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Computer analysis of wader morphometric data

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INTRODUCTION AND METHOD

Published accounts of the analysis of wader morphometric data for the identification of populations and subspecies, eg. Pienkowski & Dick (1975) and Kersten *et al.* (1983), have generally followed Griffiths (1968, 1970) in analysing their samples using the Percentage Cumulative Frequency diagram method (Harvey 1949), and making use of probability graph paper. This enables the means and standard deviations of component populations of multimodal frequency distributions to be determined and compared with data from known populations.

An alternative method is that developed by Bhattacharya (1967) in relation to fish population analysis, and based on logarithmic differences between the class frequencies. Although it contains an element of subjectivity, Bhattacharya (1967) considers it to be more objective than the probability paper method and to have a clearer mathematical basis. This method was therefore used as one tool in a study of Dunlins *Calidris alpina* in the Algarve, southern Portugal (Batty 1991), by means of the computer programme BHATTAC, contained in Sparre (1987).

Normally distributed components contained in a length frequency sample are represented as straight lines, as in the probability paper method. When the user has identified a sequence of points as conforming to a straight line with a negative slope on the Bhattacharya plot (Figure 1), the programme performs a regression analysis to give a mean length of the component, the number of individuals in the component, the correlation coefficient r, and the confidence interval and statistical significance of r. The identification of components always begins towards the left of the plot, and each component is subtracted from the remaining part of the frequency distribution after identification. As the user may have to make a choice as to which points to include in any one straight line, various options or interpretations of the data may be tried.

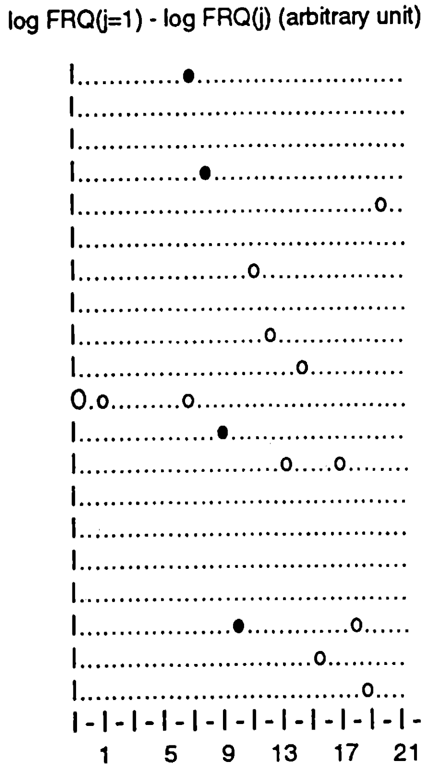
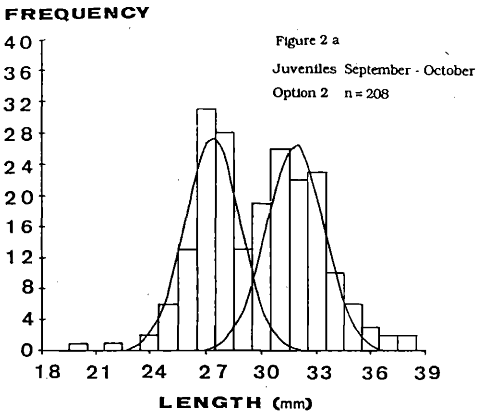
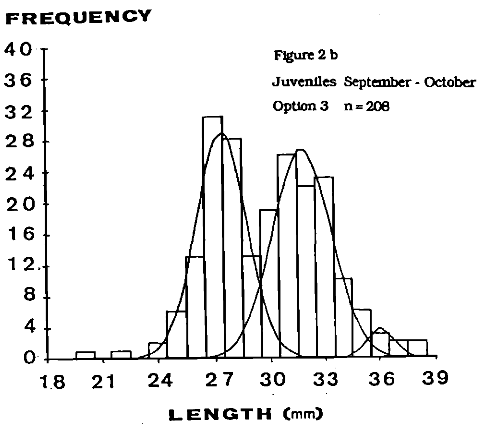


Figure 1. Bhattacharya plot of logarithmic differences of the class frequencies against the mid points of the classes for the September – October sample of juvenile Dunlins. Sequence of points comprising component 1 in option 3 is shown by solid circles.
(j = lower limit of length group)





