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Body condition and spring migration in female high-arctic barnacle geese *Branta leucopsis*

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Female barnacle geese *Branta leucopsis* were studied on their spring staging area on the coast of mid-Norway and 1,500 km further to the north on their breeding areas in the Arctic archipelago, Svalbard. The number of days between departure from their spring staging area and arrival on their breeding area ranged between 10 and 33 days. There was no significant relationship between the date of departure and the date of arrival for individual females (N = 51), indicating that early-leaving females were not necessarily the first to arrive at the breeding grounds. Late-arriving females were in better body condition upon arrival than early-arriving females (N = 25). These data imply that the barnacle geese breeding in Svalbard do not migrate directly from their traditional spring staging areas to their breeding areas, but spend a considerable amount of time, not only resting, but also feeding during their migration northwards. This result has important implications for the management of the barnacle goose population on Svalbard since areas other than their traditional spring staging grounds apparently determine the date of arrival at the breeding grounds, body reserves at arrival and subsequent reproduction.

Key words: barnacle geese, body condition, breeding ground, migration, spring staging area

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Avian reproductive potential is often linked to fat reserves that are surplus to successful migration (Perrins & Birkhead 1983). For species like Arctic geese, which have a narrow window in which to complete breeding, the timing of arrival at the breeding grounds can be crucial to success (Newton 1977, Raveling 1979). Generally, geese arrive in the Arctic when food availability is low (e.g. Barry 1962, Sedinger & Raveling 1986), and to some extent, they rely on body reserves gained on wintering and spring staging areas for development of eggs (Raveling 1979, McLandress & Raveling 1981, Ely & Raveling 1984). For example, in lesser snow geese *Chen caerulescens caerulescens* Ankney & MacInnes (1978) found a positive relationship between body reserves at the start of egg laying and the number of developing follicles, suggesting that those with most fat reserves would also have the highest fecundity. A similar link between body mass and/or fat scores in spring and the subsequent number of offspring in the following winter has been found for individually marked brent geese *Branta bernicla* (Ebbinge et al. 1982, Ebbinge 1989, Ebbinge & Spaans 1995, Prop & Deerenberg 1991), barnacle geese *Branta leucopsis* (Black et al. 1991) and pink-footed geese *Anser brachyrhynchus* (Madsen 1995).

Many researchers have assumed that the point of departure from spring staging areas is the last opportunity for feeding, even though precise information on the behaviour of geese during migration is lacking. For example, a growing body of evidence suggests that foraging on arrival at the breeding ground contributes to egg production and incubation ability (Prop et al. 1984, Budeau et al. 1991, Fox et al. 1991, Bromley & Jarvis 1993, Gauthier 1993, Ganter 1994, Choiniére & Gauthier 1995). Prop et al. (1984) have shown that intake rates of female barnacle geese during incubation is highly correlated with subsequent hatching success. Such considerations would obviously only be relevant where food was available due to the timing of snow melt in the Arctic.

In this study we observed female barnacle geese from the Svalbard population on their spring staging and breeding areas. When the geese arrive at their nesting grounds in late May/early June, almost all the vegetation is covered with snow. Nesting starts within a few days after arrival, but some pairs delay nesting for one or two weeks (Dalhaug et al. 1996). On the spring staging area we recorded the date of departure for individual females. Later in the season, the date of arrival at the breeding area was recorded for the same females. In this way we were able to calculate how many days it took before each female arrived at the breeding area. Some females were also caught at arrival in order to relate body condition to date of arrival. The importance of the traditional spring staging area for reproductive success is evaluated, and we further discuss the possible factors that may influence body condition upon arrival for barnacle geese breeding in Svalbard.

