mass could reveal a long-term cumulative effect of this type of marking. Although the sample of recaptured birds was relatively small ($n = 35$), this number was similar to another study dealing with the same issue (Legagneux et al. 2013). Effects on body condition was examined with a linear mixed model incorporating the confounding effects of “Year” and “Bird ID” as random effects and “Sex” and “Recapture” as fixed effects. “Recapture” was defined as a discrete variable distinguishing between birds caught for the first time and birds that were recaptured one or more years after the first capture. As the dataset consisted of single captures in any given year, the random variable “Year” also included potential effects of time of capture. The interaction “Recapture × Sex” was included to reveal potential gender-specific effects, and the magnitude of difference in body mass between groups was tested by comparison of least square means.

Results

Short-term effects

Body condition of Pink-footed Geese in the first 2 weeks after capture and banding were significantly influenced by “Ringing”, “Sex” and “Ringing × Period” (Table 1). This suggested that API varied between the sexes, that the procedure of capture and banding influenced body condition, and that this influence changed during the course of the 2-week period included in this analysis. The effects of “Period” and “Ringing × Sex” were not significant, indicating that APIs (apart from the effect of ringing) were more or less stable during the 2-week period, and that the response of geese to ringing did not differ between females and males. When comparing the effect of ringing between newly and previously ringed geese for each 3-day period, it became evident that the effect corresponded to a reduction of ~1 API score (equivalent to approximately 190 g of body mass; Madsen and Klaassen 2006). In both 1992 and 1995, the effect of ringing gradually decreased in the periods succeeding capture (Fig. 1). As a consequence, the short-term effect of capture and banding seemed to disappear after approximately 1 week, after which there were no significant differences between the two groups (Fig. 1).

Medium-term effects

Throughout the three spring staging sites, strong support was found for an effect of “Sex” and “Day of year” on goose body condition, indicating that APIs differed between sexes, and that APIs generally increased during spring (Table 2). The effect of day of year reflects the

Table 1 Model output from the linear mixed model describing short-term effects (until 2 weeks after capture) of ringing on body condition of Pink-footed Geese *Anser brachyrhynchus*

$n = 464$	Estimate	SE	*P* value
Ringing	0.266	0.040	<0.001*
Sex	0.103	0.039	0.010*
Period	−0.019	0.037	0.598
Ringing × period	−0.109	0.030	<0.001*
Ringing × sex	0.057	0.041	0.160

The *Ringing* variable distinguishes between newly ringed geese and geese ringed in previous years

* Significant effects ($\alpha = 0.05$)