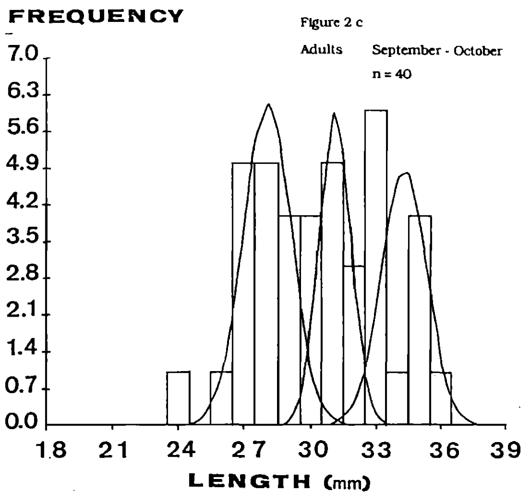
RESULTS

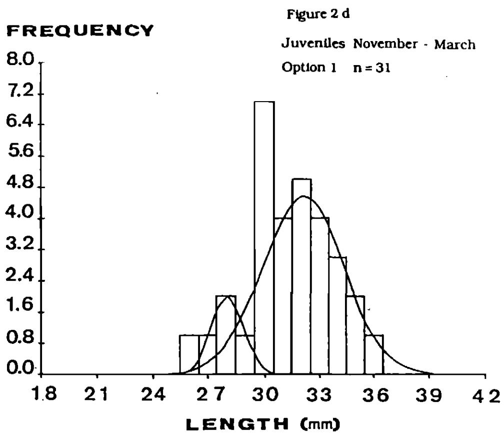
The frequency distributions and Bhattacharya analysis of the bill–lengths of Dunlins, caught in the Algarve during 1984–88 (Batty 1991), are presented in Table 1 and Figures 2a–f. Superimposed on the graphs are the normal distribution curves of the components identified and drawn by the Bhattacharya analysis programme. It should be noted that the sample sizes for all but juvenile Dunlin in September – October are too small to allow detailed conclusions to be drawn about flock composition, but the results are presented here in order to illustrate the use of Bhattacharya analysis and were supplemented by other observation in the original work (Batty 1991).

September – October

Juveniles

The Bhattacharya analysis gave three interpretations of the data, two identifying two components each, and one identifying a third.





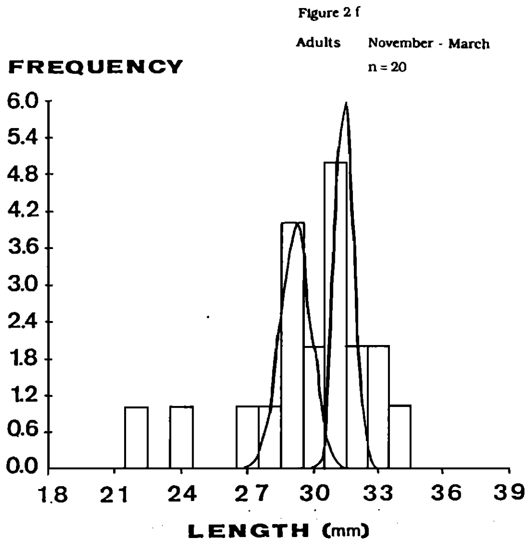


Figure 2a – 2f. The frequency distributions of the bill lengths of Dunlins caught in the Algarve during the study, with normal distribution curves of the components identified and drawn by the Bhattacharya analysis programme superimposed. Axis intervals as given on original computer printout.

Options 1 and 2 were almost identical but only option 2 was statistically significant (Table 1 & Figure 2a). Comparing the means with published data (Griffiths 1970; Cramp & Simmons 1983), these birds were readily identified as *C. a. schinzii.* The standard deviation of the bill–lengths of the presumed females (component 2) are, however, considerably higher than those published. The most likely explanation for this is the presence of *C. a. alpina* birds in the upper range, which is taken into account in option 3.

Component 1 of option 3 (Table 1 & Figure 2b) is very similar in its mean bill length and standard deviation to that in option 2, and can again be identified as *C. a. schinzii* males. The mean bill–length of component 2 is very close to that of the females of the Scandinavian population of *C. a. schinzii*, although the standard deviation is still slightly higher and may be due to the presence of a few *C. a. alpina* males. Component 3 may reasonably be identified as *C. a. alpina* females, the difference in the means being due to the small number of birds in the component sample.

Considering the apparent presence of *C. a. alpina* in the Algarve at this period according to ringing/ recovery data (Batty 1991), and in Morocco according to Pienkowski & Dick (1975) and Kersten *et al.* (1983), this third option would seem to be a better interpretation of the data. If this interpretation is accepted, and an equal sex ratio is assumed, then the percentage composition of the juvenile Dunlin population during September – October is approximately:

C. a. schinzii	males	47%	98
	females	47%	101
C. a. alpina	males	3%	7
	females	3%	7

There were also a very few birds at the lower end of the bill–length scale that did not feature in these components, suggesting the presence of a very small number of the *arctica* race.

