Arctic summer conditions and British Knot numbers: an exploratory analysis

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An attempt is made to associate annual changes in the numbers of Knots *Calidris canutus* wintering in Britain with variations in summer conditions in the Queen Elizabeth Islands and north Greenland, the breeding range of the *islandica* subspecies. Large decreases in British Knot numbers in 1972, 1974 and 1979 seem to have been due to cold arctic summers, causing many adult deaths, as well as poor breeding success in 1972 and 1974. Better information on breeding distribution and success, and on the winter distribution of first-winter and older birds is needed to improve understanding of the ability of Knots and other waders to live in the High Arctic and to cope with variations in spring and summer climate.

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INTRODUCTION

If waders, and the wetlands they need, are to be protected effectively it is necessary to know where and how they are at risk. The conservation needs in western Europe are now well-known. Much less, however, is known about the distribution of arctic-nesting waders during the breeding season and the influence of events in the far north on their abundance and breeding success. Because densities of breeding birds are very low and working in the High Arctic is very expensive, it is difficult to gather directly detailed information about variations in abundance and breeding success. It is important, therefore, to deduce as much as possible from information that can be gathered by observers in temperate regions.

The Knots wintering in western Europe are almost entirely of the race *Calidris canutus islandica* (Dick *et al.* 1976). Numbers decreased from more than 600,000 wintering in the early 1970s (Prater 1976) to about 345,000 in the late 1980s (Smit & Piersma 1989). Most of the decline took place in the 1970s and has been thought to involve unfavourable breeding seasons (Davidson & Wilson 1992), although corroborative evidence comes only from observations in north-east Greenland (Green *et al.* 1977; Meltofte 1985). This note records results of an attempt to look at the extent to which the abundance and breeding success of British-wintering Knots may have been influenced by climatic variation across their entire breeding range. It emphasizes the need for more and better information before rigorous analyses can be attempted.

C. c. islandica breeds in north-east Greenland, south to *c.* 70°N, in north-west Greenland, south to 76°N, and on the Canadian high arctic islands, from Ellesmere Island (65°W) west to Prince Patrick Island (120°W) and south at least to Prince of Wales Island (72°N) (Hayman *et al.* 1986; Godfrey 1992). See also Figure 1 in Davidson & Wilson (1992), which describes the migration system of *islandica* Knots, one of several Nearctic-breeding waders which overwinter in the western Palearctic.

The decline in numbers of Knots wintering in Britain in the 1970s, measured by monthly counts made as part of the Birds of Estuaries Enquiry (BoEE) (Prys-Jones & Kirby 1989) is shown in Figure 5 of Davidson & Wilson (1992). This figure also shows that the proportion of first-winter Knots in some British ringing samples (Underhill *et al.* 1989) was very low in the 1970s and much higher in most years in the 1980s. The year-to-year changes in numbers in Britain, however, cannot always be accounted for simply by variations in the numbers of deaths and births. The increases from January 1971 to January 1972 and from 1978 to 1979 for example, if they are not due

