The use of Balsfjord, north Norway, as a staging post by Knot during spring migration: fat deposition, muscle hypertrophy and flight strategies

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Knots of the *islandica* subspecies staging in Balsfjord, north Norway for two weeks in May 1985 and 1986, *en route* from the southern North Sea coasts to the Nearctic breeding grounds, stored substantial amounts of fat and protein. Although birds arrived in Norway with nutrient reserves larger than those carried by Knots in midwinter in Britain, they added on average another 2.5 g/d (1985) to 3.8 g/d (1986) before departure. Most of the mass increase was due to the deposition of fat, but protein-tissue was also deposited in the breast muscles and elsewhere in the body. It is suggested that Knots arrived somewhat heavier in 1985 than in 1986, but departed with rather similar body weights.

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INTRODUCTION

Studies by a joint Durham University/Tromsø University team in May 1985 and 1986 at Balsfjord near Tromsø (69°22'N, 10°18'E) focussed on the use of the fjord by migrating Knots *Calidris canutus*, which proved to belong to the Nearctic breeding population *C. c. islandica* (Davidson *et al.* 1986; Uttley *et al.* 1987). This note summarizes the results of studies on changes in body composition of birds during their period of stay in the fjord, i.e. approximately two weeks. Details of timings of arrival and departure, and of numbers occurring both at Balsfjord and elsewhere in north Norway, are given by Strann (1992).

ORIGINS

Recoveries in autumn and winter and resightings of Knots ringed and colour-ringed at Balsfjord have confirmed that birds migrating through Norway in spring spend the winter around the North Sea coasts, as illustrated in the maps published by Davidson *et al.* (1986), Uttley *et al.* (1987) and Davidson & Wilson (1992). One of 20 birds caught at Porsangerfjord in May 1987 had also wintered in the same area, as it had been ringed on the Wash, eastern England in December 1986 (Wood *et al.* 1988). In March and April, Knots prepare for migration to Norway chiefly from the German sectors of the Wadden Sea, as proved by recoveries of ringed birds, but some may depart for Norway direct from the Wash.

BODY MASS AND STORAGE OF RESERVES

The total body masses of Knots caught at Balsfjord in 1985 and 1986 are summarized in Table 1. As the first main wave of arrivals of birds occurred on the same date (10 May) in both years, the body mass data suggest that, on average, birds may have arrived in better body condition in 1985 than in 1986. Six individuals caught in both years averaged 22 g heavier (range 15-27 g) in the early morning of 12 May 1985 than in the late afternoon of 11 May 1986, which tends to confirm this. However, rates of increase in body mass can be very high. A bird caught just before departure, at 18.00 h on 28 May 1986, weighed 12 g more than at first capture 36 h earlier. Whether such rapid increases in mass can also occur soon after arrival, when birds must locate profitable feeding areas for the first time, is not known. If so, the body condition on arrival in 1985, as indicated by total mass, was probably only slightly better than in 1986, since the difference in aver-

Table 1. Body masses (corrected for time between capture and weighing) of Knots at Balsfjord, north Norway. The coefficient of variation (CV) is defined as SD/mean•100 (%).

Year	Day	*n*	mean (g)	SD (g)	CV (%)
1985	12 May	147	151.9	11.7	7.7
	19 May	699	163.3	13.7	8.4
	26 May	571	187.1	13.6	7.3
1986	11 May	213	141.5	11.8	8.3
	13 May	55	144.8	10.5	7.3
	27 May	244	205.7	12.7	6.2
	28 May	43	185.2	18.0	9.7

age mass was only 10.4 g but the time difference between catches in the two years was nearly 18 h.

By contrast, the average body mass at departure was probably somewhat higher in 1986 than in 1985. The difference of 19 g between early morning catches on 26 May 1985 and 27 May 1986 (a time difference of about 24 h) is greater than the maximum known rate of weight gain (12 g in 36 h), by more than 10 g. This conclusion is reinforced by comparisons of the body masses of six individuals caught in both years. These averaged 17 g (range 15-21 g) heavier on 27 May 1986 than on 26 May 1985.

In 1985, the main departure occurred on 28 May, whereas in 1986 many thousands left on 26 May and all but a few hundred of the remainder migrated on 27 May, after the catch on that day. Thus most of those caught on 27 May must have been in departure condition. The small catch on 28 May averaged almost 20 g less in body mass than the large catch on the previous day. Together with the information on the slightly later departure date in 1985, this suggests that birds may require to reach a threshold level of body mass (or fat reserves) before departure.

