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Clausen, Kevin Kuhlmann; Schreven, K.H.T.; Madsen, Jesper

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Effects of capture and marking on the behaviour of moulting Pink-footed Geese *Anser brachyrhynchus* on Svalbard

KEVIN K. CLAUSEN[1,*], KEES H.T. SCHREVEN[2] & JESPER MADSEN[1]

[1]Aarhus University, Department of Bioscience, Grenåvej 14, 8410 Rønde, Denmark.
[2]Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), PO Box 50, 6700 AB Wageningen, the Netherlands.
*Correspondence author. E-mail: kc@bios.au.dk

Abstract

Tracking of individuals is increasingly being used in waterfowl research. However, the effects of capture and tags on waterfowl welfare and ecology are poorly understood and too rarely reported. In this paper, time budget data are used to investigate the behavioural effects of capture and marking on moulting and brood-rearing Pink-footed Geese *Anser brachyrhynchus* on their arctic breeding grounds. The study compares the prevalence of self-maintenance and foraging time for unringed/uncaptured birds, male birds marked with standard neck collars and female birds marked with heavier GPS collars, and reports on the reduction through time in the pecking behaviour directed towards these markers. Results indicate that capture and marking substantially altered behaviour of marked birds in the days immediately after capture, but also that this effect faded quickly and was not discernible six days after marking. Proportions of time spent preening during foraging bouts indicated that, in the first six days, GPS-collared birds were significantly more affected (time preening *c.* 12%) than birds ringed with standard neck collars (*c.* 3%). Both groups showed higher proportions of self-maintenance type behaviours than unringed birds of the same sex (time preening < 1%). The probability of an individual goose pecking its marker during an observation period was initially high for GPS-collared birds (*c.* 65%), but decreased substantially to reach *c.* 2% by 11 days after capture. Our study indicates that, after an initial period of discomfort, neck collars and GPS collars are suitable for studying the behaviour of individual geese.

Keywords: GPS, neck collars, ringing, tag effects, waterfowl.

In waterfowl research, many ecological and evolutionary scientific questions rely on recognising and tracking individual birds. Marking of birds started by fitting them with simple leg rings in the early 20th century (Preuss 2001); subsequently, markers that were more conspicuous (*e.g.* colour rings, wing tags, neck collars) were applied to increase re-sighting probabilities in the field (Rees *et al.* 2005). With recent technological advances, the tagging of birds with heavier, electronic tracking devices such as backpack-mounted satellite transmitters and GPS loggers attached to neck collars ("GPS collars") has become increasingly widespread. The detailed positional data derived from these techniques have been used in a wide array of scientific studies, ranging from habitat selection and migration to behavioural studies of individual birds (Bridge *et al.* 2011; Wilmers *et al.* 2015). While these techniques certainly contribute to advancing our knowledge of bird ecology, the quantification of possible "tag effects" (impacts compromising waterfowl welfare) has been far from standard practice (Lameris & Kleyheeg 2017).

The ability to track individual birds necessitates that birds are captured and marked or tagged. These capture and marking events might entail undesirable effects on individual birds, and might influence traits of interest to the study, such as time and energy budgets or life-history traits (Brua 1998; Barron *et al.* 2010; Kölzsch *et al.* 2016). Potential tag effects may range from altered activity patterns (Ely 1990) to increased mortality (Alisauskas *et al.* 2006), and the impact can vary greatly depending on tag type, attachment type, the species involved (Lameris *et al.* 2018) and climatic conditions encountered by the species (Madsen *et al.* 2001). Likewise, the scientific importance of any tag effects may differ greatly between different studies and research questions (Barron *et al.* 2010; McIntyre 2015). Clarification of potential capture and marking effects therefore is an important initial step if relying on marked individuals to describe behavioural patterns expressed by the population as a whole. Because new tags are being developed continuously, and applied to a growing set of avian species, new knowledge and vigilance regarding this matter is constantly required.

Swans and geese have been fitted with metal and colour leg rings for individual identification over many decades and, with their large size, long necks and visibility in open landscapes, have also more recently been subject to marking with neck collars and backpack-mounted satellite transmitters (*e.g.* Eichhorn *et al.* 2006; Kölzsch *et al.* 2019; Wood *et al.* 2018). Recently, the impacts of applying backpacks and neck collars have received greater attention in the scientific literature, with negative effects of backpacks including increased mortality and divorce rates in Barnacle Geese *Branta leucopsis*, Greater White-fronted Geese *Anser albifrons* and Dark-bellied Brent Geese *Branta bernicla bernicla* (Lameris *et al.* 2018), while negative effects of neck collars include increased mortality in Ross's Geese *Chen rossii* (Alisauskas *et al.* 2006) and increased divorce rate and lower reproductive success in Snow Geese *Anser caerulescens* (Demers *et al.* 2003). While these studies indicate that irreversible impacts on the life-history traits of affected individuals do occur, other studies indicate that, at least for neck collars, effects on behaviour and body condition may only be temporary. For instance, studies on Greater White-fronted Geese (Ely 1990), Pink-footed Geese *Anser brachyrhynchus* (Clausen & Madsen 2014) and Bewick's Swans *Cygnus columbianus bewickii* (Nuijten *et al.* 2014) have shown that, although neck collars affected behaviour and body condition of marked birds, these effects diminished over time as they habituated to their markers.