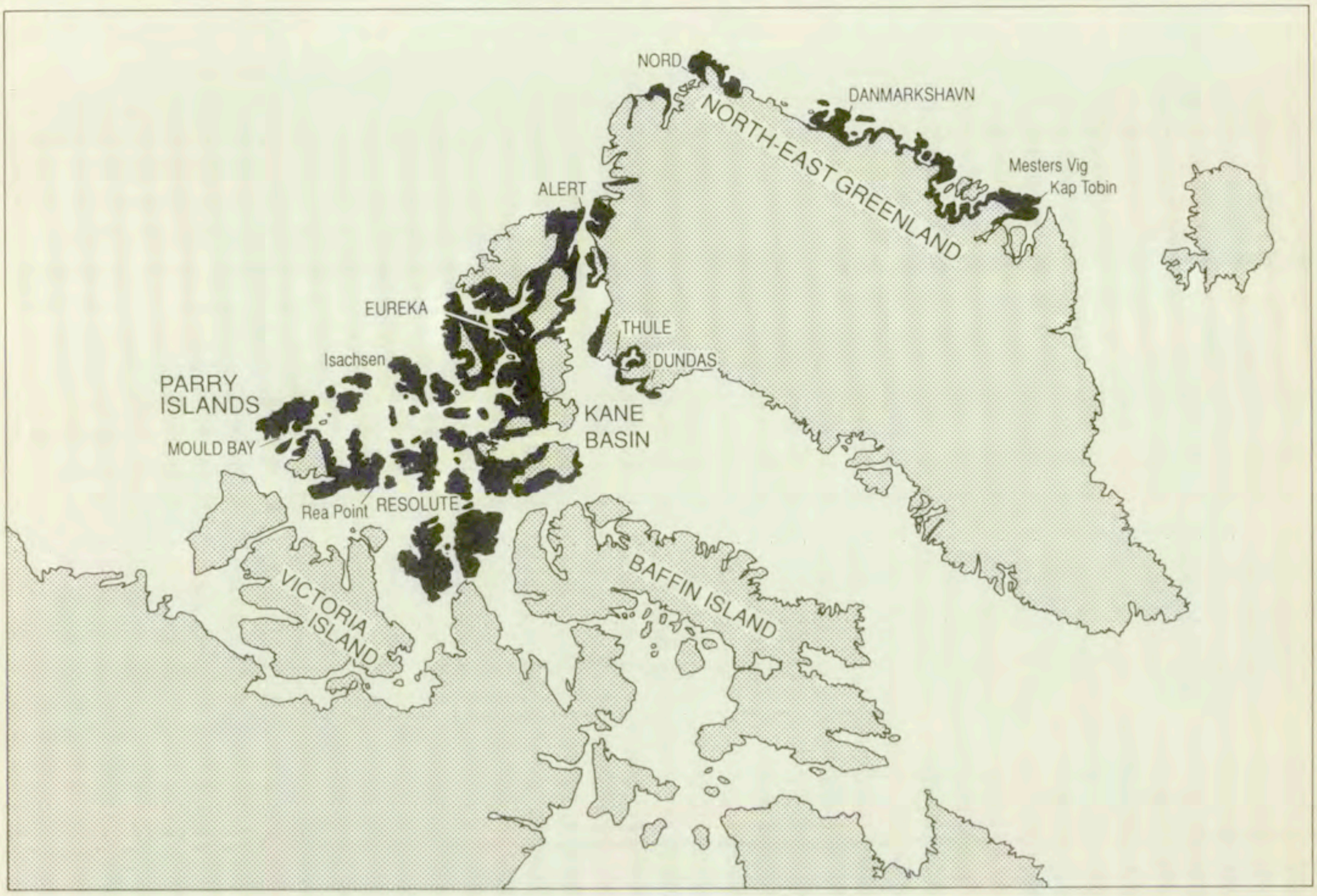

Figure 1. Weather stations in the breeding range of Knots *Calidris canutus islandica*. Weather stations marked in upper case letters are those from which most comprehensive data are available. Three regions are discerned: 1) Parry Islands represented by the Mould Bay, Rea Point, Isachsen and Resolute weather stations, 2) Kane Basin: Eureka, Alert, Thule/Dundas, and 3) north-east Greenland: Nord, Danmarkshavn, Mesters Vig/Kap Tobin.

solely to sampling or counting errors (for which there is no strong evidence), must have involved some form of additional immigration, or failure by birds to move further south.

These patterns of change in wintering numbers in part of the wintering range pose several questions of practical importance for understanding the dynamics of high arctic breeding waders. The uncertainties about the reliability and interpretation of the indices from only the British-wintering part of the population does, however, make assessment difficult. Were the very high numbers of birds in the winter of 1971 - 1972 abnormal, or would they have been usual in the 1960s? Why was recruitment so low in the 1970s? Why did numbers not increase substantially in those years in the 1980s when the percentage of young in the ringing catches was very high? Has the 'carrying capacity' of British estuaries for Knots been seriously reduced, so setting a new and lower limit to the numbers that can over-winter in Britain, irrespective of the size of the breeding stock? These are questions of practical importance. From the Canadian perspective it is important to discover whether any of the changes seen in Britain are likely to have resulted from events in the breeding range. Neither in Greenland nor in Canada have there been man-made alterations to habitat on a scale large enough to have influenced the total stock of resources available to Knots. In the 1970s much searching for oil and gas took place in the western Canadian High Arctic, involving the construction of a major supply base (now mothballed) at Rae Point, Melville Island (75°21'N, 105°43'W) and many temporary air strips and other scars elsewhere on the scarce lowland wetlands of the Parry Islands. But the total area destroyed, or damaged for many years, has been small in relation to the entire area of breeding habitat (personal observations) and the habitat choices of breeding Knots seem to be remarkably broad (Nettleship 1974). Thus it seems more useful to look for effects of climate than for those of people in the High Arctic.

