FEATURE ARTICLES

HOW TO ANALYSE BIMODAL RINGING DATA

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Introduction

In a previous article in Safring (2(3) 1973, 20-21), one of us (J.H.) presented data on the wing-lengths of the Cape Bulbul. The data were shown in the graph to have two "humps" i.e. to be bimodal. If wing-length was used as an indication of sex, the chances of being correct were calculated. It has since been suggested that this technique would be useful for ringers but as presented, the method would be difficult for most to understand.

A step by step procedure has therefore been given below which even the most non-mathematical ringer will be able to follow. The only requirement is that the ringer's data when plotted out should appear approximately bimodal. It does not matter, of course, what parameter is being considered. It could be weight, bill-length, or any other standard measurement.

Method

The method used is that of Griffiths (1968) - Multimodal frequency distributions in Bird Populations - Bird Study 15 (1):29-32. The procedure is as follows:-

STEP 1

Draw up Table 1 and then figure 1.

NOTE 1.1. A wing-length of 87mm means a wing-length of between 86,50 and 87,49mm.

1.2. Put the number of birds with a given wing-length in the appropriate cell.

1.3. Add up the number in each cell to obtain the total (in this case 122).

1.4. Divide each cell entry by the total and multiply by 100 to obain percentage frequency F.

1.5. Check that the frequencies come to 100%.

1.6. Starting at the top add up the frequencies to obtain the percentage cumulative fraction (C.F.% Down), working down the page.

1.7. Plot the cumulative fraction (C.F.% Down) against the wing-length on probability paper (available from any large stationer). To plot the graph proceed as follows:-

1. Lay the probability paper down with the linear axis horizontal and the probability axis verticle.

2. Mark the linear x - axis (horizontal) off in appropriate units for wing-length. The vertical axis is already marked off in cumulative percentage probability.

3. Plot the C.F.% (Down) against the upper limit of the cell boundary i.e. 22,96% at a wing-length of 89mm must be plotted at x = 89,5mm (not 89mm) and y = 22,96%. (Reverse this convention when plotting

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C.F.% (up) i.e. plot 23,78% at 97mm at x = 96,5% and y = 23,78%).

1.8. Note the point of inflection on the graph. The % that this occurs at (P%) is the proportion of females.   (In this case P=50). The C.F.% (down) is a composite curve (i.e. it is made up of 2 curves) above 93mm males predominate, below 93mm females predominate. The graph seems to be approximately straight at each end with a "twiddle" or "change over point" or "point of inflection" at about 93mm.   (The point of inflection is rather like a mild "S" bend).

1.9. Starting at the top of Table 1, calculate the (C.F.%(down) x 100 / P) entries until the point P is reached at about 93mm.

1.10. Starting at the bottom calculate the C.F.%(up) and the adjacent column (C.F.(up) x 100) / (100-P), until the point P is reached.

1.11. Plot both columns 5 and 7 from table 1 on to the graph.

STEP 2

It will be seen that columns 5 and 7 plot almost straight lines on the graph.   Project both these lines until they cross the 98% and 2% levels.   The points at which the male and female lines cross these levels yield the 96% confidence limits.   This means that 96% of all the males will lie within the limits of 92 - 101mm and 96% of all females will lie in the range 87 - 95mm.

The wing-lengths at which the lines cross the 50% level are the mean values.   Table 2 shows how to calculate the standard deviation.

All the required parameters can be calculated from steps 1 and 2. It is now necessary to determine the significance of the results.

STEP 3

Draw up Table 3.

NOTE:3.1. The upper limits of the wing-length interval is entered under L i.e. for a wing-length of 85, record L as 85,5.

3.2. The "standardised normal deviates" z_1 and z_2 are calculated, wing M_1, S_1 and M_2, S_2 from Table 2.

3.3. To determine the probabilities P_1 and P_2, draw up a graph of P_r ($z = \bar{z}$) vs. $\bar{z}$ from Table 5.   (This will be a straight line on probability paper).   Look up the z value and scale of the probability paper.

3.4. Column 6 in Table 3 is

$$\frac{P \times P_1 + (100-P)P_2}{200}$$

Where P is the proportion (%) of the shorter winged group (i.e. females).

3.5. Column 7 is column 6 multiplied by the total number of birds in the sample. $P_1 = P_r$ ($z_1 \le \bar{z}$) is the probability that a female will have a wing length less than or equal to some preassigned value. Similarly for P_2 and the males.   Column 6 is the mean value of the two cumulative probabilities P_1 and P_2.

STEP 4

Draw p Table 4.

NOTE:4.1. The expected number of birds with a wing-length of 87 for ex mple, is computed by subtracting the two adjacent elements

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of column 7 in Table 3 i.e. 1,04 = 1,28 - 0,24.   Subtract adjacent
pairs all the way down column 7 in Table 3 to arrive at the expected
frequencies.