So far, studies of capture and tag effects on large waterfowl have taken place mainly on the wintering grounds, where birds are mostly caught by cannon or clap netting. However, another important catching method for waterfowl is to corral post-breeding moulting birds on the arctic breeding grounds, during the vulnerable period of flight feather moult. In this study, we assessed the effects of capture and tagging on the behaviour of moulting Pink-footed Geese caught on their arctic breeding grounds, and investigated the persistence of any tag effects in the days after capture. We compared time budgets of females marked with recently developed GPS collars, males marked with traditional neck collars and uncaught, unmarked birds, with a special emphasis on preening behaviours that have previously been described as a good proxy of discomfort and annoyance associated with the capture and marking of geese (Glahder *et al.* 1998; Kölzsch *et al.* 2016). We hypothesised that marked geese would devote more time to self-maintenance (preening feathers) than uncaught, unmarked birds, and direct pecking behaviour towards their markers (*e.g.* biting the collar and/or leg rings). We also expected that any effects would be most pronounced in the days immediately after capture and fade with time.

Methods

Study area and focal species

The study was carried out in Adventdalen (78°12'07.8"N, 15°49'39.2"E) on Svalbard, which is an increasingly important breeding area for Pink-footed Geese (Tombre *et al.* 2012). Nesting usually occurs on south-facing slopes, and soon after hatching the families move to the valley bottom to forage on newly sprouted wet meadow and tundra vegetation (Fox *et al.* 2009). Important food sources in this period include alkali grass *Puccinellia* sp., Alpine Meadow-grass *Poa alpina*, horsetails *Equisetum* sp. and Scheuchzer's Cottongrass *Eriophorum scheuchzeri* (Fox *et al.* 2007).

A long-term ringing scheme for the Svalbard-breeding Pink-footed Goose was initiated in 1990 (Madsen *et al.* 2002), and since then > 5,000 birds have been marked with metal rings and standard neck collars. In 2018, after a test trial in captivity (K.H.T. Schreven, unpubl. data), the first GPS collars were deployed on wild geese, prompting the need to clarify how these heavier tags might affect behaviour. The main wintering areas are in Denmark, the Netherlands and Belgium (Clausen *et al.* 2018), and in recent years the population size has fluctuated at around 80,000 birds (Clausen *et al.* 2019).

Captures and markings

On 30 July 2018, a group of 32 moulting adult Pink-footed Geese (average ± s.d. wing length = 132 ± 24 mm, range = 83–180 mm) and 50 goslings were caught during post-breeding moult on the lake of Isdammen, Adventdalen, Svalbard

(78°12'12.7"N, 15°48'10.3"E). Geese were caught by rounding up family groups of flightless birds into a netted corral. All adult birds were sexed by cloacal examination. The primary aim of the tagging project was to follow nesting females, and to analyse spring fattening in relation to breeding success. As a consequence, only females (n = 16) were equipped with GPS collars (model: OrniTrack-N38 supplied by Ornitela UAB, Lithuania, with collars made of polyamide nylon, inner diameter: 38 mm, weight: 38 g, colour: white), while male geese (n = 16) were fitted with standard neck collars (laminated plastic, inner diameter: 44 mm, weight: 13 g, colour: white). The standard neck collars have been used since 1990, and the smaller diameter of the GPS collars was chosen following test trials with captive Pink-footed Geese, which indicated that a GPS collar with a diameter of 38 mm caused less pecking behaviour than a GPS collar with a 44 mm diameter which weighed 44 g (38 mm model, two geese: 1% of total 80 min observation; 44 mm model, four geese: 28% of total 100 min observation, during days 1–2 after marking). Because of their heavier weight, GPS collars slide more easily towards the head during foraging than standard neck collars, which initially caused a goose to interrupt foraging or drinking and walk backwards during the trials (44 mm model: 9% of the 100 min observation period). This was not observed with the 38 mm model. In addition to the GPS collars, females were ringed with a plastic leg ring with the same inscription as the GPS collar. All adult birds were also ringed with a metal ring, measured (head and wing), weighed, tested for personality traits (breath rate, handling aggression, escape test), and blood samples and cloacal swabs were taken for future analyses. After handling of all adult birds (*c.* 6 hours), adults and goslings were released simultaneously at the place of capture. Subsequent observations of ringed pairs strongly indicated that two birds (1 male and 1 female) had been assigned to the wrong sex during ringing, and these individuals were excluded from further analyses.