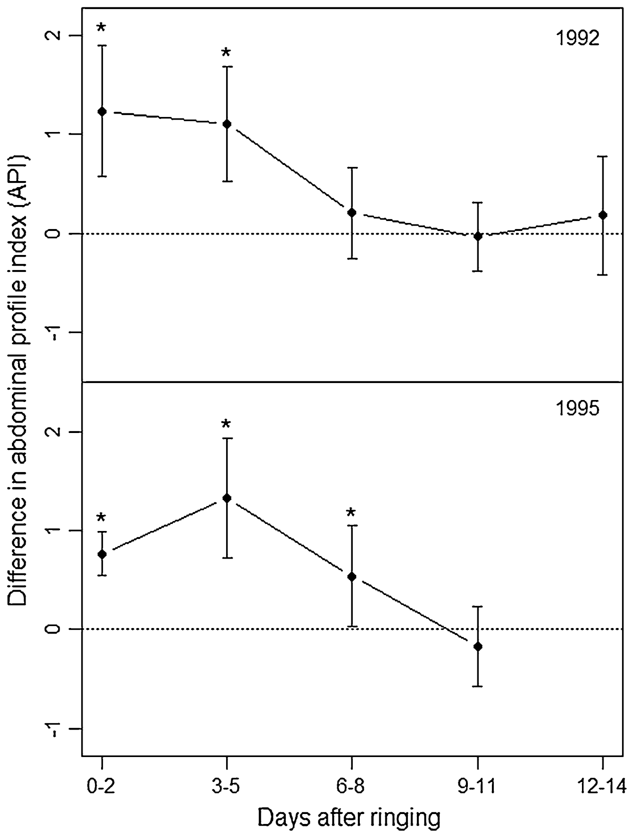

Fig. 1 Differences in least square mean API between newly ringed Pink-footed geese *Anser brachyrhynchus* and geese ringed in previous years, divided into 3-day periods during the first 2 weeks after capture and banding. *Positive values* indicate that geese ringed in previous years had a higher API than newly ringed geese (difference: previously ringed – newly ringed), and *error bars* indicate the 95 % confidence interval around the mean. *Significant differences ($P < 0.05$) between groups

gradual build-up of fat reserves during the spring season, and the effect of gender might reflect an overall difference in morphology and rate of body mass increment between the sexes. The medium-term effect of capture and banding on geese body condition differed between the three sites (Table 2), and, while the effect of ringing persisted throughout the stay in Denmark and seemed to carry-over to the stopover at Trøndelag, this effect was no longer observable among geese observed in Vesterålen (Table 2; Fig. 2). The effect of ringing was seemingly unaffected by sex ("Ringing × Sex" insignificant at all three staging sites), and the temporal decline in the effect of ringing occurred mainly at Trøndelag, as this was the only staging site with a significant effect of "Ringing × Day of Year" (Table 2). In both Denmark and Trøndelag, the effect of ringing was rather small, and corresponded to a reduction in API score of 0.1–0.3 (equivalent to 20–55 g of body mass; Madsen and Klaassen 2006; Fig. 2).

Table 2 Model output from the linear mixed model describing medium-term effects of ringing on body condition of Pink-footed Geese at each of the three consecutively used spring staging sites Denmark, Trøndelag and Vesterålen

	Estimate	SE	*P* value
Denmark (n = 14,254)			
Ringing	0.115	0.011	<0.001*
Sex	0.085	0.015	<0.001*
Day of year	0.050	0.001	<0.001*
Ringing × sex	0.020	0.011	0.091
Ringing × day of year	0.001	0.010	0.402
Trøndelag (n = 5,634)			
Ringing	0.075	0.014	<0.001*
Sex	0.196	0.017	<0.001*
Day of year	0.033	0.002	<0.001*
Ringing × sex	−0.023	0.014	0.105
Ringing × day of year	0.015	0.002	<0.001*
Vesterålen (n = 7,723)			
Ringing	−0.012	0.015	0.410
Sex	0.194	0.019	<0.001*
Day of year	0.046	0.004	<0.001*
Ringing × sex	0.013	0.009	0.284
Ringing × day of year	−0.006	0.044	0.107

The *Ringing* variable distinguishes between newly ringed geese and geese ringed in previous years

* Significant effects ($\alpha = 0.05$)

Long-term effects

The comparison between newly caught geese and recaptured geese that had lived with a neckband for at least one annual cycle revealed no statistically significant effect on body mass, suggesting that Pink-footed Geese are not subject to long-term reductions in body condition as a result of ringing with neckbands (Table 3). Gender-specific differences in morphology resulted in a significant effect of "sex" on body mass, but neither "Recapture" nor "Recapture × Sex" was supported as influencing the weight of geese. Comparison of least square means revealed an average body mass just above 2,500 g for both groups of caught birds.

Discussion

Results from this study suggested that ringing with neckbands had no significant long-term effect on the body condition of Pink-footed Geese, but also revealed that capturing and handling birds might temporarily affect body condition in a period following the ringing event. In the first week post-ringing, the API of geese was on average ~1 score lower than among birds ringed in previous years,