Methods

Barnacle geese from the Svalbard population spend approximately seven months during winter on the Solway Firth, UK, one month at the traditional spring staging areas in the Helgeland archipelago on the coast of mid-Norway and four months of the summer in Svalbard (Gullestad et al. 1984, Black et al. 1991, Black & Owen 1995). Data were collected during 1993 and 1994 on females in their spring staging area in Helgeland (65-66°N, 11°E) and in the colony near Ny-Ålesund on the west coast of Svalbard (78°55'N, 12°15'E). Barnacle geese from Svalbard have been ringed since 1970 either by rounding up during moult or caught with rocket or cannon-nets. There were about 650 geese in the Ny-Ålesund colony, and almost 70% of the adults were individually marked with coded plastic leg rings and metal rings. Leg rings were readable at distances of up to 250 m with a telescope. For further details on the ringing procedures, see Owen & Black (1989) and Black & Owen (1995).

The date of departure from Helgeland was defined as the last day a bird, hitherto recorded on a daily basis, was observed (e.g. Black et al. 1991). As geese arrived at the breeding area in Svalbard, intensive searches were made every day to record ringed individuals. Geese arrived at the breeding area in pairs. They were caught with cannon-nets which were placed on snow free areas before arrival, and body mass was measured using a Pesola spring balance (± 5 g). To adjust body mass for a bird's relative body size, a principal component analysis (PCA) was performed which combined tarsus, bill, head and wing lengths (measured to the nearest mm). The first principal component (PC1) explained 36.1% of the standardised variation in these characters, and the residuals from a regression of body mass on PC1 ($r^2 = 0.20$, $N = 41$, $P < 0.004$) were used as an index of body condition. In analyses concerning date of arrival at the breeding grounds and body mass, we only used females caught within three dates of arrival, as we do not know how body mass changes in the period between arrival and egg laying. However, 18 of 24 females were caught on their date of arrival, and using the number of days between arrival and catch as a covariate, did not significantly affect the results of our analyses. A linear regression of the number of days between arrival and catch on the date of arrival showed no significant relationship ($r^2 = 0.01$, $N = 24$, $P > 0.6$). In analyses where observations from different years were pooled or compared, the dates of arrival or departure were adjusted to the first date of arrival or departure in each year (relative to the first departure or first arrival).

As only nine females with known dates of departure and arrival were caught within three days after arrival at the breeding area, we used univariate tests to avoid the reduction of sample sizes (SAS Institute Inc. 1990). All tests were two-tailed and values were given as means ± 1 SE. The significance level was set at $P < 0.05$.

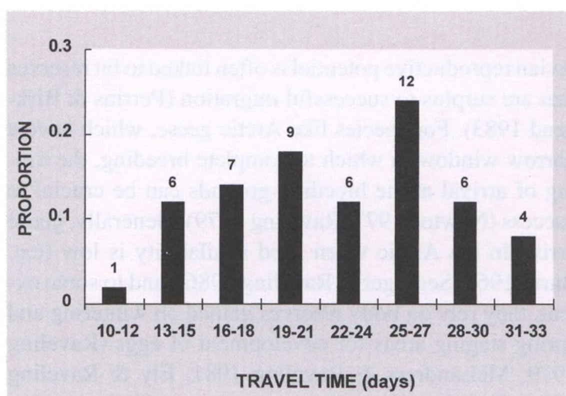

Figure 1. Number of days between departure from the traditional spring staging area in Helgeland, Norway, and arrival at the breeding area in Svalbard for female barnacle geese. Sample sizes are given above each column.

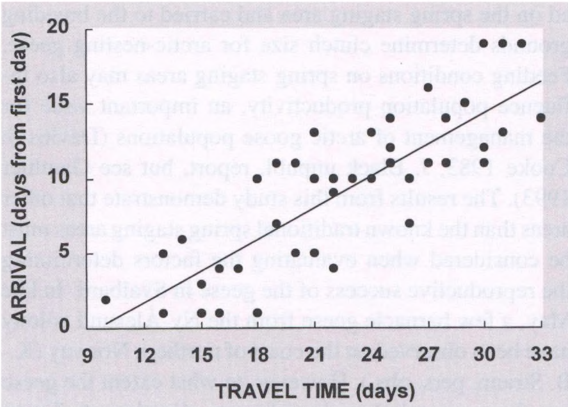

Figure 2. Arrival at the breeding area in relation to number of days spent on migration for female barnacle geese breeding in Ny-Ålesund, Svalbard, during 1993-1994; (Y = 0.7X - 6.7, r^2 = 0.69, N = 51, P < 0.0001).