Of the 32 marked geese, 31 individuals were seen alive after the day of capture. A single male bird was never observed after marking. One female bird died two days after release (on 1 August between 4:00–5:00 h, based on data from the GPS tag), and the intact GPS collar (without bird) was found on the shore of Lake Isdammen a couple of days later. The bird was observed alive the day after capture, but was clearly acting strangely and weakened through being relatively immobile and not foraging. Although uncertain, this may have been a consequence of capturing and handling the bird, which could have led to fatal injuries or circumstances exposing it to predation by Arctic Foxes *Vulpes lagopus* that were common in the area.

Family status was determined for the 31 re-sighted individuals, during observations made in the 11 days following capture. Due to the capture of family groups, the majority of marked adults were paired with each other (14 females and 14 males), with one female and one male paired with unmarked birds and one female seemingly unpaired. All but two of the pairs were accompanied by goslings. The unpaired female also had no goslings. Marked individuals were typically foraging in small flocks (usually of 20–100 individuals) which included a mix of marked and unmarked birds. The behaviour of the marked geese that were unpaired and/or had no goslings differed substantially from that of family groups, as they spent considerably less time actively foraging in lowland areas. To minimise sources of variance, all the observations described below therefore were restricted to successful breeders (pairs accompanied by young), observed in flocks consisting mainly of family groups.

Time budget data

Collection of time budgets in family groups of Pink-footed Geese took place in Adventdalen, Svalbard every day in the period from 1–11 days after capture (31 July–10 August 2018). During the study period daily average temperatures in Adventdalen varied between 6.3°–10.8°C and there was no precipitation (all days < 0.1 mm, source: www.eklima.no). Behaviours of individual birds during foraging bouts were scored using focal sampling (*cf.* Altmann 1974), by one person (KKC) from a car without disturbing the geese. Focal individuals were followed intensively using a telescope for a period of 10 min, chosen arbitrarily so that birds were sampled in as many flocks as possible, whilst minimising repeated sampling of the same individuals immediately after each other. Whenever possible, the sex of focal individuals was determined based on the sexual size dimorphism of Pink-footed Geese (Madsen & Klaassen 2006), which is rather distinct in post-breeding family groups. If individuals were lost from sight or started roosting during the 10 min period, only samples covering > 5 min were retained for analysis. A total of eight behavioural activities were defined (Table 1), and the length of time devoted to different activities within the sampling periods was scored using a multiple stopwatch. During the study period, groups of families alternated between longer periods of active foraging and shorter periods of roosting, sleeping and preening. Collection of behavioural data was restricted so that only individuals seen to be actively foraging were included, and because preening of unringed birds primarily was observed during inactive periods, the prevalence of this activity during feeding bouts was regarded as an expression of discomfort. Prior to analysis, all time budget data were converted to proportions in order to account for differences in sampling length (18% of samples had a duration of < 10 min). Gradual shifting of the timing of the observation period resulted in data being collected over the entire 24 h cycle. Geese used lakes and rivers merely for roosting and locomotion, and consequently all active foraging bouts included in this study took place on land. A thorough description of foraging habitats can be found in Fox *et al.* (2006, 2009). Because data were collected during the Pink-footed Goose moulting period, no flying was observed.

Pecking behaviour

During each of the focal samples, the presence or absence of pecking and/or heavy preening behaviour towards collars and rings was noted, resulting in an additional binary data set (Y/N) describing

Table 1. Behaviours identified and noted during the collection of time budget data from focal individuals during 10 min sampling sessions.

Behaviour	Definition
Foraging	Actively foraging with head down, usually walking/standing, but occasionally lying down
Guarding	Standing with raised head (lookout), but not alerted by specific threat in its surroundings
Locomotion	Walking or swimming (when on water)
Roosting	Lying down briefly, between periods of actively foraging
Interactions	Participating in aggressive encounters as either initiator or recipient
Drinking	Drinking from lakes or rivers
Preening	All kinds of preening, cleaning, pecking and tidying feathers
Alert	Standing with head raised, alerted by specific danger or running away from potential risk

the prevalence of discomfort in both groups of marked birds. Pecking behaviour was defined as observing one or more of the following actions: biting the metal ring, biting the plastic leg ring (GPS-collared birds only), biting the collar, heavy preening around collar or head shaking (presumably due to the presence of the collar). It should be noted that, because GPS-collared birds were also marked with plastic leg rings, the discomfort of these birds could stem from the plastic rings in addition to the collars and metal rings. However, the vast majority of pecking and heavy preening behaviour seemed to be associated with the collars (see Results section).

