DISCRIMINANT AND GRAPHICAL ANALYSES OF NORWEGIAN KNOT BIOMETRICS: THE SEX AND RACE PROBLEM REVISITED

by A. G. Wood

A number of recent studies have used wader biometrics in the analysis of intraspecific problems such as sex discrimination (Puttick 1981, Harrington & Taylor 1982, Skeel 1982, Maron & Myers 1984). With the lack of between-sex plumage differences in a number of bird species, discriminant analysis has become valuable tool for sex determination (Green 1982, Wood 1987). This paper presents some preliminary analyses of a sample of Knot *Calidris canutus* data provided by recent expeditions to a migration staging area in north Norway (Davidson & Evans 1986, Davidson *et al.* 1986, Uttley *et al.* 1987).

METHODS AND RESULTS

2 267 Knots were caught with cannon nets in May 1985 and 1986 in Balsfjord, Norway (69°21'N, 19°18'E). A sample was measured in the field and then sacrificed to be used in studies of body condition. Thus they provided a sample of known sex birds. Only adult birds were used in this analysis. Four measurements were taken: (1) wing length, (2) bill length, (3) head + bill length (head length being derived from this), (4) tarsus + toe length. Data were transferred to computer file and analyzed using standard software packages (SAS and MINITAB).

A number of body size measurements were made on these Knot but not all were required in a discrimnant analysis which calculates a linear combination of the measurements serving to differentiate the sexes (Chatfield & Collins 1980). A stepwise discriminant analysis was performed on the data (using the method of inclusion and removal at each step) to investigate the best combination of sex predictor variates. The analysis identified wing and bill as the best sex prediction measurements, and the following discriminant function was derived:

$$D = 0.494B + 0.203W - 51.33$$

where D is the discriminant score, B the measured bill length and W the measured wing length.

The main problem with this discriminant function (and hence with the data) is that the probability of misclassification of a bird is 0.24 for females and 0.28 for males. These figures are more readily understood by reference to Figure 1, where measurements of the sexed birds are presented along with the discriminant line (50% probability of misclassification) and the 90% confidence prediction limits[1]. We can be 90% certain of the sex of an individual Knot if it lies outside the confidence limits on Figure 1.

Data from the Knot found in Balsfjord are providing very strong evidence that they are from the Nearctic population *C.c. islandica* (Davidson *et al.* 1986, Uttley *et al.* 1987). It is still possible to speculate, however, that there may be some birds from the Siberian population *C.c. canutus* mixed with the Nearctic birds. If this latter hypothesis were correct, then the biometrics of the Balsfjord Knot would exhibit a multimodal size frequency distribution within the sexes of the population. To give a theoretical example, if we expect just one race of birds in the population, then the size frequency distribution of measurements should be as in Figure 2a below. However, two races with a sexual dimorphism gives a more complicated picture as in Figure 2b.

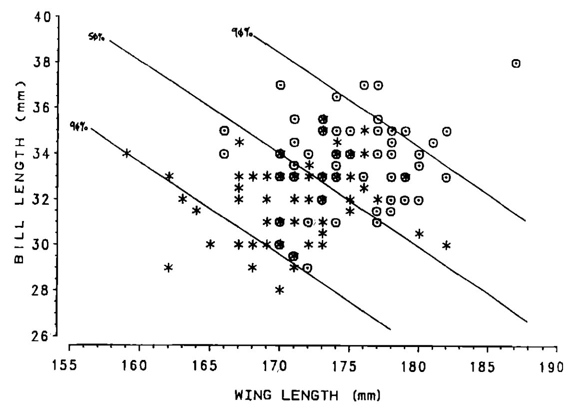

Figure 1. Bill and wing lengths of male (*) and female (o) Knot, with the discriminant line (0.494B = 51.33 - 0.203W) labelled 50%. Birds lying outside the 90% confidence prediction limits have a less than 10% chance of being misclassified.

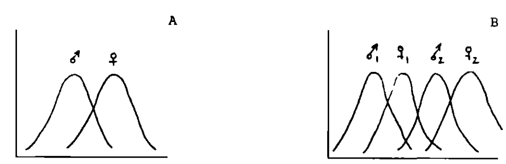

Figure 2. Theoretical size frequency of birds a) one population with sexual dimorphism, b) two populations with sexual dimorphism.

This hypothesis can be tested using a simple graphical technique of a theoretical quantile-quantile plot (Chambers *et al.* 1983) (for an explanation of this technique see appendix). Measurements of wing length are presented for this analysis although other measurements give similar results.

Figure 3 presents the simple frequency histograms of male and female Knot wing lengths. Few patterns may be envisaged in these data but we need a technique for comparing the frequency distributions with what might be expected if the data were sampled from a normally distributed population. Figures 4 and 5 give such a graphical comparison, where the original data are plotted against the theoretical normal distribution (normal score) for such a sample of data. Any departures from normality in the Knot wing lengths would show

[1] these approximate to ± $\log_e(0.90/(1.0-0.90))/y$ variate coefficient from discriminant function

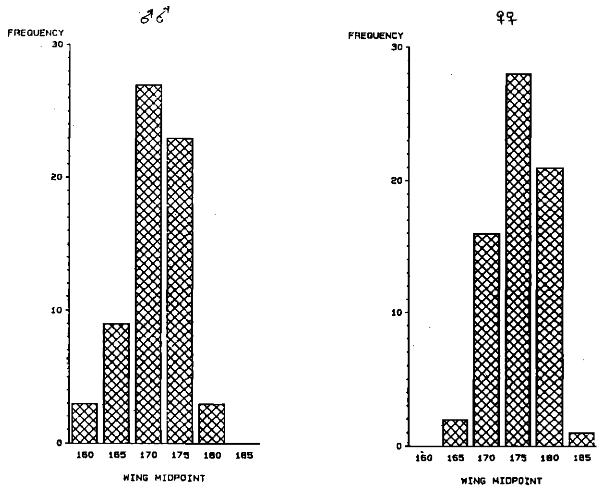

Figure 3. Frequency histograms of male and female Knot wing lengths.

up as departures from a straight line in Figures 4 and 5 (Chambers *et al.* 1983). Clearly both male and female Knot wing lengths exhibit little deviation from what would be expected if the data were samples from one population. Therefore we conclude that there is only one "population" of Knots in Balsfjord in May.