The overall rate of gain of mass in 1986 (64 g between 11 and 27 May, i.e. about 3.8 g/d) is considerably less than the maximum recorded (8 g/d) in the single bird recaptured on both 27 and 28 May at the end of its stay in Balsfjord. Two birds caught on both 11 and 27 May 1986 had increased in mass by 55 and 72 g respectively. The overall rate of mass gain in 1985 (averaging 2.5 g/d) was slightly less than in 1986, but the rate of gain in the second half of the 1985 period (19-26 May) was higher and closely similar (3.4 g/d) to the overall average in 1986. It is possible that the very cold first half of May 1985 may have depressed the rate at which body reserves could be stored, though the direct effects of low temperatures and any indirect effects acting via food availability cannot be separated with the data available.

Samples of birds were collected, under licence, in the two years to examine changes in body composition and muscle structure (Table 2). By chance, the sample taken on 12 May 1985 was significantly lighter (by 14 g) than the average of the catch on that day, but the birds selected as the sample, were also significantly smaller than the rest of the catch (wing

Table 2. Body composition of *islandica* Knots during their stopover in north Norway and in Britain. Figures quoted are means with SE in brackets. The lipid index is defined as the mass of fat divided by total body mass (x100%). The flight muscle index = (Lean dry mass of pectoral muscles)/(Standard muscle volume). Consult Evans & Smith (1975) and Piersma *et al.* (1984) for details of the latter method.

Date	Sample size (*n*)	Body mass (g)	Days after main arrival (before main departure)	Lipid index (%)	Flight muscle index (g/mm^3)
Balsfjord, north Norway					
12 May 1985	19	137 (2.3)	2	11.0 (0.8)	0.308 (0.005)
11 May 1986	24	135 (2.6)	1	14.0 (1.3)	0.308 (0.005)
26 May 1985	16	196 (2.7)	(2)	30.3 (1.9)	0.326 (0.004)
27 May 1986	27	206 (2.1)	(0)	33.5 (0.4)	0.327 (0.003)
Teesmouth, northeast England					
1 August 1985	7	112 (1.3)	2	4.5 (0.95)	0.224 (0.011)
10 December 1984	10	136 (2.4)	-	7.8 (0.66)	0.287 (0.004)

lengths of sample 172 mm ± 0.76 SE, n = 20; of catch 174.65 mm ± 0.35 SE, n = 146). This may not account for the lower lipid indices of the birds caught two days after arrival in 1985 (11%) when compared with those of the sample caught one day after arrival in 1986 (14%), since lipid indices should be independent of body size. This result runs counter to the finding of lower average body mass in the 11 May 1986 than 12 May 1985 catch. Again, by chance, it may be that the sample selected in 1985 happened to be the less fat birds amongst the catch, as well as the smallest birds.

Comparison between the 1985 and 1986 pre-departure samples must also be made with caution. Those selected in 1985 were deliberately chosen to include the heaviest individuals of a particular wing length, over a range of wing lengths. They are therefore significantly heavier, on average, than the rest of the catch on that day, but were also chosen to indicate the likely body compositions of birds at departure (which for most birds was two days later). The sample taken in 1986, however, was typical for the whole catch, and, as indicated earlier, most birds departed a few hours later. It is thus likely that the higher lipid indices recorded in the 1986 birds are better indicators of departure condition and that the apparent difference between the two years may not be biologically meaningful.

Table 2 illustrates that birds arriving in Norway in spring had higher fat reserves than those reaching Teesmouth in late summer or staying at Teesmouth in winter. This suggests that they accumulate much more fat than needed for the spring flight from the North Sea coasts to north Norway - perhaps as an insurance against finding poor feeding conditions in north Norway (Evans & Davidson 1990).

Protein reserves, measured in the form of flight muscle indices, were also larger on arrival in north Norway than in mid-winter at Teesmouth, and much larger than on arrival at Teesmouth in late summer after a (presumed) direct flight from the Nearctic breeding grounds. The flight muscle indices were closely similar for the 1985 and 1986 Balsfjord samples, both on arrival and just before departure, in spite of the reservations indicated above about the representativeness of the 1985 samples. They represent an average increase of 6% in dry mass of flight muscles, equivalent to an increase in (wet) muscle mass of some 2-3 g, depending on the size of the bird. As the total body mass increased between 11 and 27 May 1986 by some 64 g (Table 1) and lipid index from 14% (equivalent to 19.8 g fat) to 33.5% (equivalent to 69 g fat), an increase of 49.2 g fat, it is clear that the mass of parts of the body other than flight muscles and fat cells must also have increased during the birds' stay in Norway, by some 12 g. At present it is not known which organs and tissues are involved.

The functions of the increase in tissue masses (other than fat) at migration staging posts need further study. They could include insurance against food (protein) shortage at the destination but may also be important in affecting optimum flight speeds and therefore journey time.

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