Travels in a changing world flexibility and constraints in migration and breeding of the barnacle goose

Eichhorn, Götz

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Part

I

Tools and techniques

Box

A

Tracking migratory geese

Götz Eichhorn

Tracking devices

We used two techniques to track annual movements of female Barnacle Geese nesting at the Tobseda colony: global location sensing and satellite telemetry. The **global location sensing (GLS) approach** is based on the principle of geolocation by light levels (Wilson et al. 1992). Light-sensitive archival tags equipped with an inbuilt clock record ambient light levels from which both dusk and dawn events are estimated. These are used to calculate geographical positions (two fixes daily): day (night) length determines latitude and time of local midday (midnight) determines longitude. Each 9 g tag (produced by the British Antarctic Survey) was attached to one of our standard plastic leg rings (inscribed with an individual code, see picture in chapter 3). The total mass of the logger and all 3 rings (two inscribed colour plastic rings and one stainless steel numbered ring from the Ringing Centre in Moscow) was 21 g, corresponding to 1.5% of the average female body mass at the end of incubation, the leanest period in the annual cycle. The GLS units (54) were attached to the geese during their breeding/moulting period in 2003 and retrieved in subsequent seasons (24 and 12 units in 2004 and 2005, respectively, of which 5 and 3 units, respectively, failed delivering any data).

Accuracy of GLS loggers of the same model we used had been previously measured in trials with free-ranging albatrosses and yielded a mean error of 186 km (Phillips et al. 2004). The longitude estimate is generally more accurate than the latitude estimate (standard deviations of the mean in the albatross study were 110 and 185 km, respectively). One drawback of this method is an increased latitudinal error close to the periods of equinox, especially at the winter side. However, the longitude estimate is not affected. Fortunately the largely eastwards movement of our barnacle geese along a narrow coastal corridor facilitated reconstruction of shifts between stopover sites by relying on the longitude estimates alone. A more serious limitation for our study is that the GLS system requires at least a few hours of darkness to allow geographical fixes, hence measurements were not possible after our birds crossed the Arctic Circle in late May. However, despite the limited accuracy and the need to retrieve units to download the records, GLS has advantages over other tracking techniques. The low weight and compact form of the unit that allow it to be attached to the leg ring keep any possible interference with the bird to a minimum. The energy consumption of the logger unit is very low, thus enabling a working duration over several years while providing, apart for the period around equinox, a high temporal resolution of fixes (i.e., two per day) the year round.

Tracking radio transmitters or PTTs (platform transmitter terminals) via satellite is now a widely used tool for studying animal movements. Timed fixes of high accuracy provide not only information about the migratory route, but also allow calculation of crucial migration parameters such as speed of migration and length of flying and resting bouts. These tantalising possibilities are subject to limitations, among them a possible impact on the animal's behaviour due to the weight or mode of attachment of the device. The safest way to minimise this potential interference is to avoid the use of any harness by implanting the device in the body cavity. This meant that only the transmitter's flexible antenna would protrude through the feathers. Inserting the transmitters while the geese were moulting gave the birds a few weeks to recuperate before taking to the wing again. By catching birds during the annual moult roundups and checking for rings we aimed to select individual females with a known breeding history. These individuals were then carried to our base camp where the transmitters were surgically implanted under anaesthesia under strict sterile conditions while monitoring heart rate (a twenty minute operation performed by A. Flagstad). The surgical implantation procedure followed the "abdominal implant technique" developed by Korschgen et al. (1996). Afterwards the implanted birds were returned to the catch area and released along with the others. There were no fatalities during this procedure. We used internal PTTs (built by Microwave, Maryland, USA) of 30 g (less than 1.5 percent of body mass of the migratory female goose). These devices were programmed to broadcast in two cycles: from implantation in August 2004 through early April 2005 at 4 hrs on 90 hrs off, then for 8 hrs on 20 hrs off until batteries ran out (in late June-mid July 2005) potentially providing coordinates 6 times a week. Given the limited battery life of about 750 hrs, this schedule would provide us with detailed information about the spring journey, which was our main priority. In all, we deployed 16 satellite transmitters to 15 females and 1 male in the 2004 breeding season. One unit suffered technical failure and two went 'off the air' during the autumn hunt before the geese left the Arctic. The remaining 13 satellite carriers successfully reached their wintering grounds and returned to the breeding grounds the following spring where direct observation in the field confirmed breeding in eight individuals in the colony of original capture. For another two birds we did not succeed in locating the nest but judging from the consistent locations from ARGOS we assume they nested. Data generated by the ARGOS system was further handled and analysed with a Satellite Tracking and Analysis Tool (STAT, Coyne and Godley 2005).