All the data used here are derived from published sources, with total numbers of Knots derived from BoEE indices (Prys-Jones & Kirby 1989) and preliminary information on proportions of juveniles from Underhill *et al.* (1989). The weather data have, however, been combined and averaged in non-standard ways. The treatment of climate here is almost wholly confined to variations in mean monthly temperatures, though variations in precipitation, snow depth in spring, the lengths of melting and growing periods and in synoptic types have also been examined. It would have been better to use daily maximum and minimum temperatures during critical periods, rather than monthly means, to explore seasonal differences. But they were not readily available for all stations and there seems little merit in using elaborate climatological material while the Knot data are so limited.

BREEDING DISTRIBUTION

To select and interpret the weather data appropriately it is necessary to know the breeding range and distribution of *islandica* Knots. The full extent of the breeding range of *islandica* in Canada is, however, still uncertain (Godfrey 1992). The range is certainly large: some 3,000 km from east to west and 1,400 km from north to south. Much of the territory is uninhabitable. Icecaps cover most of northern Greenland and large tracts on Ellesmere, Axel Heiberg and Devon Islands, and only a small fraction of the area not covered by ice in summer is likely to be useful to Knots. On the Parry Islands, at the west end of the range, Boyd & Maltby (1979) estimated that no more than 2,820 km² (2.3%) of the total area of the islands (124,060 km²) could be used by Brent Geese, including 1,600 km² of 'well-vegetated terrain' and 1,200 km² of lakes, ponds and braided channels, only the shorelines of which could be used by Knots.

No similar estimates seem to have been made for the eastern Queen Elizabeth Islands or northern Greenland. Meltofte (1985) estimated the areas below 200 m above sea level as 51,000 km² in the region here defined as north-eastern Greenland, with 16,500 km² in north-western Greenland and 27,400 km² on Ellesmere and Axel Heiberg Islands, for a total of 43,900 km² in what is here called the Kane Basin region (Figure 2). The total areas of Ellesmere and Axel Heiberg Islands are 212,690 and 40,870 km², so that the lowlands occupy about 10.8%.

Meltofte (1985) estimated the numbers of breeding pairs of Knots as 6,700 in north-east Greenland, 3,000 in north-west Greenland and 10,000 on Ellesmere and Axel Heiberg Islands, a total of 20,000 pairs, compared to a midwinter count of 350,000 birds (Meltofte 1985: Table 3). Meltofte noted the great discrepancy between the numbers of breeding birds accounted for and the numbers found in winter, even after allowing for young of the year and non-breeders, and suggested that the breeding estimates were too low. The recent confirmation by Godfrey (1992) that the Knots breeding on Ellef Ringnes, Prince Patrick and Prince of Wales Islands (a total of 33,230 km²) are *islandica* expands the known breeding range of this race considerably. There is as yet too little evidence of nesting densities in the Parry Islands or on Prince of Wales Island to allow a direct estimate of numbers breeding in the west of the range.

Extrapolation from the departure directions of flocks of Knots leaving Iceland in spring (using Figures 5 and 7 of Alerstam *et al.* 1990) suggests that, if there are 20,000 pairs in northern Greenland and on Ellesmere and Axel Heiberg Islands, there may be another 40,000 pairs breeding further west: of 119 departing flocks, 79 followed tracks south of 300°, which would take them on rhumb line courses to western breeding areas. A total of 60,000 breeding

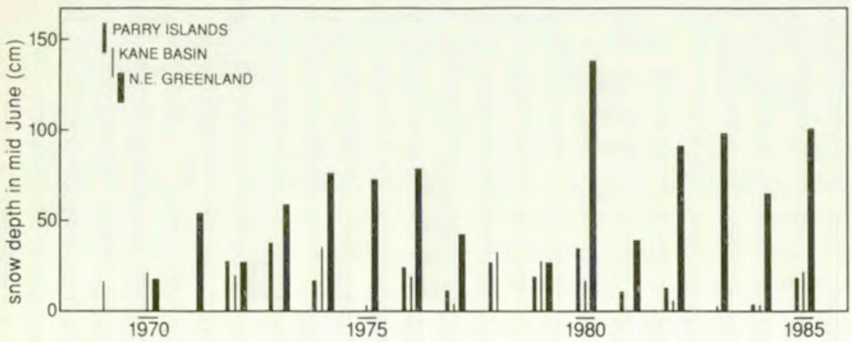

Figure 2. Mean snow depth (cm) in mid-June at stations in three regions in the breeding range of *C. c. islandica*.