Statistical analyses

On grouping the time budget data into four daily phases (midnight–06:00 h, n = 42; 06:00–12:00 h, n = 87; 12:00–18:00, n = 77; 18:00–00:00 h, n = 42), the prevalence of preening behaviour (thought to reflect discomfort) was found to be unaffected by time of day (Kruskal-Wallis test: $\chi^2_3 = 2.58$, $P = 0.46$, n.s.). This may be due to the 24 h of daylight during the study period reducing diurnal variation in the birds' behaviour, and all within-day observations therefore were lumped to investigate differences in prevalence of preening among marked and unmarked geese. Given the confounding effects of sex and tag type, we focussed on comparing the marked birds (GPS-collared females and neck-collared males, respectively) with uncaught, unmarked birds of the same sex. Because of the limited number of marked birds, daily sample sizes were rather low for both neck-collared and GPS-collared birds (ranging from

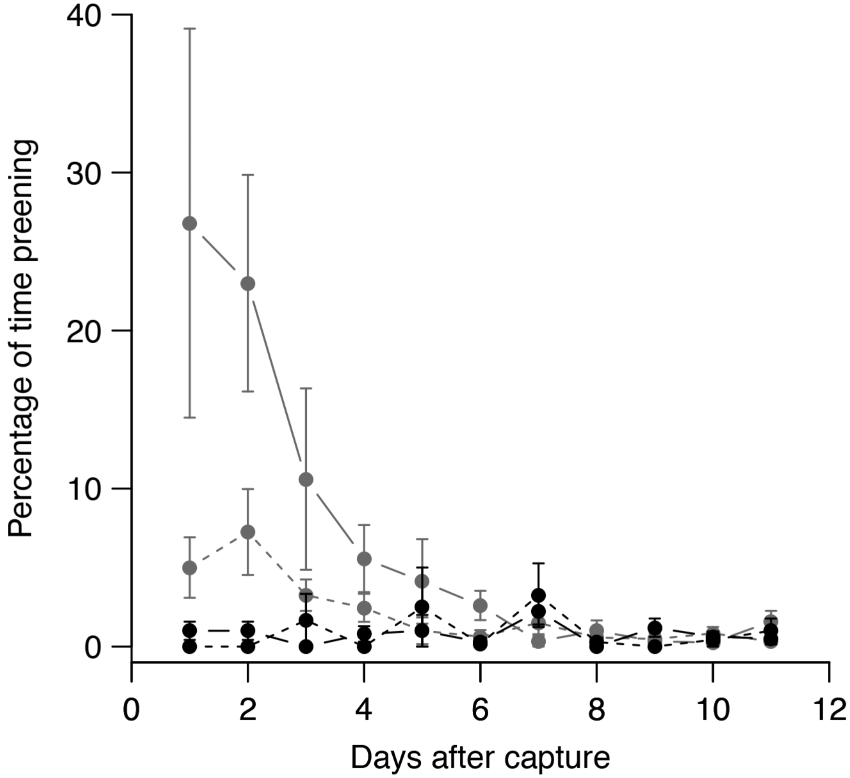

Figure 1. Daily average (± s.e.) percentages of time spent preening for unringed females (black solid line), unringed males (black dashed line), GPS-collared females (grey solid line) and neck-collared males (grey dashed line). Please note that due to the limited number of birds, daily sample sizes are rather low.

3–9 sampling periods). In addition, the proportions of time spent preening was highly zero-inflated, which hampered the use of parametric statistics. We therefore commenced by determining the daily averages of time spent preening for unringed, neck-collared and GPS-collared birds, respectively (Fig. 1). This indicated that preening activities were considerably higher for marked birds than for unmarked birds during the days immediately after capture, but was rather comparable after six days. Similar findings have been reported by Kölzsch *et al.* (2016), who demonstrated that GPS collars affected behaviour of captive Canada Geese *Branta canadensis* six days after marking. To investigate this apparent fading of capture/tag effect with time, we divided our 11 days of time budget data into two periods (*i.e.* day 1–6 and day 7–11), and used nonparametric Wilcoxon tests (Wilcoxon 1945) to test for behavioural differences between periods as well as differences in the prevalence of preening between marked and unmarked birds of both sexes within each period.

Individual birds were sampled only once during a single foraging bout, but because the number of marked geese was limited, the same individuals featured between 1–6 times within each of the two defined periods of several days. It was, naturally, impossible to distinguish between individuals of unmarked geese, and occasionally observations of marked birds were carried out at distances that precluded identification of the individual, with only the type of collar (GPS *vs.* standard collar) ascertained. Consequently, behavioural differences among individuals could not be fully accounted for. The time budget data from the unmarked birds, however, revealed that behaviours were very consistent for geese that were certainly different individuals, and the inability to account for individual differences therefore was unlikely to have a major influence on the comparison between groups in our study.

