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STATISTICS FOR THE BIRDS

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ABSTRACT.—There are a great many assumptions which go into bird counting. Most ornithologists feel that once they have acknowledged these assumptions, they are free to proceed with impunity in their analyses. The fallacy of this procedure is described, and comments made on idealized solutions to the problems.

In medieval times a favorite topic with theologians was estimating how many angels could stand on the head of a pin. It is with a certain relief that one notes the objective of this symposium is concerned with terrestrial matters, but in the writer's opinion, there is room for much more down-to-earthiness. For mathematical models and computer simulations are excellent in their proper place, but it should be pointed out that all models have to be based on data, and that no model is of any value if the data are not reliable. I propose therefore to look closely at data gathering as seen through the eyes of a statistician.

PURPOSE

Recent literature often refers to a census, so we should perhaps begin by asking: What is a census? Statistically, we mean the complete enumeration of all the objects under study. This is difficult enough with people, probably not possible with plants, almost certainly not possible with mammals, and especially not possible with birds—because of the three-dimensional effect introduced by the latter. So instead of thinking of a census, we think of estimating the number that we would get were we able to carry out the impossible and get a complete count. And as soon as estimation is the topic, it is necessary to decide: (1) which method of estimation to use; (2) what mathematical assumptions are involved in applying the method chosen (with the further thought that the mathematical assumptions must bear some relation to reality).

It is a commonplace among statisticians that before starting any investigation it is necessary to define, with as much precision as possible, the final objective. And so far as is possible, to state the causes, any one or all of which may cause a variation in the final result. A great deal is known about bird behavior, and any count has to consider the kind of bird, the time of day, the time of year, and the terrain, to mention only some of the factors known to have an influence. If the investigation is to determine only the number of kinds of bird, without requiring the numbers of each kind, then to a certain extent the emphasis of the enumeration procedure will be different. But for all investigations, the type of terrain is of importance.

MICRO-ENVIRONMENT

To reiterate, it is necessary to postulate the exact purpose of the investigation. A loosely worded statement such as, for example, "to find out the effect of spraying an area with insecticide on the bird population," has to be whittled down so that the kinds of bird are specified as well as the area. The area has then to be split up into roughly homogeneous sub-areas in much the same way that the counters of deer, for example, split up their basic areas. If one of these smaller areas should happen to be a field of grain or cotton, then the problem of specification of terrain is considerably easier than if it is a natural forest. This latter presents difficulties, so I will consider it chiefly in my further remarks.

The natural forest is not uniform but is built up of a number of micro-environments, in some of which it will be easy to see specified birds, and in others, it will be very difficult. If it is desired to make a bird count before and after some treatment, such as spraying, the makeup of the forest in terms of micro-environments may be of crucial importance. For the spraying may affect leaf cover, etc. and hence alter the basic conditions. Or again, if it is desired to compare two forested areas as far as bird counts are concerned, no reliable comparison can be made unless they are approximately the same in their micro composition. For, since the best we can do is some sort of sampling procedure, the basic conditions must be equivalent. This is true for all sampling procedures, of which there are many. For illustration let us consider a simple lattice.

Suppose a map of a forest. A random line is drawn across it and a random point is chosen in it. A line is drawn through the random point at right angles to the random line. Choose a distance l and draw a square lattice to cover the area studied with the lines a distance l apart. The crossover points of the lattice are commonly referred to as nodes, and these are the sampling points. At each node a description of the micro-environment in a circle of 30 yards (say) surrounding the point can be made. (The area

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need not necessarily be circular, provided the same size area is maintained for all nodes.) Data such as amount of ground cover, height and plane area of shrubs, dimensions of trees and their position, height of canopy and so on, may be recorded. This may all be done by eye, as in similar fashion is also the chance that any particular type of bird may be seen in such an environment. Clearly, some facets of the micro-environment will vary in importance, depending on the type of bird studied. Thus, for a bird of pedestrian habits, probably the ratio of shrub cover to the total area will be descriptive enough; while for another kind, the canopy will be of importance. Similar logic can be applied to l, the distance apart of the lines composing the lattice.