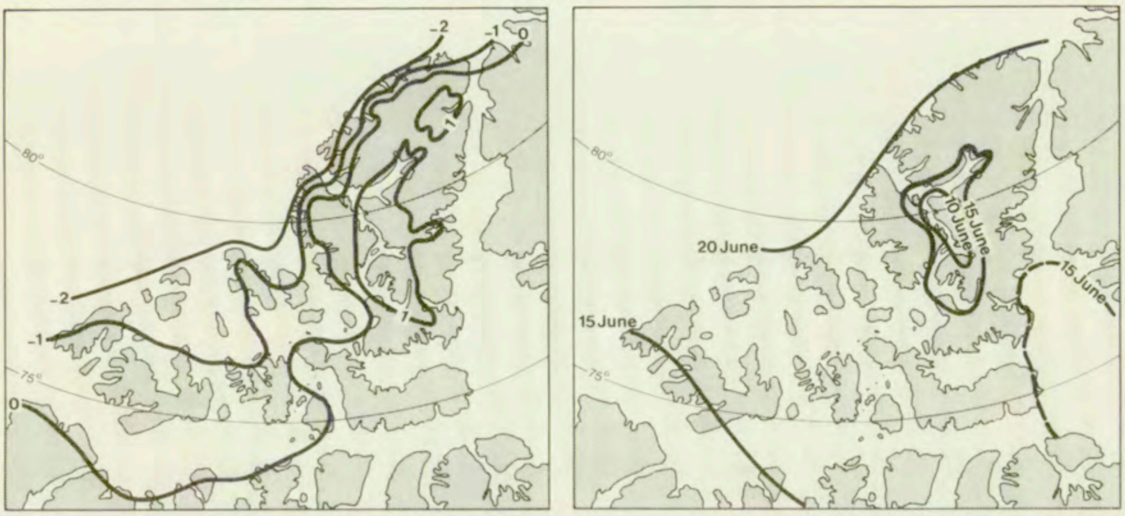

Figure 3. Mean June temperature (left) and mean date of initiation of melt (right) in the Queen Elizabeth Islands on the basis of the 1951 - 1980 normals (from Edlund & Alt 1989).

pairs is reasonable in relation to winter numbers. It also suggests that some 83% of the population may breed in Canada. Thus when looking for associations between weather, breeding success and adult survival in summer, it will be appropriate to give more weight to meteorological data from Canada than from Greenland. For this initial analysis I have, however, given equal weighting to three regions within the known breeding range. From west to east (Figure 1), they are 1) the Parry Islands, represented by the weather stations at Mould Bay and Resolute (supplemented by data from Rea Point and Isachsen, with shorter runs of data); 2) the Kane Basin-Eureka, Alert and Thule (with Dundas); and 3) north-east Greenland, represented by Nord, Danmarkshavn and Kap Tobin (with Mesters Vig).

ARRIVAL AND DISPERSAL

Islandica Knots arrive in their breeding range in late May and the first ten days of June (Salomonsen 1950; MacDonald 1953, 1954; Parmelee & MacDonald 1960; Nettleship 1974; Meltofte 1985), from Iceland and north Norway (Davidson & Wilson 1992). They usually occupy breeding territories almost immediately, without waiting for the snow cover to melt, nesting beginning 5-10 days later (Parmelee & MacDonald 1960; Meltofte 1985). The laying date is highly correlated with the extent and rate of loss of snow cover in early June in Greenland (Meltofte 1976, 1985; Green *et al.* 1977) and on northern Ellesmere Island (Parmelee & MacDonald 1960; Nettleship 1974; Morrison & Davidson 1990) but less so in the west of the range. There the annual snowfall and snow depth in spring are generally much smaller (Figure 2), so that many areas may be free of snow when the Knots arrive, although that was not so on Melville Island in 1974 (Maltby 1978).

With such a breeding timetable, temperature changes in June are likely to be important, both by affecting the clearing of nest sites and, more crucially, by determining when and how well adults can feed to supplement or restore reserves depleted during their flights from Iceland or north Norway and across Greenland. On arrival they feed almost entirely on grass shoots, seeds and other plant materials, changing to insects only in the second half of June (Salomonsen 1950; Parmelee & MacDonald 1960; Nettleship 1974). Spells of below-freezing temperatures may cause Knots to abandon attempts to feed; if the cold is prolonged the birds may die (Morrison 1975; Morrison & Davidson 1990).

RESULTS

Monthly temperatures

Figure 3 (from Edlund & Alt 1989) shows that there are substantial regional differences in mean June temperatures across the Queen Elizabeth Islands and that the date of initiation of snow melt is nearly a week earlier in the vicinity of Eureka than elsewhere.