The presence or absence of pecking behaviour towards rings and collars was modelled as a binomial response variable (generalized linear model with logit link function) with "Days after capture" and "Observation time" as explanatory variables. Observation time was included because a minority of the focal samples (*c.* 14%) were of < 10 min duration. This enabled us to evaluate whether the discomfort of rings and collars faded with time during 1–11 days after capture.

Results

Time budget data

In unringed birds, the only noticeable difference in time budgets between males and females was a higher proportion of guarding among males (Wilcoxon test: $Z = 7.88$, $P < 0.01$), whereas females spent longer foraging ($Z = -7.45$, $P < 0.01$, Table 2). The prevalence of preening did not differ between the sexes of unringed birds in either period 1 ($Z = -1.20$, $P = 0.226$, n.s.) or period 2 ($Z = -6.65$, $P = 0.51$, n.s.). GPS-collared females showed substantially higher proportions of preening than unringed females in period 1 (Wilcoxon test: $Z = -3.75$, $P < 0.001$, Table 2, Fig. 2a), but in period 2 this difference was no longer discernible ($Z = 0.50$, n.s., Table 2, Fig. 2b). Likewise, neck-collared males spent significantly more time preening in period 1 than unringed males ($Z = -2.59$, $P < 0.01$, Table 2, Fig. 2a), but in period 2 this difference had disappeared ($Z = -0.64$, n.s., Table 2, Fig. 2b). Due to sex being confounded with tag type in our data, a formal test of differences between standard and GPS collars was problematic. Nevertheless, GPS-collared females seemed to be more affected with respect to time spent preening than males wearing standard collars in period 1 (Fig. 1, Fig. 2a).

For marked birds, the increased time devoted to preening behaviours during the first six days after capture came largely at the expense of time devoted to foraging (Table 2). As a result, GPS-collared females had an 18% reduction in foraging time in comparison to unringed females (61.5% *vs.* 75%, respectively in period 1), while the response of standard neck-collared males was smaller at *c.* 3% (53.8% *vs.* 55.7% for neck-collared and unringed males, respectively), reflecting the smaller effect of preening on their time budget (Table 2).