4.2. To calculate the chi - square it is necessary that the expected
values in adjacent cells be coalesced so that they exceed three i.e.
the first four cells are coalesced.

$$\text{Expected} = 0,06 + 0,18 + 1,04 + 3,24$$
$$\text{Observed} = \quad 1 \quad + \quad 1 \quad + \quad 1 \quad + \quad 1$$
$$\text{and chi squared} = (\text{Obs} - \text{Exp}) \, 2 \, / \, \text{Exp.} = 0,06.$$

4.3. Calculate each chi-squared and find the total.

4.4. Determine how many chi-squared values were used to arrive at
this total.   In our case 12.

4.5. The number of parameters estimated is 5 (i.e. M, M_2, S_1, S_2 and
P).

4.6. The "number of degrees of freedom" is 6 = 12 - 5 - 1.   We must
sacrifice a degree of freedom because chi^2 has been estimated).The
chi-squared test compares the observed and expected valves of an
actual and theoretical distribution.   If the chi-squared value is
higher than a tabulated confidence limit then the theoretical dist-
ribution (i.e. explanation) is rejected.

4.7. Compare the chi-square value of 3,48 against the values in Table
6, to determine the significance.   In this case 3,48 is much higher
than 2,20 (chi-squared for 6 degrees of freedom and at the 90%
level is = 2,20).   Thus we should not accept the theoretical dis-
tribution.   (Chi-squared at 6 degrees of freedom corresponds to a
probability of 74%).   The conclusion is that in this case there is
no statistically significant difference between the wing-lengths of
male Cape Bulbuls and female Cape Bulbuls.

Discussion:

It should be pointed out that the whole procedure described above
starts from the point at which the ringer plots out his wing-length
data and finds the suggestion of bimodality.   In the example given
above, it has always been assumed that the two humps are due to
males being larger than females.   In the original article this
assumption was based on information derived from published material
on museum skins where sex was directly determined.   If this know-
ledge had not been available, the bimodality could have been pro-
duced by, for example, two populations of birds being present or
juveniles in the population or some other factors.   Therefore one
has to have some sort of back-up information to support the proposal
that the larger group is male and smaller group is female.   It would
also be more likely for sex to divide the group in 50% of one and 50%
 of the other, than say age where the proportion of young birds
would change according to the time of the season.

Although in the example given of 122 Cape Bulbul data, the pro-
cedure described produces a negative conclusion, certain conclusions
can be drawn.   It seems likely that the bimodality would be proved
(statistically) if the following conditions are applied:-

1. The use of a much larger sample (at a guess about 500 birds).

2. Birds with obviously worn feathers should be excluded from
the analysis.

TABLE   1

Wing-Lengths of the Cape Bulbul

Wing Length mm	No.	Fraction F%	Cumulative Fraction C.F.%(Down)	$\dfrac{\text{C.F.\%(Down)} \times 100}{P}$	Cumulative Fraction C.F.%(Up)	$\dfrac{100-\text{C.F.(Up)} \times 100}{100-P}$
85	1	0,82	0,82	1,64		
86	1	0,82	1,64	3,28		
87	1	0,82	2,46	4,92		
88	1	0,82	3,28	6,56		
89	10	8,20	11,48	22,96		
90	10	8,20	19,68	39,36		
91	13	10,66	30,34	60,68		
92	14	11,48	41,82	83,64		
93	9	7,38	49,20			
94	7	5,74	54,94			
95	13	10,66	65,60		45,10	9,80
96	13	10,66	76,26		34,44	31,12
97	12	9,84	86,10		23,78	52,44
98	7	5,74	91,84		13,94	72,12
99	6	4,92	96,76		8,20	83,60
100	2	1,64	98,40		3,28	93,44
101	2	1,64	100,04		1,64	96,72

Total: <u>122</u>   <u>100,04%</u>

<u>Note</u>: P is proportion at point of inflection   P = % Females

100 - P = % Males

TABLE   2

Calculations of Means and Standard Deviations

	Males	Females
mean mm	$M_1 = 96,3$mm	$M_2 = 91,0$mm
96% Confidence limits Upper	92,0	87
Lower	101,0	95
96% Range	9 m	8 m
S.D.= $\dfrac{96\% \text{ Range}}{4,64}$	$S_1 = 1,94$mm	$S_2 = 1,72$mm

TABLE 3

Calculation of Expected Numbers of Males and Females

Wing Length (Upper bound)	MALES $z_1=\dfrac{L-M_1}{S_1}$	$P_1=P_r(z_1=\bar{z})$	FEMALES $z_2=\dfrac{L-M_2}{S_2}$	$P_2=P_r(z_2=\bar{z})$	$\dfrac{P\times P_1+(100-P)\times P_2}{200}=P$	$P\times 122^{*}$
85,5	-5,57	0	-3,20	0,001	0,001	0,06
86,5	-5,05	0	-2,62	0,004	0,002	0,24
87,5	-4.54	0	-2,03	0,021	0,011	1,28
88,5	-4,02	0	-1,45	0,074	0,037	4,51
89,5	-3,51	0	-0,87	0,192	0,096	11,71
90,5	-2,99	0,001	-0,29	0,386	0,193	23,61
91,5	-2,47	0,007	0,29	0,614	0,311	37,88
92,5	-1,96	0,025	0,87	0,808	0,416	50,81
93,5	-1,44	0,075	1,45	0,926	0,500	61,06
94,5	-0,93	1,176	2,03	0,979	0,577	70,46
95,5	-0,41	0,341	2,62	0,996	0,668	81,56
96,5	0,10	0,540	3,20	0,999	0,769	93,88
97,5	0,62	0,732	3,78	1,000	0,866	105,65
98,5	1,13	0,866	4,36	1,000	0,933	113,83
99,5	1,65	0,951	4,94	1,000	0,975	121,01
100,5	2,16	0,985	5,52	1,000	0,992	121,09
101,5	2,68	0,996	6,10	1,000	0,998	121,76