DETECTION

Statisticians may be pardoned if they treat with scepticism the counts of birds that ornithologists produce and that are the basis of their models. Obviously there are two main types of error—all the birds will not be counted, and some birds may be counted several times. Preston (1979) faces up to the first kind of error in his paper "The Invisible Birds," but the general tendency is to ignore the obvious flaws in the data and introduce a variety of mathematical assumptions that, it is hoped, will give validity to the conclusions drawn. The investigator remains forgetful of the truth that conclusions based on assumptions are dependent on those assumptions. (The next step in bird censuses should undoubtedly be to introduce a credibility function.) The probability of seeing a bird is dependent on the type of micro-environment, discussed in the previous paragraphs. In open grassland, possibly all the birds present will be seen. In some of the micro-environments in a forest, it will be easier to see some kinds of birds than others, so the chance of observing a bird in a given area will depend on its kind and on the composition of the environmental area. What is certain is that the count will not be a comprehensive one.

The problem of counting the same bird several times is usually dismissed in research papers (if it is mentioned at all) with the remark that care must be taken to avoid duplication of observations, etc.; yet it can be a significant source of error. For instance, the use of bird song or calls to identify the presence of a particular kind of bird is useful in that it indicates that at least one individual of that kind is in earshot. But no number of songs can definitely indicate more than that, unless they are accompanied by visual sightings.

INTRUSION OF THE OBSERVER

There have been enough recent references to Yapp's (1956) classic paper to send one back for a rereading. He wished to count Rooks (*Corvus frugilegus*), so he rode the side of a railway engine from Leamington Spa to a point south of Bicester—say about 20 miles—counting the birds within 50 feet of the line. The railway line passes through a variety of micro-environments even if we exclude, as he does, the tunnels and the cuttings. In the end he multiplied his count by two, because he could only see one side of the track, to arrive at the number of Rooks per square mile. But leaving all this aside, it is the effect of human intrusion which is unknown, but undoubtedly present. Do the birds all remain when they hear the train approaching? Are the birds attracted to the line instead of being dispersed over a larger area? These are only two of the many questions which have to be answered before giving a figure of number of Rooks per square mile.

Again, recent research papers have given bird counts obtained by driving a car and stopping at intervals for observations. Some birds like roads, as is instanced by the number of kestrels (*Falco* sp.) along many highways. Other birds will avoid roads because of the human intrusion. The counts are indicative that at least one bird of the kinds seen was present. But how representative the actual numbers counted are of the true numbers of birds in the vicinity, and whether all the different kinds of birds were seen, is a moot point.

The same remarks can be made regarding transect sampling. Apart from the fact that an observer moving through a forest will pass through a number of different micro-environments, his movement will make a noise. The count will therefore be indicative of the reaction of the birds to a human intrusion, rather than a partial unbiased estimate of the number of birds. Using the sampling lattice described earlier may offer the minimal human intrusion, although it will not eliminate it entirely. If there are twelve nodes then one would ideally require twelve observers. If the count is to be made at 10:00 the observers must of necessity be in place at a time sufficiently far beforehand for them to be accepted as part of the landscape at count time.

The tricky problem of counting the same bird twice is caused partly by the bird's natural three-dimensional activity, but partly also by the intrusion of the observer. Accordingly, with the lattice scheme it is important that the time of counting is restricted—say to five minutes—and ideally that all observers start at the same time. There seems to be no objection to there being

3 to 4 five-minute counts within 30 or 40 minutes, provided the counts are kept separate, since they will not be independent. The dimensions of the lattice will need to be such that it is unlikely that a bird startled by one observer can fly to within sight of another during the same five minute period.