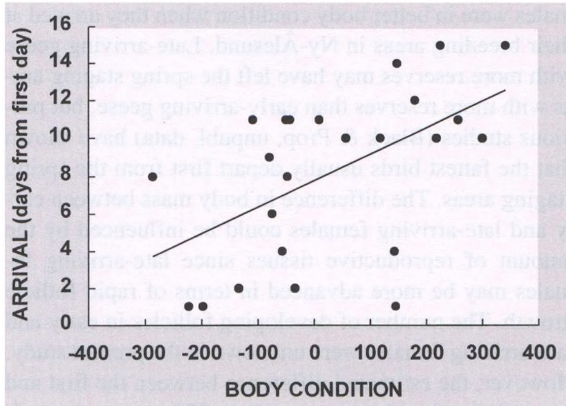

Figure 3. Linear regression of the date of arrival at the breeding ground on body condition upon arrival for female barnacle geese breeding in Ny-Ålesund, Svalbard, during 1993-1994; (Y = 0.01X - 7.7, r^2 = 0.29, N = 24, P < 0.007).

Results

There were no differences between years in date of departure from the spring staging area (Wilcoxon 2-Sample Test, Z = 1.93, N = 53, P > 0.05) or date of arrival at the breeding area (Wilcoxon 2-Sample Test, Z = 1.11, N = 76, P > 0.2). Neither were there differences between years in body mass (1993: 2,099 ± 55 g, N = 13; 1994: 2,219 ± 44 g, N = 11, t = 0.34, df = 23, P > 0.1) or in body condition upon arrival at the breeding area (t = 0.82, df = 23, P > 0.08). Furthermore, using year as a covariate had no significant effects on the results of our analyses and, therefore, years were pooled and adjusted values were used for departure and arrival.

Mean number of days between departure and arrival was 22.4 ± 0.8 (range 10-33 days, N = 51, Fig. 1). There was no significant relationship between the date of departure and the date of arrival for individual females (r^2 = 0.0008, N = 51, P > 0.8), indicating that early-leaving females were not necessarily the first to arrive at the breeding grounds.

Females arriving later spent significantly more time on spring migration (r^2 = 0.69, N = 51, P < 0.0001, Fig. 2) and were in better body condition on arrival than earlier-arriving females (r^2 = 0.29, N = 24, P < 0.007, Fig. 3). There was a positive, although not significant, relationship between the time spent travelling and body condition at arrival (r^2 = 0.29, N = 9, P = 0.13, Y = 21.46 + 0.02X).

Discussion

Barnacle geese breeding in the Ny-Ålesund colony in Svalbard do not seem to migrate directly from their traditional spring staging area at Helgeland in Norway to the breeding areas in Svalbard. The geese completed the 1,500 km journey in three weeks, on average, but they require only one or two days to cover a similar distance when migrating from their wintering areas to their spring staging areas (Owen 1981, Owen & Gullestad 1984). Furthermore, there was no relationship between date of departure and date of arrival for individual females. Therefore, the results show that the geese spend a considerable amount of time elsewhere before they arrive at their breeding area in Ny-Ålesund.

Ny-Ålesund holds one of the northernmost colonies of barnacle geese in Svalbard (Prestrud et al. 1989), and snow-melt generally takes place later there than further south in the archipelago. In May, large flocks of barnacle geese have been observed in south-facing slopes and underneath sea-bird cliffs in southern areas in Svalbard (Owen & Gullestad 1984, Prop et al. 1984, Prop & de Vries 1993). Geese feeding underneath a sea-bird cliff (Ingeborgfjellet) in May in southwest Svalbard (Nordenskiöld-kysten) were observed breeding in colonies further south and further north the same season (Black & Prop, unpubl. data) suggesting that birds from several colonies use this area as a staging area. For geese from the Ny-Ålesund colony, the availability of food is probably much greater in these southern Svalbard areas in May than in Ny-Ålesund where food usually is covered with snow until June. As has been shown in previous studies on geese, including barnacle geese in Svalbard, new plants of high energetic value become available as the snow melts (Fox et al. 1991, Gauthier 1993, Prop & de Vries 1993). Geese from the Ny-Ålesund colony may, therefore, benefit from spending some time in these snow-free areas before arriving at the nesting grounds further north. The length of the stay and the food quality may, therefore, determine body condition at arrival in Ny-Ålesund.