DISCUSSION AND CONCLUSIONS

A discriminant analysis of the biometric data from this population does not give a clear distinction between the sexes. Despite the substantial overlap in the size of male and female Knot, the extremes can be sexed, using the derived discriminant function, from measurements taken in the field.

Simple univariate plots of the distribution of measured wing lengths of Norwegian Knot provide further evidence for the hypothesis proposed by Davidson *et al.* 1986 and Uttley *et al.* 1987, that only the race *Calidris canutus islandica* is present in Balsfjord, North Norway in May.

ACKNOWLEDGEMENTS

I would like to thank all those members of the 1985 and 1986 Durham Shorebird Research Group expeditions to North Norway, and our Norwegian hosts, without whose work the data for this paper would not have been collected. Thanks also to John Croxall for his comments on an earlier draft of this paper.

REFERENCES

Chambers,J.M., Cleveland,W.S., Kleiner,B. and Tukey,P.A. 1983. *Graphical Methods for Data Analysis.* Duxbury Press, Boston.

Chatfield,C. and Collins,A.J. 1980. *Introduction to Multivariate Analysis.* Chapman and Hall, London.

Davidson,N.C. and Evans,P.R. (eds.). 1986. *The ecology of migrant Knots in North Norway during May 1985.* Report SRG1/85, Shorebird Research Group, Durham University.

Davidson,N.C., Strann,K-B., Crockford,N.J., Evans,P.R., Richardson,J., Standen,L.J., Townshend,D.J., Uttley,J.D., Wilson,J.R. and Wood,A.G. 1986. The origins of Knots *Calidris canutus* in arctic Norway in spring. *Ornis Scand.* 17: 175-179.

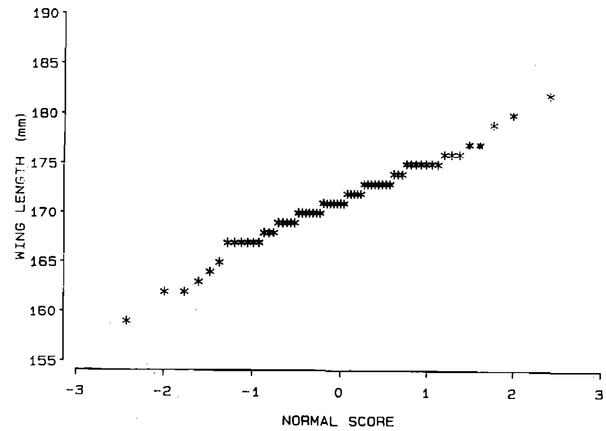

Figure 4. Wing length of male Knot plotted against the theoretical normal distribution.

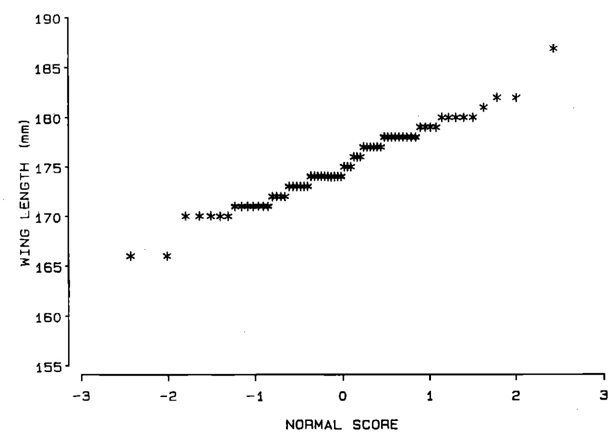

Figure 5. Wing length of female Knot plotted against the theoretical normal distribution.

Green,P.T. 1982. Sexing Rooks *Corvus frugilegus* by discriminant analysis. *Ibis* 124: 320-324.

Harrington,B.A. and Taylor,A.L. 1982. Methods for sex identification and estimation of wing area in Semipalmated Sandpipers. *J. Field Ornithol.* 53: 174-177.

Maron,J.L. and Myers,J.P. 1984. A description and evaluation of two techniques for sexing wintering Sanderlings. *J. Field Ornithol.* 55: 336-342.

Puttick,G. 1981. Sex-related differences in foraging behaviour of Curlew Sandpipers. *Ornis Scand.* 12: 13-17.

Skeel,M.A. 1982. Sex determination of adult Whimbrels. *J. Field Ornithol.* 53: 414-416.

Uttley,J.D., Thomas,C.J., Davidson,N.C., Strann,K-B. and Evans,P.R. 1987. The spring migration of Nearctic Knots *Calidris canutus islandica*: a re-appraisal. *Wader Study Group Bull.* 49, *Suppl./IWRB Special Publ.* 7: 80-84.

Wood,A.G. 1987. Discriminating the sex of Sanderling *Calidris alba*: some results and their implications. *Bird Study* 34: 200-204.