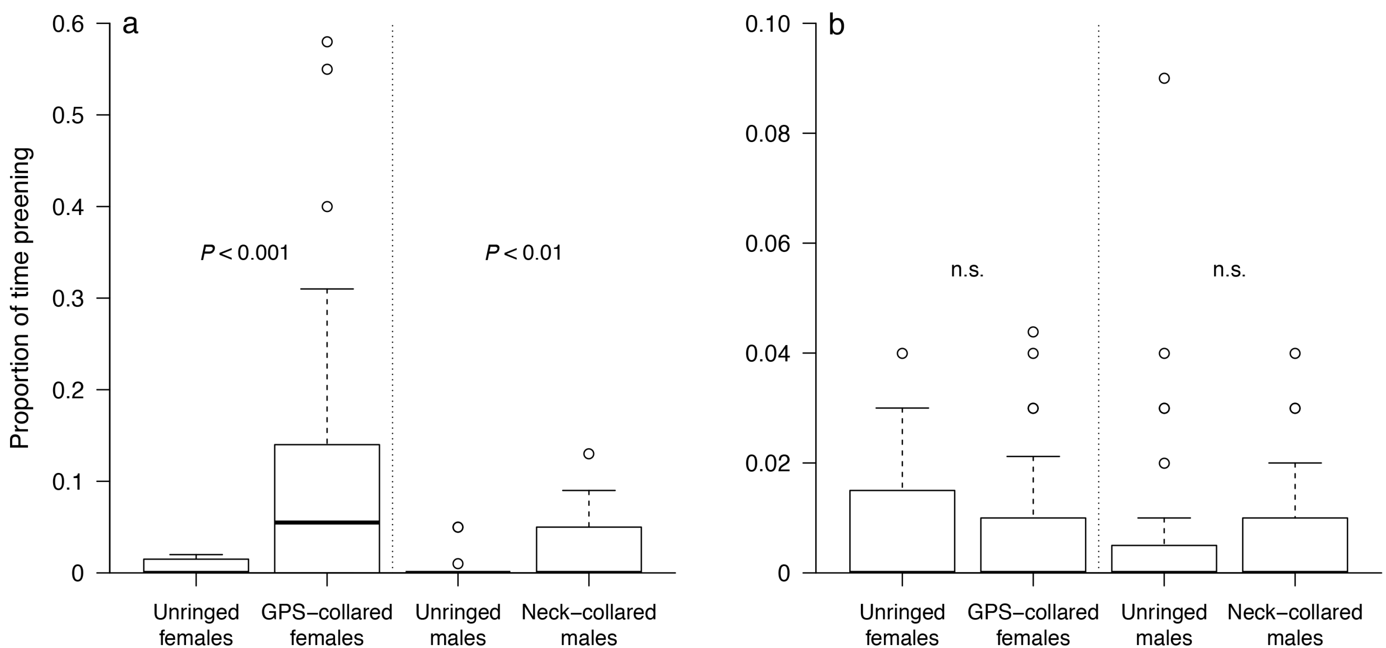

Figure 2. Boxplots of the proportion of time spent preening by unringed females, GPS-collared females with plastic leg ring, unringed males and neck-collared males during foraging bouts in the post-breeding moulting period at Adventdalen, Svalbard, in 2018: (a) 1–6 days after capture, and (b) 7–11 days after capture. The plots indicate the median, the lower and upper quartiles, and whiskers (1.5 interquartile range) values. Results of statistical analyses (Wilcoxon tests) between groups within the two time periods are indicated. Note the different y-scale in the two plots.

Table 2. Proportions of time spent on each of the eight different behaviours (mean ± s.e.) for uncaptured, unringed birds, birds with standard neck collars and birds with GPS collars (+ plastic leg rings), during post-breeding foraging bouts of moulting Pink-footed Geese in Adventdalen, Svalbard, in 2018. Wilcoxon test statistics indicate whether the proportions of time spent in each behaviour differed between period 1 (1–6 days after capture) and period 2 (7–11 days after capture). n = the sample size (number of 5–10 min samples), which may include the same individuals multiple times, but always in separate foraging bouts. * indicate significant differences between the two periods, at α-level 0.05.

Mark type	Mean proportions		Test for difference between periods	
	Period 1	Period 2	Z value	P value
Unringed females	$n = 24$	$n = 31$		
Foraging	0.750 ± 0.014	0.769 ± 0.011	–1.403	0.161
Guarding	0.171 ± 0.010	0.153 ± 0.011	1.395	0.163
Locomotion	0.050 ± 0.007	0.059 ± 0.006	–0.768	0.443
Roosting	0.009 ± 0.005	0.003 ± 0.002	0.880	0.379
Interactions	0.003 ± 0.002	0.002 ± 0.001	0.690	0.490
Drinking	0.005 ± 0.002	0.003 ± 0.002	0.471	0.638
Alert	0.006 ± 0.003	0.003 ± 0.001	–0.219	0.827
Preening	0.006 ± 0.002	0.008 ± 0.002	–0.372	0.710
GPS-collared females	$n = 30$	$n = 32$		
Foraging	0.615 ± 0.034	0.778 ± 0.014	–4.222	< 0.001*
Guarding	0.147 ± 0.014	0.135 ± 0.011	1.619	0.105
Locomotion	0.067 ± 0.009	0.066 ± 0.008	0.428	0.669

Roosting	0.040 ± 0.016	0.005 ± 0.002	2.325	0.020*
Interactions	0.003 ± 0.002	0.001 ± 0.001	0.597	0.551
Drinking	0.004 ± 0.002	0.002 ± 0.001	–0.057	0.954
Alert	0.006 ± 0.002	0.007 ± 0.003	0.66	0.509
Preening	0.117 ± 0.029	0.007 ± 0.002	4.301	< 0.001*
Uringed males	$n = 20$	$n = 28$		
Foraging	0.557 ± 0.030	0.577 ± 0.022	–1.106	0.232
Guarding	0.356 ± 0.026	0.330 ± 0.017	1.041	0.294
Locomotion	0.064 ± 0.013	0.075 ± 0.011	–0.862	0.389
Roosting	0.002 ± 0.001	0.002 ± 0.001	–0.059	0.953
Interactions	0.008 ± 0.003	0.002 ± 0.001	1.265	0.206
Drinking	0.001 ± 0.001	0.001 ± 0.001	–1.178	0.239
Alert	0.008 ± 0.003	0.004 ± 0.002	1.606	0.108
Preening	0.006 ± 0.003	0.008 ± 0.004	–0.737	0.461
Neck-collared males	$n = 39$	$n = 34$		
Foraging	0.538 ± 0.020	0.611 ± 0.020	2.651	0.008*
Guarding	0.344 ± 0.019	0.298 ± 0.017	–1.583	0.113
Locomotion	0.073 ± 0.008	0.074 ± 0.009	–0.244	0.807
Roosting	0.002 ± 0.001	0.001 ± 0.001	–0.45	0.653
Interactions	0.004 ± 0.002	0.005 ± 0.002	1.272	0.203
Drinking	0.006 ± 0.003	0.001 ± 0.001	–0.325	0.745
Alert	0.006 ± 0.002	0.002 ± 0.001	–1.522	0.128
Preening	0.027 ± 0.006	0.007 ± 0.002	–2.204	0.028*

Again, the effect had disappeared in period 2, when no clear differences in foraging time were recorded for marked and unmarked males.