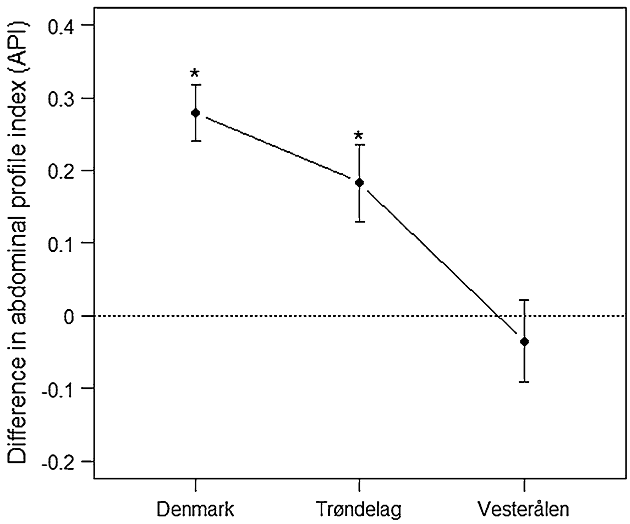

Fig. 2 Differences in least square mean API between newly ringed geese and geese ringed in previous years at three staging sites (Denmark, Trøndelag and Vesterålen) used consecutively during spring migration succeeding a capture and banding event in Denmark. *Positive values* indicate that geese ringed in previous years had a higher API than newly ringed geese (difference: previously ringed − newly ringed), and *error bars* indicate the 95 % confidence interval around the mean. *Significant differences ($P < 0.05$) between groups

Table 3 Model output from the linear mixed model describing long-term effects of ringing on body condition of Pink-footed Geese

$n = 2{,}200$	Estimate	SE	*P* value
Recapture	14.910	22.173	0.501
Sex	−115.253	22.184	<0.001*
Recapture × sex	−3.942	22.180	0.8590

The *Recapture* variable distinguishes between geese caught for the first time and geese that were recaptured (already wearing neckbands)

* Significant effects ($\alpha = 0.05$)

but only a minor part of this effect persisted on a seasonal scale. The fact that the short-term effect seemed to disappear after approximately 1 week, while a minor observable effect was still detected later during spring migration, is attributable to differences in sample size. The short-term analysis was founded on observations from only 2 years and a relatively short time period, while the medium-term analysis incorporated data from all years and was therefore able to pick up even very small differences. The medium-term effect appeared to fade quickly after the stopover in Trøndelag, and this notion was supported by results from the linear model as only this staging site showed a significant temporal change in the effect of ringing (Ringing × Day of year). The stopovers in Norway are known to be a time of rapid energy gain for Pink-footed Geese (Madsen and Klaassen 2006), which might allow for rapid replenishment of energy stores, compensating for lower intake rates earlier on.

The difference in magnitude of the ringing effect between temporal scales might be explained by (1) that body condition is mainly influenced by the capture procedure and only a little by the neckband itself and (2) that geese gradually compensate the short-term loss in body condition as they habituate to the presence of the neckband (Ely 1990). In addition, the use of abdominal profile indexes may also influence temporal variation in the assessment of body condition. Because API scores were based on assessing the appearance of Pink-footed Geese abdomens, this measure could be somewhat affected by the foraging state of individual geese. Caught birds were denied up to an entire day of foraging, and a lower API score in the days succeeding capture could be partly explained by a movement of internal organs associated with a completely empty stomach. In support of this, Owen (1981) showed that Barnacle Geese *Branta leucopsis* arriving at the feeding grounds in the morning had an average API 0.5 units lower than geese assessed later the same day. Although foraging state might temporarily affect the assessment of API scores, this effect is unlikely to persist for several days. Moreover, the protocol for assessing body condition of Pink-footed Geese instructs observers not to score APIs in the first hour following sunrise. As a consequence, the explanatory power of foraging state might be limited in the current study. The daily energy expenditure of Pink-footed Geese staging in Denmark during spring has been reported as 1,184 kJ/day (mean value; Madsen 1985), and, assuming an energy conversion factor of fat around 37 kJ/g, the daily energy expenditure in terms of fat deposits would equal ≈32 g. Madsen and Klaassen (2006) showed that a drop in API of 1 unit corresponded to a loss in abdominal fat content of ~29 g, and collectively these figures indicate that denied foraging for a longer time period might indeed manifest itself in observable effects on the appearance of goose abdomens. Waterfowl are known to exhibit great changes in body mass within relatively short time periods (Boismenu et al. 1992), and although other internal energy stores (such as glycogen deposits and unprocessed food) might contribute to cover the energetic expenses associated with capture and ringing, it seems likely that the lower API of newly ringed birds at least partly represents a temporary drop in abdominal fat stores and hence body condition. A similar drop in body condition following a capture event has been demonstrated among moulting Barnacle Geese by Owen and Ogilvie (1979).