Route maps for three birds are illustrated in Figure BoxA.1. During the pre-migratory fattening period Goose Clara was found in the Dollard estuary at the

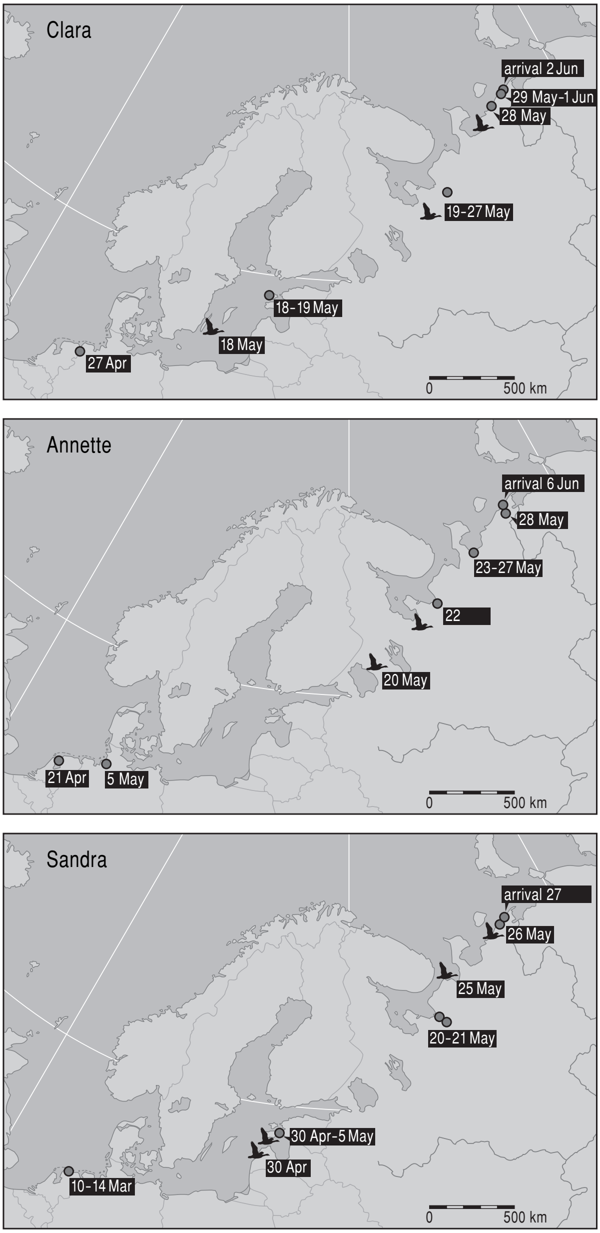

Figure Box A.1. Route maps of selected satellite-tagged birds (named Clara, Annette and Sandra) in spring 2005 (from Eichhorn 2005). Fixes from the same position (within a radius of 25 km) over several days are combined into one location marker. Bird silhouettes mark fixes during migratory flight. Note periods lacking position fixes in the western part of the study area. In this densely populated region the total emission of radio waves is high and may have hampered signal transmission of our PTTs to the satellite. The chance to be located by the satellite seemed greater during flight.

Dutch-German border, a staging site which has come in use only since the early 1990s. Clara left the North Sea on 18 May and reached the river Dvina near Arkhangelsk already the next day on 19 May, where she spent 8 days before heading to the breeding area. Except a pause of less than a day in western Estonia, this bird skipped Baltic staging sites altogether. In contrast, goose Sandra stayed in the Baltic at least since 30 April and probably until mass departure from there around 19 May. All three birds spent a relatively short time in the White Sea, likely influenced by an exceptionally early season in the breeding area (mean date of nest initiation was 7 June in 2005, compared to 12 June as the long-term mean). This allowed the birds to stay in close vicinity (< 100 km) of the colony already in the end of May, a time at which the area is in the grip of snow and ice in most other years.

Evaluating device-induced effects on survival

Attaching tracking devices to the geese was the only practical way for us to gather detailed knowledge of their long-distance migratory journeys. However, one should bear in mind the possible effects on the animal induced by these devices, not only for reasons of animal welfare, but also to assure the data obtained being representative for the animal under study, i.e., compared to unrestrained conditions. Information on the timing of migration and reproduction of tracked birds compared to birds without tracking devices is given in chapters 3 to 5 of this thesis (see also Eichhorn 2005). The following section examines whether survival of females equipped with these devices differed from control birds.