Pecking behaviour

Of the 137 focal samples of collared birds (*n* = 73 and *n* = 64 for standard and GPS collars, respectively), presence of pecking and/or preening behaviour towards rings and collars were observed during 15 scans. Of these, 13 events were directed towards collars, 1 towards the metal ring and 1 towards an unknown leg ring (plastic or metal). The probability of observing pecking behaviours towards markings varied with collar type. For birds with standard neck collars the probability of observing pecking behaviour was *c*. 5% across the 1–11 day period, and while the presence of pecking behaviour decreased with days after capture, the relationship was not significant

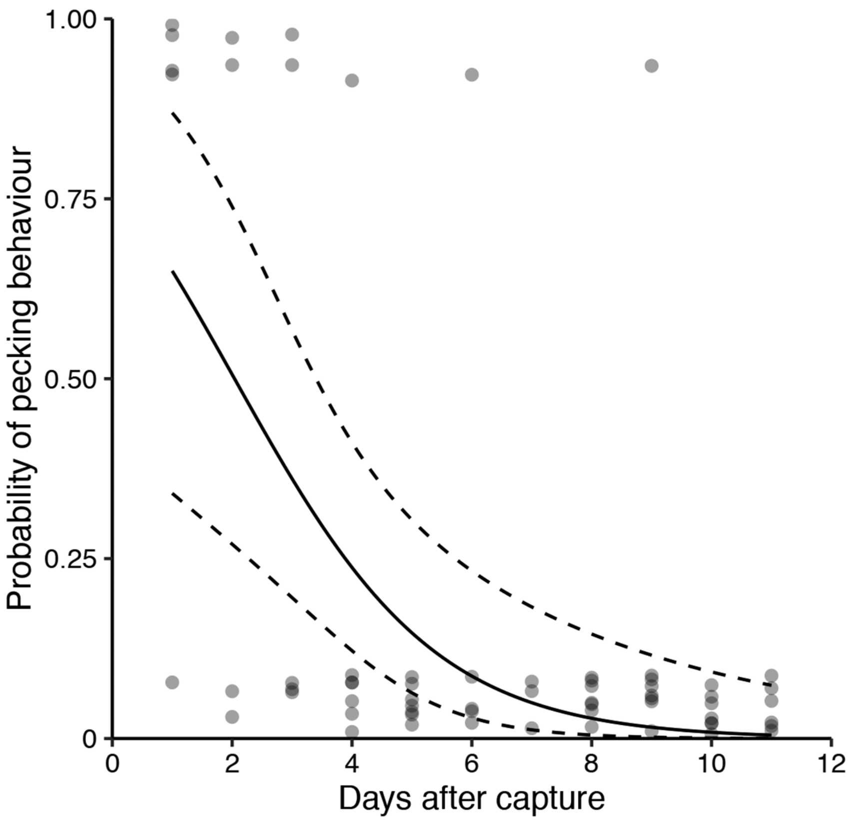

Figure 3. The probability of female GPS-collared Pink-footed Geese being observed pecking at their markings during foraging bouts, 1–11 days after capture during the post-breeding moult period at Adventdalen, Svalbard, in 2018. Dashed lines indicate the 95% confidence interval. Data points (binary 0/1) are plotted with vertical jitter and slightly shifted for visualisation purposes.

(binomial GLM: z = –0.980, *d.f.* = 70, P = 0.327, n.s.). For GPS-collared birds, the probability of observing pecking behaviour was initially very high (*c.* 65%), but due to a clear negative effect of days after capture (z = –3.155, *d.f.* = 61, P = 0.002) it declined to only a few per cent by the end of the study period (Fig. 3). Observation time had no discernible effect on the probability of observing pecking behaviour in either of the two groups (neck collars: z = –1.404, P = 0.160, n.s.; GPS collars: z = –0.010, P = 0.992, n.s.), which may at least partly relate to the fact that very few samples (n = 9 and n = 11 for the two types of collars) ended before the targeted 10 min period.