Compared to early-arriving females, late-arriving females were in better body condition when they arrived at their breeding areas in Ny-Ålesund. Late-arriving geese with more reserves may have left the spring staging areas with more reserves than early-arriving geese, but previous studies (Black & Prop, unpubl. data) have shown that the fattest birds usually depart first from the spring staging areas. The difference in body mass between early and late-arriving females could be influenced by the amount of reproductive tissues since late-arriving females may be more advanced in terms of rapid follicle growth. The number of developing follicles in early and late-arriving females were unknown in the present study. However, the estimated difference between the first and last arriving females is as much as 270 grams. Accordingly, it is very unlikely that the differences in body mass between early and late-arriving females can be explained by differences in reproductive tissues alone.

In general, late-nesting females produce fewer eggs and suffer a higher loss of goslings than early-nesting females (e.g. Cooke et al. 1984, Owen & Black 1989, Prop & de Vries 1993, Dalhaug et al. 1996, reviewed in Cooke et al. 1995). So why do late-arriving females of good body condition not fly directly to Ny-Ålesund, thus arriving earlier and thereby being able to produce more surviving young? One possible explanation may be that the fitness value of the brood decreases and that females invest less in the young and more in self-maintenance and survival late in the season (Drent & Daan 1980, Toft et al. 1984, Daan et al. 1990, reviewed in Rohwer 1992). Early in the season, females in poor body condition may therefore 'decide' to feed more in order to gain body mass before departure to the breeding ground. Accordingly, as the season progresses, the optimal body mass when arriving on the breeding grounds should increase in order to maximise survivability.

Several studies have reported that arctic-breeding geese spend a considerable amount of time feeding, and that they even gain body mass, in the pre-laying period on their nesting grounds (Budeau et al. 1991: greater white-fronted geese *Anser albifons frontalis*; Bromley & Jarvis 1993: dusky Canada geese *Branta canadensis occidentalis*; Gauthier 1993: greater snow geese *Chen caerulescens atlantica*; Ganter 1994: lesser snow geese). However, none of these studies have detailed information about dates of arrival of individual females. In three of these studies the mass gain results are based on samples from shot birds (Budeau et al. 1991, Bromley & Jarvis 1993, Gauthier 1993). The chronologically-dependent body condition at arrival found in the present study may therefore serve as an alternative explanation to these results since late samples of geese merely may have contained more late-arriving and thus heavier females than early samples.

Ryder (1970) suggested that food reserves accumulated on the spring staging area and carried to the breeding grounds determine clutch size for arctic-nesting geese. Feeding conditions on spring staging areas may also influence population productivity, an important issue for the management of arctic goose populations (Davies & Cooke 1983, J. Black unpubl. report, but see Gauthier 1993). The results from this study demonstrate that other areas than the known traditional spring staging areas must be considered when evaluating the factors determining the reproductive success of the geese in Svalbard. In late May, a few barnacle geese from the Ny-Ålesund colony have been observed on the coast of northern Norway (K.-B. Strann, pers. obs.). However, to what extent the geese use these areas is largely unknown. Gauthier & Tardif (1991) argued that geese with a long and costly migration distance have a long pre-laying period which enables them to replenish energy reserves used on migration. Possibly, barnacle geese use resources in more southern areas of Svalbard in their pre-laying period. More research is needed to locate these areas and evaluate their importance for barnacle goose reproduction in Ny-Ålesund.

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