Use of monthly mean temperatures for May and June to detect the impact of 'late springs' on the survival and nesting of Knots is obviously crude, because temperatures in most of May and in late June are unlikely to have much direct impact. Yet, at least for stations in northern Canada, the June mean

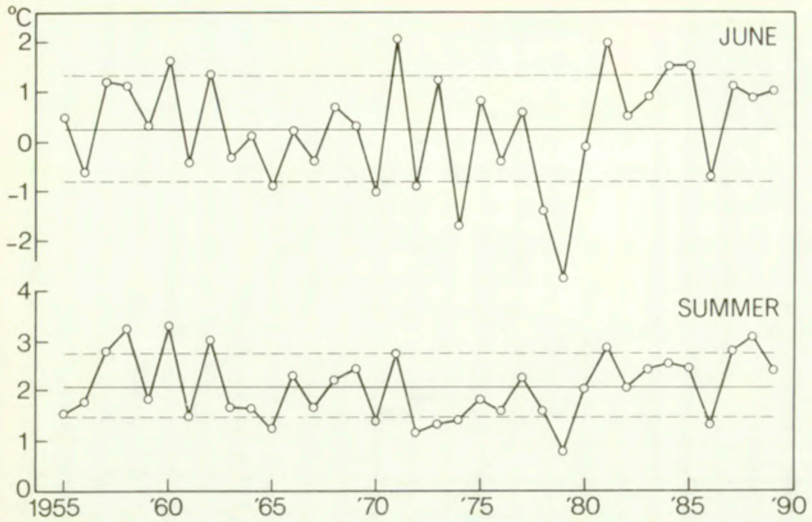

Figure 4. Mean monthly temperature (°C) in the breeding range of *C. c. islandica* in June and in summer (June, July and August) 1955 - 1989. The long term average and SD are indicatedby the thin and broken lines.

is a good index of conditions in the first half of the month, because the curve of increase in daily temperatures tends to be similar from year to year. Most variation is in the date on which the rapid increase in the daily mean temperature begins. A low monthly mean is usually the result of delayed onset of warming, rather than of a cool late June (Maxwell 1980).

Though the published index of Knot numbers in Britain goes back no further than 1970 - 1971, it is useful to look at a longer run of summer temperatures. Observations at most of the weather stations in the range of *islandica* began in the late 1940s or early 1950s. The composite series shown here cover the period 1955 - 1989. The mean June temperatures for the entire range (Figure 4) show that in the 1970s there were five years when the temperature was less than the period mean minus 1 standard deviation (0.3 - 1.1 = -0.80°C), with only one other year (1965) in the entire period below that limit. The summer temperatures (mean of June + July + August) show a similar picture of cooler summers in the 1970s than before or since, with four very warm summers between 1957 and 1962, unmatched until 1981 and 1987 - 1988.

The range-wide June temperatures are more variable than those of the entire summer. The June temperatures at individual sites are even more variable: Figure 5 shows the annual values for Mould Bay (close to the western limit of the range); Eureka (in

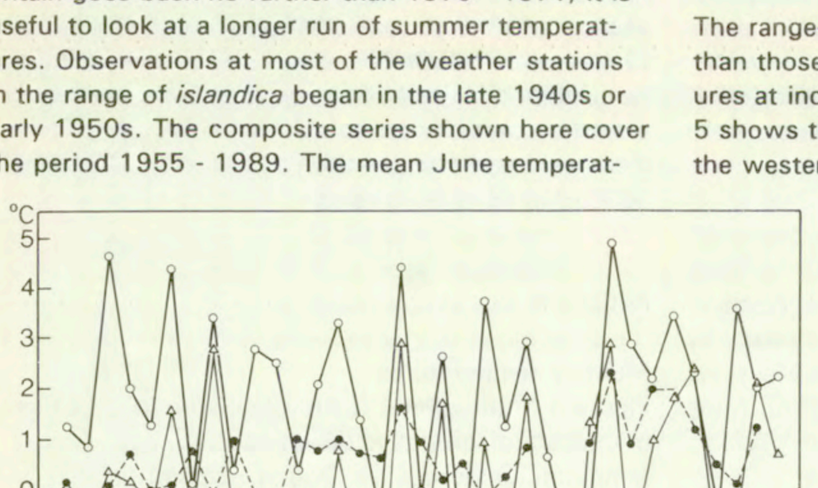

Figure 5. Mean monthly temperatures (°C) in June at three stations (Mould Bay, Eureka and Kap Tobin) in the breeding range of *C. c. islandica* during 1955 - 1989.