Methods

Apparent survival (Φ) and resighting probabilities (P) of adult female barnacle geese were estimated with Cormack–Jolly–Seber (CJS) capture–recapture models (Lebreton et al. 1992) in program MARK (White and Burnham 1999). Birds belonged to three different groups: 1) radiomarked with implanted Platform Transmitter Terminals (PTTs) and coloured legrings; 2) equipped with Global Location System (GLS) loggers and coloured legrings; 3) the control group: birds marked with inscribed coloured legrings only. Three of the 'PTT birds' received a GLS tag in addition and from one of these the tag was removed the next year. For the analysis here, requiring a reasonable sample size, we assigned these three birds to group 1. All females, regardless of group, were tagged in the breeding and moulting area at Kolokolkova Bay, Russia, when caught on the nest and/or during moult drives. Implantations of PTTs were conducted only during the moulting period. See above for details about devices.

Birds were resighted at two places and during two seasons per year from winter 2003 to summer 2006: 1) in the breeding and moulting area at Kolokolkova Bay, Russia during summer and 2) at their wintering grounds along the North Sea coast. The former resighting interval, referred to as 'summer', extended from June to August, the latter, defined as 'winter', lasted from December to February. Although birds in the wintering area have been resighted also before and after this period, those observations are excluded in this analysis to restrict resighting intervals to a comparable length.

Thus the CJS models consisted of 3 groups (PTT, GLS, and ringed birds), 7 encounter periods (including initial captures) and spanned 3 years. However, in the PTT group the first 2 encounter periods (year 2003) contain no data because initial capture started in summer 2004. Furthermore, survival and recapture probabilities cannot be estimated separately in the final season (White and Burnham 1999). In cases where GLS loggers were removed from birds in the course of the study only encounter histories up to and including the moment of detachment were included in the analysis. An overview of numbers of geese and periods when gadgets/tags were deployed (removed) is given in Table Box A.1.

Table Box A.1. Year of capture and numbers of adult female barnacle geese marked with legrings only or receiving either a GLS tag or PTT implant in addition and used in the survival analysis.

Capture summer	PTT	GLS (removed)	Rings
2003		54	130
2004	15	6 (10)	60
2005		2 (5)	

Model selection was based on a modified Akaike's Information Criterion (AICc) (Anderson et al. 2000). Goodness of fit to the CJS model was tested using a bootstrap procedure provided in MARK. Using the bootstrap results, a scale parameter was calculated ($\check{c} = 1.417$) and used to adjust deviance and AICc values (QAICc). Starting with the full model containing main variable effects of group (g), season (s), years since capture (t), and all possible interactions among them, we first examined variation in resighting rate (P) while survival (Φ) was kept constant with the full design. P was constrained stepwise, beginning with the interaction terms followed by modelling of main effects. The resulting model with lowest QAICc was then used to model Φ following the same strategy. For the best candidate models for Φ derived from this exercise, additional constrains on P were tested to see if this might lead to models with even lower QAICc.

Results and discussion

Resighting probability was similar among years but differed between seasons (places) with a higher resighting probability on the breeding grounds (Table Box A.2, Fig. Box A.1). This pattern was enhanced for 'PTT birds' (causing an interaction between group and season) and birds from both groups equipped either with PTT or GLS tag were resighted at a higher rate than birds marked with coloured

Table Box A.2. Model selection for effects of group (g: PTT, GLS, and ringed birds), season (s) and time (t: years since capture) on survival (Φ) and resighting rate (P) of adult female barnacle geese from the Russian breeding site at Kolokolkova Bay. Models were ranked by the difference in the corrected Quasi Akaike's Information Criterion (Δ QAICc) relative to the model with lowest QAICc. Only the seven top models with Δ QAICc < 5.0 and the full model are presented.

No.	Model	Δ QAICc	Likelihood	Parameters	Deviance
1)	Φ(s), P(g*s)	0.000	1.000	8	164.4
2)	Φ(g*s), P(g*s)	1.852	0.396	12	158.0
3)	Φ(s), P(g+s)	2.555	0.279	6	171.0
4)	Φ(g+s), P(g*s)	2.592	0.274	10	162.8
5)	Φ(g+s+t,g*s), P(g*s)	3.714	0.156	14	155.7
6)	Φ(g+s+t), P(g*s)	4.473	0.107	12	160.6
7)	Φ(s), P(s)	4.508	0.105	4	177.0
	Φ(g*s*t), P(g*s*t)	25.338	0.000	29	145.5

legrings only (Fig. Box A.1). These differences are not surprising. First, the study birds are confined to a much smaller area during breeding and moult (i.e., the capture area) compared to the winter season spent along the North Sea coast. Second, prior to ringing the exact nesting site is generally not known and part of the ringed birds may come from colonies outside the study area. In contrast, most of the geese which received a GLS tag were caught on the nest and all of the 'PTT birds' had been previously marked and were seen nesting at a certain site. For these birds resighting probability is higher due to their faithfulness to a nesting territory.

