RANDOM DISTRIBUTION OF BIRDS IN FLOCKS: SIGNIFICANCE TESTING

by J. J. D. Greenwood

Furness and Galbraith (1980) dyed part of a catch of Redshanks (Tringa totanus) and subsequently counted the numbers of dyed individuals in groups of 10 birds in the roosting flock. The distribution of dyed birds appeared to be clumped; more groups than chance would dictate contained no or several dyed birds and fewer contained average numbers. This is an interesting finding and the technique should certainly be used more widely to see if the phenomenon is general. The purpose of this note is to point out that the statistical test used by Furness and Galbraith is unduly conservative when the birds are clumped - i.e. it gives rise to a significant result less often than it should. I shall indicate a less conservative test and point out that even this is somewhat conservative, so that other, less straightforward, methods may be needed in some circumstances.

The data obtained by Furness and Galbraith are shown in Table 1 with their "expected numbers", based on the Poisson distribution. This distribution is based on the assumption that it is possible for an infinite number of dyed birds to occur in any one group. Since the sampling technique sets an upper limit of 10, this assumption is violated. The appropriate distribution to use is the binomial distribution, since this is concerned with the number of dyed birds in a sample of finite size. Binomial expectations are also shown in the table. It is clear that, as theory predicts, data which show clumping are fitted even worse by the binomial distribution than by the Poisson: the result is thus actually more significant than Furness and Galbraith supposed.

The calculation of the binomial expectation is easy. Suppose that the frequency of dyed birds, estimated by dividing the total number of dyed birds in all the groups by the total number of birds in the groups, is p (0.0772 in the present case). Then, if n is the group size (10 in the present case) and N is the number of groups counted (177), the expected number of groups with no dyed birds is

$$E(0) = N\ (1 - p)^n$$

The expected numbers with 1, 2, 3, ...n dyed birds are:

$$E(1) = [n/1]\ [p/(1-p)]\ [E(0)]$$
$$E(2) = [(n-1)/2]\ [p/(1-p)]\ [E(1)]$$
$$E(3) = [(n-2)/3]\ [p/(1-p)]\ [E(2)]$$
$$\vdots$$
$$E(n) = [1/n]\ [p/(1-p)]\ [E(n-1)]$$

In practice, if p is small the expected numbers fall off rapidly as one goes through this series. Given the restrictions of the χ^2 test (see below), such small expectations are individually of no interest. In general, once one has reached a value of x such that E(x + 1) is likely to be much less than 5, one calculates the expected number of groups containing more than x dyed birds by adding up the expectations E(0) to E(x) inclusive and subtracting from the total number of groups (N). In the present case:

$$E(\text{more than } 3) = 177 - (79.3 + 66.3 + 25.0 + 5.6)$$

To test the significance of the departure of the expected numbers from the observed data, one uses the chi-squared test. As always, this should not be used when more than 1 in 5 of the expected values is less than 5 or when any expected is less than 1. To overcome this problem, one may combine adjacent rows: in Table 1, I have combined the rows for "3 dyed birds" and "more than 3 dyed birds", since the latter has an expectation of only 0.8. For each pair of observed (0) and expected (E) values one calculates $(0-E)^2/E$ and sums them to obtain χ^2 in the usual way. This is compared with the tabulated chi-squared with c-2 degrees of freedom, c being the number of values of $(0-E)^2/E$ used. For the present data, $\chi^2 = 19.6$ with 2 d.f., which is less than the tabulated value at P = 0.001: the result is highly significant.

Strictly speaking, even the binomial distribution is not appropriate for these data, since it assumes that the total number of birds in the population from which the N groups are drawn is infinite. The correct distribution to use, though it is not at all easy, is the hypergeometric. Fortunately, if the number of birds remaining unsampled is several times greater than the size of individual samples, then the binomial is a good approximation. Furthermore, application of the binomial will result in a conservative test: if clumping is demonstrably significant using the binomial approximation, it would certainly be significant if one applied the hypergeometric distribution. However, if p is large or the number of birds remaining unsampled is small, one may miss what is actually significant clumping by using the binomial.

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References

Furness,R.W. & Galbraith,H. 1980. Non-random distribution in roosting flocks of waders marked in a cannon net catch. Wader Study Group Bulletin 29: 22-23

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Table 1. Observed and expected numbers of dyed birds per group of ten.

Number dyed in group of ten	Observed number of groups		Poisson expectation	Binomial expectation		$(0-E)^2/E$
0	97		81.8	79.3		$(97-79.3)^2 / 79.3 = 3.95$
1	40		63.1	66.3		$(40-66.3)^2 / 66.3 = 10.43$
2	28		24.4	25.0		$(28-25.0)^2 / 25.0 = 0.36$
3	9	12	6.3	5.6	6.4	$(12-6.4)^2 / 6.4 = 4.90$
3	3		1.2	0.8		
						$\chi^2 = 19.64$