Discussion

Our study indicated that both standard neck collars and heavier GPS collars were associated with initial discomfort among marked geese. The proportion of time spent preening was initially highest for female geese wearing GPS collars and plastic leg rings, but was also elevated for male geese wearing standard collars compared to unmarked birds. The difference between GPS-collared females and neck-collared males was clear despite the fact that behaviours of the paired birds in this study were probably not fully independent. As such, the behaviour of neck-collared males paired to GPS-collared females could potentially copy an altered behaviour of their partner, for instance by increasing frequencies of preening. The discomfort of collared birds faded with time, and during the period 7–11 days after capture the prevalence of preening did not differ between marked and unmarked geese for both sexes. The probability of pecking behaviour towards collars (majority) and leg rings (minority) was especially pronounced for GPS-collared individuals in the first days after capture, but likewise faded quickly during the first week. It should be noted, however, that occasional pecking behaviour was still observed for both types of collars by the end of the study period.

Results from this study demonstrate that, for the Pink-footed Geese, the major behavioural effects were confined to approximately one week after capture, when increased preening and pecking activity coincided with reduced foraging time for collared birds. Initial discomfort was obvious, which might affect behaviour, movements and energy accumulation in the days after capture – especially among birds wearing heavier GPS collars. These findings suggest a temporary effect on the energy balance of marked birds, but also indicate that geese were able to habituate to the collars rather quickly. A similar short-term effect has been described in an earlier study of the same species looking at effects of standard neck collars on body condition (Clausen & Madsen 2014). Short-term behavioural impacts due to heavier collars (more preening at the expense of foraging) has also been described for captive geese (Kölzsch *et al.* 2016), and our findings confirm the same initial pattern among free-ranging geese.

Besides the differences in self-maintenance and foraging time among marked and unmarked birds, the sex-specific differences in guarding and foraging time is noteworthy. The time budget data for both marked and unmarked birds clearly demonstrated that males spent considerably more time guarding the family in comparison to female birds. Such sex-specific behavioural patterns have previously been shown for Pink-footed Geese by Lazarus and Inglis (1978), for Cackling Canada Geese *Branta canadensis minima* by Sedinger and Raveling (1990) and for Light-bellied Brent Geese *Branta bernicla hrota* by Bregnballe and Madsen (1990). This reinforces the view that males invest substantially in guarding of the family during this period, while the females forage to a greater extent to regain mass following the incubation period.

To ensure a substantial sample size within the limited time available in Adventdalen, the focus was on groups of families actively foraging. As a consequence, no data were available to evaluate whether the time spent roosting or sleeping differed between marked and unmarked geese. This decision was taken because: 1) family groups subject to observations in this study spent the vast majority of time actively feeding (K.K. Clausen, pers. obs.), which was probably driven by the foraging needs of the growing goslings; and 2) collection of data on duration of sleeping periods would necessitate constant observation of an individual for long periods where no other data could be collected – especially for unmarked geese that could not be distinguished. Consequently, any potential effects of capture and marking on the duration of foraging bouts and inactive sleeping and roosting periods could not be evaluated based on the data available, and the activity patterns presented here are representative only of actively foraging birds.

In this study on short-term behavioural effects, the effects of capture and presence of tags cannot be fully separated. Thus, some of the behavioural impacts observed within the time budgets in the days after capture might be due to the capture and handling of birds, leading to a subsequent increase in preening behaviour. The opportunity to mark birds always necessitates a preceding catch, and the combined effect of capture and marking therefore should be considered. As a result, elevated levels of preening are likely to be observed immediately post capture, irrespective of the type of tag used. Our control group of unringed birds were not caught, and therefore we have no way of separating capture and tag effects. Nevertheless, the clear difference in preening activities between standard collars (males) and GPS collars (females), as well as the higher pecking activity among GPS-collared birds, suggest that parts of the effect is associated with tag type and not a result of the capture alone. The complete association between sex and collar type in our study precludes assessing causal relationships in more detail, such as whether the higher level of discomfort among GPS-collared birds is influenced not only by tag type, but also by the sex of the bird. At least for standard neck collars, however, previous studies have shown that females are not more susceptible to marking than males (Clausen & Madsen 2014).

Recently, there has been some concern over harness-attached tracking devices, which have been found to increase divorce and mortality rates in several species (*e.g.* Ward & Flint 1995; Lameris *et al.* 2018). This study indicates that GPS collars might (after an initial period of discomfort) be suitable to study behaviour of individual geese. However, our study only covered activity patterns of moulting and flightless birds. Recent reviews by Barron *et al.* (2010) and Lameris & Kleyheeg (2017) emphasise that tracking devices can have negative impacts on important life-history traits such as survival, energy expenditure and breeding propensity, and that these might persist for prolonged periods. Consequently, care should be taken when relying on demographic data from marked birds, and the current study should be followed by further studies assessing the potential collar-induced impacts on survival and reproduction of Pink-footed Geese.

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Photograph: Family groups of Pink-footed Geese crossing the road in Adventdalen, Svalbard, August 2018, by Kevin Kuhlmann Clausen.