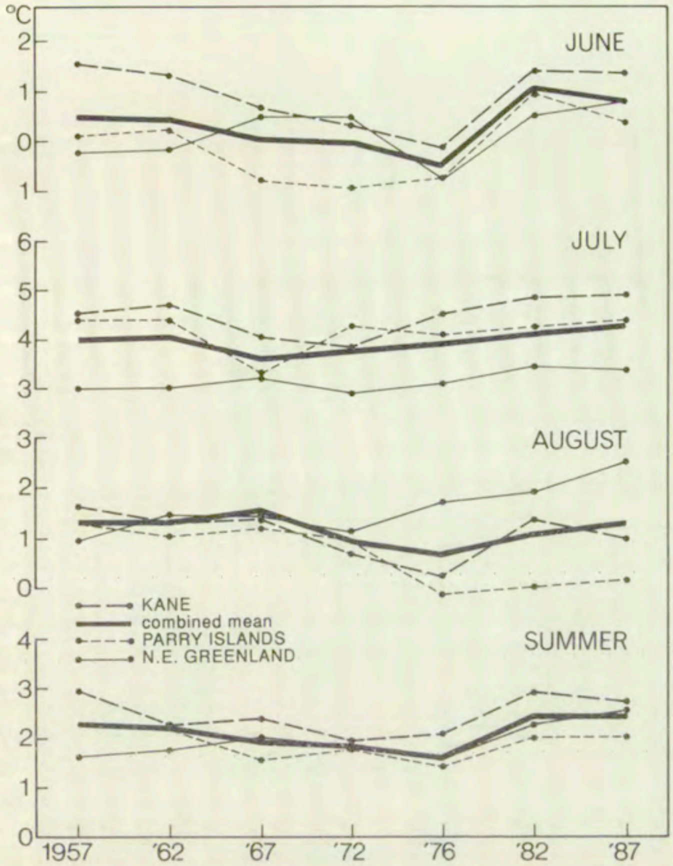

Figure 6. Five-year mean temperatures (°C) in June, July and August in the breeding range of *C. c. islandica* in 1955-59 to 1985-89.

the much warmer centre of the range); and Kap Tobin (at the eastern limit). The temperature at Kap Tobin (for which the June records for 1978 and 1979 are incomplete) has varied much less than at the western stations. In some years (notably 1962 and 1985) the station values did not move together. Among the six coldest years, 1965 was unusual in that Eureka was above average and Kap Tobin cold; in the other cold Junes Kap Tobin was relatively warm. These anomalies show that in some years weather conditions in different parts of the range may be dissimilar, so that the chance of successful nesting may be much greater in one region than in another.

Using 5-year means to look for short-term trends, Figure 6 shows differences between the three summer months, as well as between regions. The most obvious discrepancy has been in August: since 1970 north-east Greenland has grown much warmer, while the Parry Islands have been cool. (This might have led to increased regional differences in the ability of young Knots to fledge and migrate successfully, although there is, as yet, no evidence.) In the west and the east of the range, June temperatures tended to be higher in the 1980s than in 1955 -1964, but there is no strong indication of sustained general warming in summer.

British winter Knot numbers and arctic June temperatures

Figure 7 compares fluctuations in the numbers (derived from an index of numbers - Prys-Jones & Kirby 1989) of Knots found in Britain in January with those in high arctic June temperatures. There is a general correspondence, which is made much clearer by comparing the change in numbers from one January to the next with the temperature in the intervening June (Figure 8). With 1978 as a striking exception, the numbers in January tended to fall after cool Junes and rise after warmer ones (by some 11% for a change of 1.0°C).