It could be argued that the short- and medium-term analyses are biased because we compare the effect of newly marked versus older marked individuals. However, the long-term comparison (between marked and unmarked birds) found no difference between groups, justifying the use of older marked birds as a control against the newly marked group in the examination of transitory capture effects.

Although this study found no support for a persistent negative impact of neckbands on the body condition of Pink-footed Geese, we cannot completely rule out that other demographic traits might be affected. Recent studies have suggested that neckbands might affect breeding and survival (Menu et al. 2000; Schmutz and Morse 2000; Reed et al. 2005), and Legagneux et al. (2013) suggested reduced body condition as one explanation of these findings. Legagneux et al. (2013) report a negative effect of neckbands on Snow Goose *Anser caerulescens* body condition, and demonstrate that this effect was only significant for the first year after capture. This further supports the importance of temporal scales when assessing the impacts on marked birds. Further studies are necessary to completely unravel the likely species-specific responses to neckbands and to clarify important factors giving rise to potential differences between species. Thus far, there are strong indications that impacts might vary greatly between taxonomic groups. Brent Geese *Branta bernicla* and Emperor Geese *Anser canagica* seems to respond strongly to the use of neckbands (Lensink 1968; Schmutz and Morse 2000), whereas the effect on Snow Geese, White-fronted Geese *Anser albifrons* and Pink-footed Geese seems to be smaller and/or relatively transient (Ely 1990; Menu et al. 2000; this study). Even though body mass could be an important factor in explaining these differences because of variations in the relative cost of carrying certain-sized neckbands, negative effects have also been described for the large-bodied Canada Goose *Branta canadensis* (Castelli and Trost 1996), indicating that the impacts of neckbands might relate to additional factors that are only poorly understood.

The assumption of most CMR analyses, that ringed birds are suitable representatives of natural population dynamics, might be strongly violated in species adversely affected by banding. Quantifying the potential biases in body condition, survival and reproduction associated with different marking techniques is a prerequisite to fully trust analyses dealing with this kind of data. As long as these biases are thoroughly accounted for, however, CMR techniques can be a powerful tool for estimating population demographics (Frederiksen et al. 2014). In the case of neckbands and waterfowl, these analyses are relatively straightforward because of the conspicuous lifestyle of these species, and the ability to use markings that enable repeated sampling without further interfering with caught birds. In many other animal taxa, sighting probabilities are very small, greatly complicating the ability to track animals post-capture (Bryja et al. 2001; Courtois et al. 2013).

Although marking of waterfowl with neckbands has been widely used across Europe, this study is the first to actually quantify potential effects of these markers in the Western Palearctic. Madsen et al. (2001) pointed out that neckbanded Pink-footed Geese might experience neckband icing under very cold conditions, but were able to show that these events had no effect on body condition compared to banded individuals where no icing occurred. Although this study indicates that body condition of Pink-footed Geese might be negatively affected by capture and banding in the shorter term, there is so far no support for a long-term effect on this species. This study suggests that the most harmful intervention is that of capturing and handling the geese, while the additional cost of living with the neckband (if any) are relatively small. While this might be true for Pink-footed Geese in Western Europe, other species might respond very differently to the use of these markers.

In spite of no long-term effect on body condition, neckbands might influence important life-history traits such as survival and reproduction in other ways. Demers et al. (2003) showed that radio-collared Snow Geese had higher divorce rates than unmarked geese, but found only a minor effect in birds wearing traditional neckbands. Decreased dominance rank (Legagneux et al. 2013), impaired mate acquisition (Lensink 1968) and higher susceptibility to hunters (Alisauskas et al. 2006) have also been suggested as potential consequences of markers altering the normal appearance of birds. To what extent neckbands may interfere with social relationships and interspecific interactions are still not fully understood, and the use of these markers should always be implemented with caution—especially when dealing with species of high conservation concern.

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