The top model (no. 1) in Table Box A.2 does not indicate survival to be different among treatment groups, and the next best supported models that include a group effect (i.e., models 2 and 4) do not describe the data significantly better than the reduced model 1 (Likelihood Ratio Tests: $\chi^2 = 6.37$, df = 4, $P = 0.17$ and $\chi^2 = 1.51$, df = 2, $P = 0.47$, respectively). Survival estimates according to the top model (that is for birds from all groups combined) were 0.956 and 0.896 for survival from summer to winter and from winter to summer, respectively, yielding an annual survival of 0.856.

Most likely the same aspects causing a seasonal pattern in resighting probability are responsible for seasonal differences of survival (Fig. Box A.2). Survival from winter to summer is always lower for birds carrying legrings only since those likely include birds that are less likely to be seen in subsequent summers (ringed as non-breeders, stragglers). Survival from summer to winter is higher for these birds since in winter all birds have a similar chance to be seen regardless of their status (even if P is lower in absolute sense, Fig. Box A.1). To achieve more balanced resighting probabilities among groups for the summer it would be better to restrict the sample of birds from the group marked with rings only to those birds that were observed breeding in the year of capture (i.e. seen with a nest). Essentially, this would require capture on the nest instead of captures during moult. Nevertheless, the aim of the present analysis was to test for group (treatment) effects and not to examine seasonal patterns of survival. The reason for choosing two resighting events per year was to run this preliminary survival analysis with data spanning over a period of only two to three years. With the extension of the study period to three and more years an analysis based on resightings restricted to the winter season will be possible in near future.

In conclusion, over the time of study (2-3 years since attachment of devices) we found no effects on the survival of geese potentially caused by the applied tracking tools. However, a re-examination at a later stage is advised to check for possible long-term effects. From the marked synchrony in timing of migration and breeding of birds with and without devices (ch. 3 and 4) we have great faith that the data obtained are representative for birds of our study population. Concerning the heavier PTT devices, studies on other waterfowl species confirm the notion that abdominally implanted devices compared to harness type attachments have least adverse effects on survival, breeding propensity and behaviour of the carrier (Garrettson and Rohwer 1998; Garrettson et al. 2000; Hupp et al. 2003; Hupp et al. 2006a).

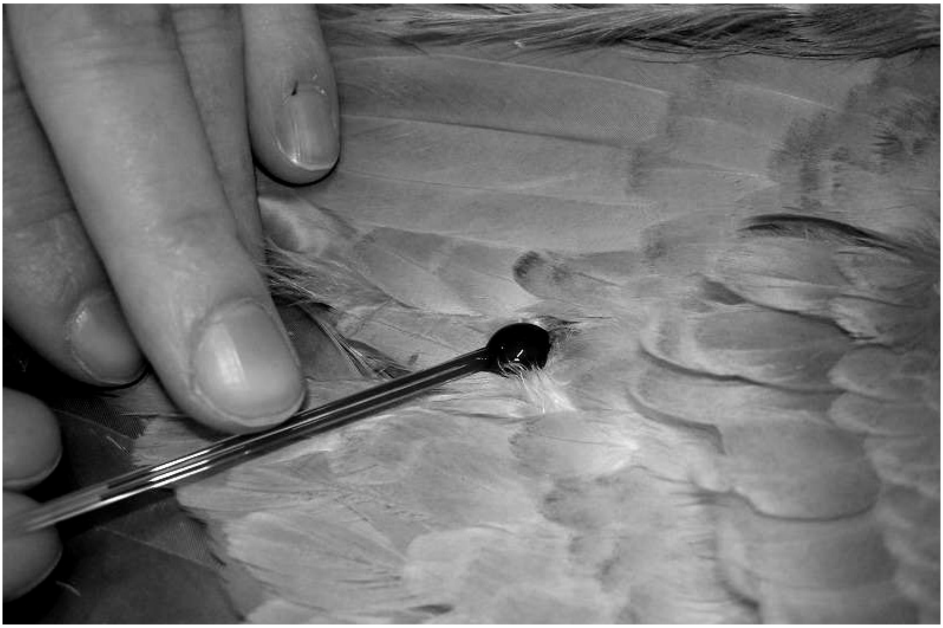

Photo by René Adelerhof.