Adults
Although the total sample size (40) was much smaller than that of the juveniles (208), the Bhattacharya analysis produced a three component interpretation of statistical significance (Table 1 & Figure 2c). Component 3 can again be identified as mainly female *C. a. alpina*. Component 2 presumably contains a mixture of female *C. a. schinzii* and male *C. a. alpina* and component 1 is principally male *C. a. schinzii* with possibly a small proportion of female *C. a. arctica.*

November – March

Juveniles
The small sample size (31) makes these data difficult to interpret. Two analyses were performed (Table 1, Figure 2d & 2e), and although the regression analysis was more significant in the first option (Figure 2d), the standard deviation of the second component was very high, suggesting the presence of a third component, which was identified in option 2 (Figure 2e). Although none of the components in option 2 produced a statistically significant regression coefficient, the means of the first two were almost identical to those in option 1. Components 1 and 2 in both interpretations can be identified as *C. a. schinzii* (closest to means for Icelandic population). Component 3 can be identified again as *C. a. alpina* females. The female *C. a. schinzii* component 2 (including presumably male *C. a. alpina*) is much larger than the other two, but this may be a result of the small sample size. It is therefore difficult to reach any meaningful conclusions regarding the relative numbers of each race.

Adults
The adult sample size was even smaller (20) so that no definite conclusions could be drawn from these data (Table 1 & Figure 2f). The sample did, however, contain birds with bill–lengths of 25 mm or less, which suggests a possible *C. a. arctica* component. The rest of the sample was probably mainly *C. a. schinzii* with perhaps a very few *C. a. alpina.*
CONCLUSION

Table 1. Summary of results of Bhattacharya analysis of Dunlin bill-lengths (mm.)

a	n	Interval	Mean	S	N	Cal.N	r	p
September-October, Juveniles								
Option 1								
1	5	25-30	27.812	1.473	102	101		
2	6	31-37	32.444	2.037	104	108		
Option 2								
1	5	25-30	27.812	1.473	102	101	-0.929	< 0.001
2	4	31-35	32.302	1.566	98	104	-0.898	< 0.001
Option 3								
1	4	26-30	27.845	1.337	100	98	-0.931	< 0.001
2	4	31-35	32.243	1.602	99	108	-0.891	< 0.001
3	3	35-38	36.584	0.708	7	7	-0.866	< 0.01
September-October, Adults								
1	3	27-30	28.504	1.044	17	16	-0.916	< 0.001
2	3	30-33	31.580	0.720	11	11	-0.962	< 0.001
3	4	33-37	34.784	1.022	12	13	-0.556	< 0.05
November-March, Juveniles								
Option 1								
1	2	28-30	28.500	0.849	5	4	0	
2	5	32-37	32.625	2.226	26	26	-0.957	< 0.001
Option 2								
1	2	28-30	28.500	0.849	5	4	0	
2	2	32-34	32.500	1.495	23	19	0	
3	2	35-37	35.432	1.139	3	4	0	
November-March, Adults								
1	2	29-31	29.666	0.693	10	7	0	
2	2	31-33	31.905	0.326	7	9	0	

a = Component number
n = Number of observations used to estimate component
S = Standard Deviation
N = Number in component (observed)
Cal. N = Calculated number in component
r = Correlation coefficient of regression analysis
p = Probability

cally significant regression coefficient, the means of the first two were almost identical to those in option 1. Components 1 and 2 in both interpretations can be identified as *C. a. schinzii* (closest to means for Icelandic population). Component 3 can be identified again as *C. a. alpina* females. The female *C. a. schinzii* component 2 (including presumably male *C. a. alpina*) is much larger than the other two, but this may be a result of the small sample size. It is therefore difficult to reach any meaningful conclusions regarding the relative numbers of each race.

Adults
The adult sample size was even smaller (20) so that no definite conclusions could be drawn from these data (Table 1 & Figure 2f). The sample did, however, contain birds with bill-lengths of 25 mm or less, which suggests a possible *C. a. arctica* component. The rest of the sample was probably mainly *C. a. schinzii* with perhaps a very few *C. a. alpina.*

CONCLUSION

BHATTAC was an easy, fast, very convenient way of analysing the Dunlin bill-length frequency data and I recommend anyone with access to friendly fisheries biologists to investigate this programme.

The analysis shows the majority of juvenile Dunlin in the Algarve in the autumn and winter are of the race *C. a. schinzii* in agreement with Pienkowski & Dick (1975) and Kersten *et al.* (1983) for nearby Morocco. The interpretation of adult data was more difficult, owing to the much smaller sample sizes, but the proportion of adult *C. a. schinzii* was almost certainly to some degree smaller than that of the juveniles. This may possibly reflect an earlier onward migration by the adults to N.W. Africa.

The smaller proportion of juvenile *C. a. alpina* in autumn is consistent with the findings of Pienkowski & Dick (1975) in Morocco, and the apparent increase in winter can be attributed to post-moult dispersal of birds from the Wadden Sea and the Wash. The adult data are again more difficult to interpret but, although the apparently high proportions of *C. a. alpina* adults is in contrast to the findings of Pienkowski & Dick (1975), it is consistent with ringing/recovery data (Batty 1991) and supported by Kersten *et al.* (1983) in Morocco.
A small number of adults and juveniles of the *arctica* race were present in autumn, although only adults were recorded in winter.

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