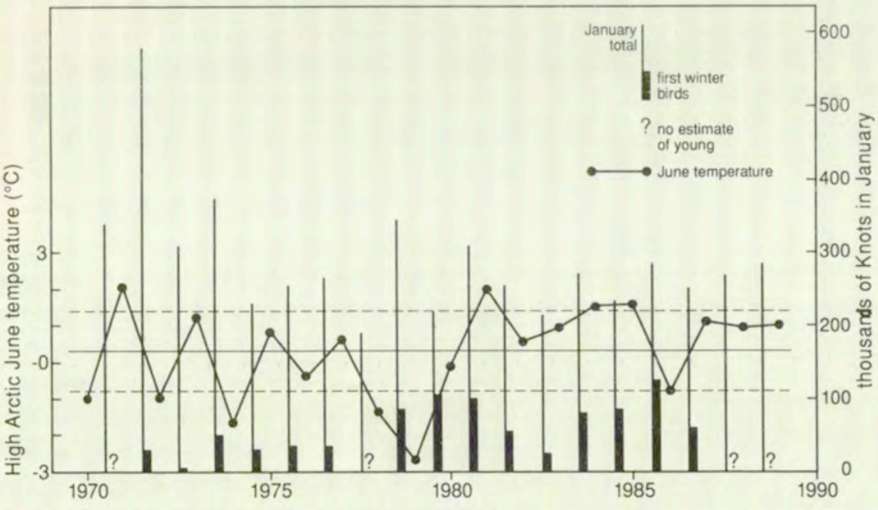

Figure 7. Fluctuations in the numbers of Knots in Britain in winter, in the proportion of first-winter birds in British ringing samples, and in June temperatures in the breeding range in 1970 - 1988.

The numbers found in Britain in January of year t + 1 can be represented by the equation:

$$N_{t+1} = N_t - L_t + Y_t + E_t + e$$

where N = no. of Knots counted in Britain, L = no. of deaths of British-wintering adults from one January to the next, Y = no. of young reared in year t and surviving to reach Britain, E = no. of *islandica* in other parts of the wintering range, and e an error term.

It is possible to estimate N, L and Y each year from the combination of BoEE winter counts and the proportion of young in British ringing samples, assuming that the latter reflect the proportion in the entire British-wintering stock, and that the efficiency of the winter counting has not varied much. No annual estimates of E can yet be made, because the counting of Knots in midwinter in some other parts of the range has been less complete and consistent than in Britain. Smit & Piersma (1989) compared the numbers found wintering in Europe in the early 1970s (from Prater 1976) with those in the late 1980s. In the earlier period 350,000 (57.5%) of a total of 609,000 birds were found in Britain. In the late 1980s Britain held 218,000 (63.2%) of 345,000 birds. Given the low precision and accuracy of the estimates, it could be argued that these figures imply that the proportion of the total stock wintering in Britain has remained nearly constant.

One major uncertainty, increased by the nature of the recorded variations in the percentage of young in the British ringing catches, is whether that proportion is affected only by the numbers of young

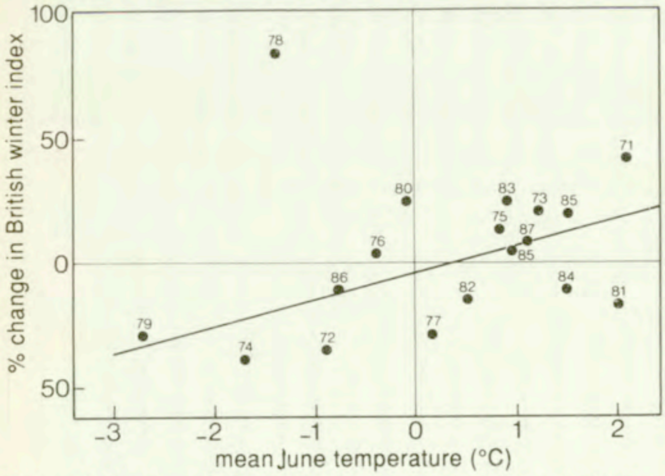

Figure 8. Percent change from one winter to the next in the numbers of Knots in Britain compared with the mean temperature in the breeding range in the intervening June. If the point for 1978 is included, r = 0.22, NS. However, that is so wild an outlier that it seems reasonable to exclude it: then n = 17, r = 0.59, p = 0.01.

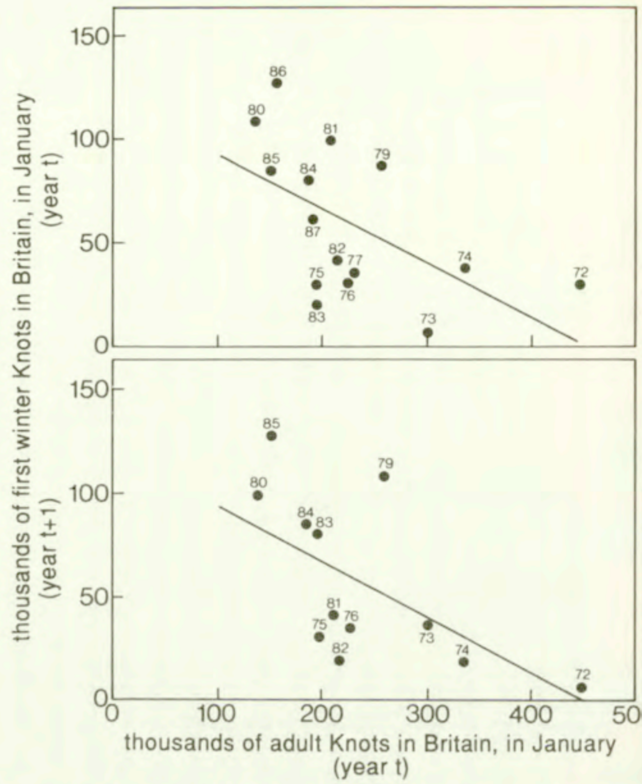

Figure 9. Numbers of first-winter Knots estimated to be present in Britain in January compared with the number of adult Knots in a) the same January, and b) the previous January.

