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SUMMARIZING REMARKS: DATA ANALYSIS

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First of all I should like to say that I have really enjoyed and benefited from this Symposium. I believe that it will stimulate important future research on techniques of sampling bird populations from both the biological and statistical perspectives. On a lighter note I mention that this is the first conference where I have seen participants use binoculars to read data slides!

With apologies to the authors of papers on other topics I would like to devote the major part of my summary to a discussion of the line transect and variable circular plot sampling techniques which have occupied central stage at this Symposium. It is unfortunate that we had to wait until so late in the program for three of the most important papers on these techniques.

The goal of these two techniques is to estimate the average density of birds in the study area. In each case the "effective area" sampled is estimated from the observer to bird distances. The same four basic assumptions (which obviously may not be realized in practice) apply: (1) Birds in the immediate vicinity of the observer (as he moves along the transect line or stands at the center point of the circular plot) will always be detected; (2) there is no movement of birds in response to the observer; (3) all measurements are made without error; and (4) sightings of different birds are independent of each other.

The first assumption is critical to density estimation and will cause a negative bias when it fails. It is perhaps more likely to be satisfied for variable circular plots because the observer is stationary and devoting his full attention to detecting birds. Movement will typically be away from the observer causing a negative bias on density estimates. On occasion, however, birds will move towards the observer causing a positive bias. The assumption of independent sightings will obviously be false for flocking birds but there we can consider the flock as a unit and extend the theory (as in Quinn's [1981] paper).

The detection function ($g(x)$) which relates the probability of a bird's detection to its distance from the observer (x) (usually defined in terms of perpendicular distance for line transects) is central to all methods of density estimation. In particular the assumption (1) which can be stated mathematically as $g(0) = 1$ is crucial. The nature of the detection function and how to use it is a point of rather fundamental disagreement.

Burnham et al. (1981) in their paper (and also Quinn 1981) take the approach of modelling the detection curve (using a Fourier Series) and assuming it is a decreasing function with distance. Ramsey and Scott (1981) (following J. T. Emlen 1971, 1977a) assume the detection function is constant and equal to one (all birds detected) for an appreciable distance from the observer and they concentrate on determining this distance. Ramsey and Scott (1981) state ". . . if one feels that there is some substantial region of uniform, near-perfect detectability, the modified Emlen technique is recommended." It seems to me, however, that the Fourier Series approach of Burnham et al. (1981) would work just as well on this type of detection function.

From a statistical modelling viewpoint I believe that line transects and variable circular plots are basically equivalent. From a biological viewpoint, however, they are very different. Line transects estimate the average density of birds in a long narrow strip so that Ramsey and Scott (1981) suggest they are less useful in variable habitats. They also suggest the disadvantage of line transects in rugged terrain where movement of the observer along a line is difficult, if not impossible! As mentioned earlier it may also be less likely that line transects will satisfy the assumption (1) of perfect detectability of birds in the vicinity of the observer. Line transects on the other hand have the important practical advantage of often covering much larger areas in the same period of time.

A problem not considered in any detail during the symposium is what to do about birds which occur in flocks (groups). Thus the paper by Quinn (1981) is particularly welcome. Although framed in terms of line transects, the methods and conclusions apply equally well to variable circular plots. Two approaches to the problem are considered and compared. The first approach uses a two stage procedure. All group sizes are pooled and the average detection function fitted using a flexible form like the Fourier series. This gives rise to an estimate of the density of groups. The estimate of the density of individual birds is the product of the estimated number of groups and the average group size. The estimated average group size must be weighted to account for the increased probability of sighting larger groups. The second approach "post stratifies" the data by group size and uses line transect theory to estimate the density of each group size separately. Quinn's (1981) conclusion is that overall the method of

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pooling is to be preferred. I believe the group size influence on the detection function should be the subject of more research.

Before concluding I should like to make a couple of points about some of the other papers. During this conference I have been a little worried by the wide use of the spot mapping method as a census with no sampling problems and was pleased to see that Eagles (1981) has given serious attention to its problems. The paper by Johnson (1981) is excellent. We all too often ignore auxiliary information (which costs nothing!) when we calculate our estimators.

In conclusion I would like to make some general comments. I feel that some biologists at this conference have been too optimistic about the use of indices of abundance. I know there are a lot of problems with methods of estimating absolute abundance but there are important assumptions behind indices as well and these have tended to be neglected. In particular I mention the large variability of indices and the assumption of direct proportionality to absolute density. There is a need for new statistical procedures to be made easily available to biologists through monographs and computer packages. The work of Burnham et al. (1980) on line transects will hopefully encourage similar efforts for other techniques. There is also the need for small workshops for biologists to study the new statistical procedures. Ecology graduate programs in the universities should also be encouraged to strengthen their courses on sampling methods. Finally, I would like to stress the need for biologists and statisticians to work closely together in the future.