MECHANICAL COUNTING

There is an agreement among ornithologists that some of them see, and therefore count, birds better than others, in spite of a frequent assumption that all the birds are counted. Moreover, they present a united front against any suggestion that possibly in this mechanical day and age, a mechanical means of counting would lead to greater consistency in enumeration; for cutting out the observer error would mean cutting out a source of variation. Thus, if we revert to the idea of a sampling lattice, when the region is surveyed to mark out the nodes and to obtain an idea of the micro-environment in an area around each node, the area itself could be marked out, and some form of mechanical counters operated by remote control installed. The remote control would rule out another source of variation, the human intrusion. Accordingly, it is suggested that experiments directed towards the mechanization of the counting process may be fruitful in producing, what should be the basis of the investigation, an unbiased count. If the chief deterrent to mechanization is not prejudice, but expense, one may ask whether it is preferable to obtain a few accurate counts or a plethora of inaccurate ones.

VARIATION

If the statement is accepted that time of year is a source of variation for the count, then the observer has to decide when this time shall be, bearing in mind that any conclusions drawn will be valid for the chosen period only. If it is accepted that the time of day is important, then this day-time interval should be narrowly postulated with reference to what is known of the bird's activity habits, for it will possibly not be so easy to see a bird in its inactive period as opposed to it active. There are also other possible sources of variation such as temperature and precipitation. A list of these has been given by W. M. Shields (1979). Once it has been determined over what period in the year and over what time of day the background conditions relating to activity can be considered to be more or less consistent, it is desirable that observations be taken on a number of successive days. The variability of temperature and the intervention of precipitation may be used appropriately to divide the series of days, thus providing further information.

MODEL BUILDING

It is not my purpose to introduce yet another mathematical model. Yet it is perhaps interesting to note gaps in estimation and difficulties still to be overcome, even with the simple lattice sampling design, so I will illustrate this for just one node. The extension to more than one node and to different micro-environments is straightforward.

Suppose there to be N birds in an area A. It will be assumed that throughout the period of observation there will be N birds. These will not necessarily be the same—some will fly out, others will fly in—but the total number is assumed constant. This number N is not known and we wish to estimate it.

Various assumptions can be made concerning how these N birds are dispersed over the area A. They may be distributed randomly, they may tend to go about in clusters, or they may tend to avoid each other. Whatever we assume will make very little difference to the estimate, N, of N, although it may alter the variance.

Consider an area, a, surrounding a given node. Suppose that an observation count is made in a for each of s successive days, and that these counts are $r_1, r_2, \ldots, r_s$. Some of these may be zero but not necessarily so. Write for the average count ($\bar{r}$) and the proportion of the total area sampled (P):

$$\bar{r} = \frac{1}{s}\sum_{i=1}^{s} r_i \qquad P = a/A$$

then

$$E(\bar{r}) = NPp$$

Where E stands for the mean value in repeated sampling, and p is the chance that a bird is observed in a.

It is worthwhile to point out that this p is not the chance of detection, which we are told increases with the number of birds in a. Instead, p depends on the micro-environment of a. Thus, for example, if a is a square, half covered with undergrowth and shrubs, then the chance of observing a pedestrian bird is one half, since the possible visibility is one half.

There are many ways of estimating N. The simplest is, possibly, to say:

$$N = \bar{r}/Pp$$

Because a is small compared with A, and therefore P is very small, the effective result will be that r_i, ($i = 1, 2, \ldots, s$) has a Poisson distribution whatever we assume for the dispersion of the N birds over A.

It will be noticed that p is important in the estimation of N. If it is routinely put equal to unity, then there will be underestimation of N in a number of cases. It would seem worthwhile to consider whether accurate estimation of p is possible from field observation, or whether we should try to include such estimation in the sampling scheme.

CONCLUSIONS

It is not the writer's desire to state flatly that all bird census data are invalid. However, merely acknowledging assumptions does nothing to pardon the researcher from the responsibility of eliminating the biases introduced by those assumptions.