$*$ (P = mean cumulative probability
(122 = total number of birds

TABLE 5

The Cumulative Normal Probability Function

z	$P_r(z = \bar{z})$
-3	0,001
-2	0,023
-1	0,159
0	0,500
+1	0,841
+2	0,977
+3	0,999

TABLE 4

Comparison of Actual and Expected Numbers

	Expected Number (e)	Observed Number (o)	CHI Square $= (0-e)^2/e$
85	0,06	1	
86	0,18	1	
87	1,04	1	0,06
88	3,23	1	
89	7,20	10	1,09
90	11,90	10	0,30
91	14,27	13	0,11
92	12,93	14	0,09
93	10,25	9	0,15
94	9,40	7	0,61
95	11,10	13	0,33
96	12,32	13	0,04
97	11,77	12	0,00
98	8,17	7	0,17
99	7,19	6	0,53
100	0,08	2	0,53
101	0,67	2	0,53

Total $=$ 3,48

TABLE 6 — % Points of CHI-Squared

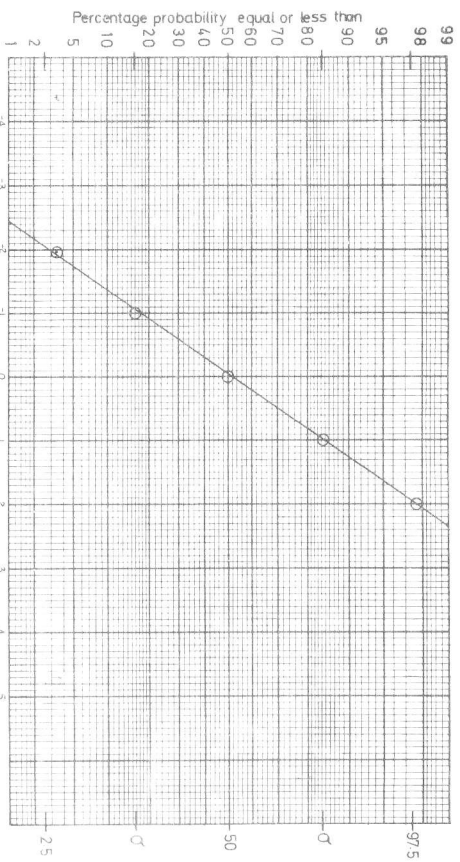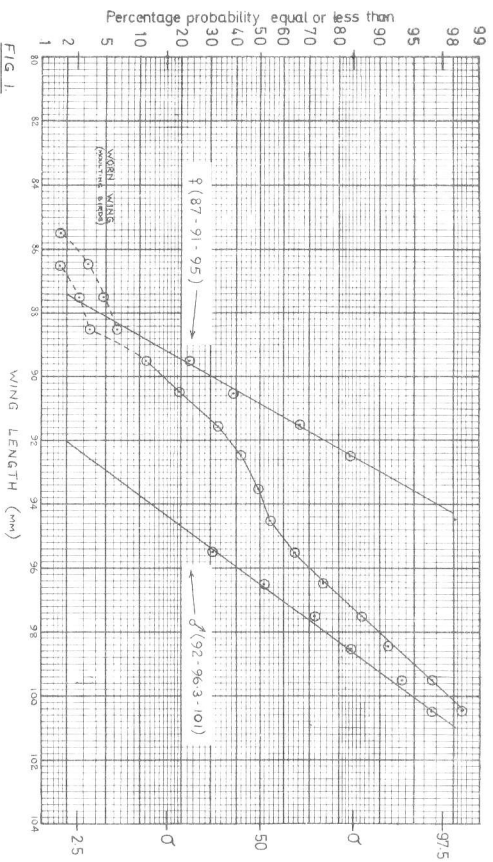| Degrees of freedom	Percentage Points		
	99%	95%	90%
1	0	0	0,02
2	0	0,10	0,21
3	0,11	0,35	0,58
4	0,30	0,71	1,06
5	0,55	1,15	1,61
6	0,87	1,64	2,20
7	1,24	2,17	2,83
8	1,65	2,73	3,48
9	2,09	3,33	4,17
10	2,56	3,94	4,87
15	5,23	7,26	8,54

FIG 2.

THE CUMULATIVE NORMAL DISTRIBUTION

Percentage probability equal or less than

FIG 1

WING LENGTH (mm)

Percentage probability equal or less than

♀ (87 · 91 · 95)

♂ (92 · 96·3 · 101)

WORN WING
(PROLETING SEASON)