fledged or whether there are winters in which the numbers of young reaching, or remaining in, Britain are affected by differential migration. It is important to find out more about this topic. Despite the strong association between June temperatures and changes in the numbers of wintering Knots, there is no simple relationship between June temperatures, or other measures of summer weather, and either the percentage of young in ringing catches in the following winter or the number of wintering young (derived from that percentage).

Yet the apparent variations in the proportion of young in Britain are not random. There are negative correlations between the estimated numbers of young in January of year t and the numbers of adults present in the same year (r = -0.5476, n = 15, $p < 0.05$) and in the previous winter (r = -0.6044, n = 13, $p < 0.05$) (Figure 9). The relationships may not be linear; but the scatter of the points probably does no more than emphasize the difference between the 1970s (with few young found in Britain until 1979) and the larger numbers of young found in most years in the 1980s. There is no estimate yet available of the percentage of young in the winter of 1977 - 1978, when the numbers of Knots in Britain were at their lowest, and which was followed by a massive increase, unlikely to be achieved solely by the recruitment of young birds.

One important point, noted briefly earlier and to be dealt with in detail elsewhere (Boyd in prep.) is that occasionally there may be substantial losses of adult Knots on spring migration. In 1972 and 1974 there were large numbers of recoveries in west Greenland, most south of the breeding range and some well before the time of nesting (Alerstam *et al.* 1986). In 1979, with the coldest June in the period of record, there were no recoveries in Greenland and the proportion of young in British catches in the following winter was unusually high (44%). Yet there was a 29% drop in numbers in Britain, from 344,200 birds in January 1979 to 245,900 in 1980. This suggests that many adults died during 1979, although the survivors bred successfully. No event that might have produced massive losses in 1979 has yet been identified, though the severity of the summer cold may have been sufficient. In most parts of the breeding range the chance of dead Knots being found must be very small.

DISCUSSION

Requirements for research and monitoring

Despite the limitations of the data used in this analysis a surprisingly strong correlation emerges between weather on the breeding grounds and changes in British wintering numbers. This would repay further investigation. The main purpose of this note is to emphasize how much remains to be learned about the *islandica* population of Knots and to identify what gaps most need to be filled to provide a sound basis for conservation actions.

To track changes in stock size it would be particularly helpful to:

1) extend annual monitoring of numbers across the entire winter range, and
2) collect data on the proportions of first-winter birds in different parts of that range.

Is it possible to make direct observations of the numbers of young birds in many places, or can that only be done under exceptionally favourable conditions? Can larger samples of ringed birds of known age be assembled? Both kinds of data are likely to be biased and it would be useful to know by how much, and in what ways, and also whether generally accepted corrections could be made, so as to provide an index of annual recruitment to the winter stock.

Winter surveys are unlikely to provide much information on the relative performance of Knots in different parts of the breeding range since populations are thought to mix extensively in winter. Hence there is a great deal of work to be done in the Canadian High Arctic. First, to define more precisely the breeding range of *islandica*, especially its southern limits. Second, to carry out more censuses associated with assessment of habitat so that it becomes possible to estimate, much more accurately than can be done at present, the quantitative distribution of the breeding birds, and to learn by how much local stocks can be expected to vary in numbers and breeding success.

Very little is known about how Knots leave the High Arctic. Are there places where substantial numbers of adults, or young, assemble before emigrating, or do they trickle away in small groups? If there are gathering areas, perhaps used to accumulate fat and protein before flying to Iceland and western Europe, do these require special protection, especially with the likelihood that exploitation of Arctic sources of oil and minerals will soon be expanded? Will public use of the Northern Ellesmere National Park, now still in the development stage, be a boon or a menace to Knots and other animals? Perhaps we need an international management plan for high arctic waders? If so, how should it be developed? How easy it is for a modest enquiry to raise difficult questions; and how important it is that biologists should 'get their retaliation in first', to borrow a phrase from another recreational field.

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