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LENGTH OF COUNT PERIOD AS A POSSIBLE SOURCE OF BIAS IN ESTIMATING BIRD DENSITIES

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ABSTRACT.—Observers using point counts to estimate the numbers of birds in an area spend 2 to 20 minutes counting. The assumption inherent in this technique is that birds don't move during the count period. The degree to which this assumption is violated is determined by the length of the count period, and the speed at which birds move. The longer the count period and the greater the speed of the birds, the greater the potential for a biased estimate of density or other measures of abundance.

We use field observations and simulation studies to determine the effects of bird movement and length of count period on estimates of bird abundance.

The variable circular plot design (Reynolds et al. 1980) offers many advantages in bird surveys. With this design, transects are drawn through the region being surveyed. Observers proceed along the transects, conducting their surveys only at stations marked at regular intervals. The period of time during which observers survey on station is fixed in length. Observers record the distances from station to detected birds. These distances are used to estimate the area effectively surveyed for each bird species detected. Hence the "variable" circular plot, as opposed to circular plots of predetermined size outside of which observers ignore birds.

In practice, circular plot surveys (variable and fixed distance) have been conducted with count durations ranging from 2 min (Kimball 1949) to 20 min (Blondel et al. 1970). This paper examines some factors which influence how long the survey period at each station should be. We do not consider costs or total time available as constraints, but concentrate on those factors that affect the quality of the data obtained.

SOME THEORETICAL CONSIDERATIONS

The impossible (Preston 1979) ideal that an observer strives to obtain is an instantaneous picture of the birds and their locations surrounding a station. We recorded the time at which various species were first recorded in two Hawaiian forests, one with 14 and one with 5 species of birds. Figure 1 displays the cumulative number of species detected as a function of time on station, expressed as a percent of the total detected in 32 min. If a person stayed at a point long enough, all species in that particular habitat type would appear and be detected. This may be a convenient way to obtain a species list, but it would be difficult to convert waiting time to detection into densities or relative abundances. Examination of Figure 1 shows that, in both forest areas, about 80% of the species recorded in 32 min. of surveying were detected within the first 10–12 min. The rate of new detections declined steadily with time, indicating that more productive surveying can be accomplished by moving to a new location before all species are detected. Determining a good time to move is a difficult problem, compounded by the fact that cumulative numbers of detections vary from species to species.

In Figure 2 the 'Apapane (*Himatione sanguinea*) is the most mobile of the species shown while the 'Oma'o (*Phaeornis obscurus*) is the least mobile (C. J. Ralph pers. comm.). Fifty percent of all observations for the 'Oma'o were recorded with 1 min while it took 7 min to achieve this figure for the 'Apapane. We attribute these differences to 'Apapane that were beyond the area surveyed when the count was started moving to within the count area. This movement thus inflates the density estimate significantly.

Results such as these assist us in identifying advantages and disadvantages attending longer counting periods. Some of these are itemized below, and we consider in later sections ways to deal with them.

ADVANTAGES:

A1. Birds inconspicuous because of their distance from the station have a higher chance of being detected.

A2. Birds that vocalize infrequently will have a smaller chance of being missed during the count period.

A3. Birds that react to the presence of the observer by becoming silent and immobile may resume more normal behavior.

A4. The observer has more time to make careful identifications and to record distances accurately.

A5. In an area of high bird density, the observer has more time to observe and record.

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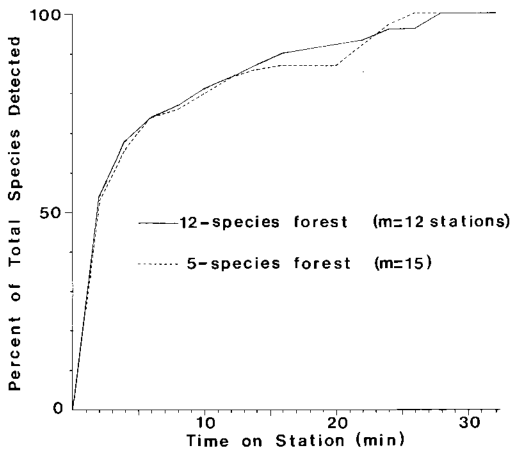

FIGURE 1. Cumulative percentages of bird species detected with increasing count duration in two Hawaiian forests. Fifteen 32-minute counts were conducted in the 5-species forest and 12 in the 12-species forest.

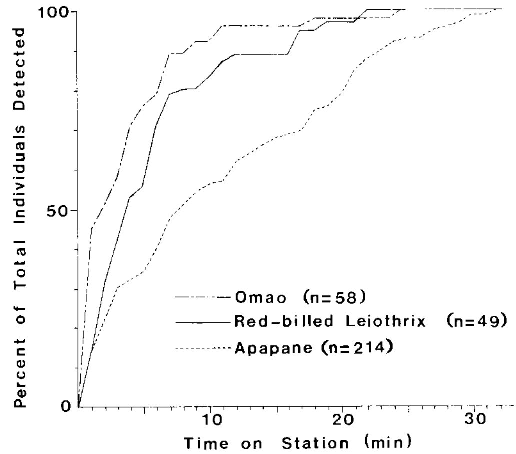

FIGURE 2. Cumulative percentages of total individual counts with increasing count duration for three Hawaiian species.

DISADVANTAGES:

D1. Birds that are initially beyond the range of detection have a greater chance of moving close enough to be detected *at distances too near to the observer to allow for accurate assessment of the area being covered.*

D2. The chance of recording a single bird more than once increases, because the bird may move or the observer may forget its location.

D3. The observer's ability to detect birds may decline because of boredom.

D4. The observer has greater freedom to allocate effort among species.

D5. There is more time for birds to be attracted by the observer's presence.

SOME PRACTICAL REMEDIES

Some of the disadvantages listed above can be neutralized by careful control over field technique. Consider D4, for example. The problem here concerns relatively common species. At a station where few species occur, the observer can spend nearly the entire count period locating members of these species. At a station with many species, however, the observer will tend to ignore a very common species after an initial count in order to concentrate on other species. Eight min at one station versus 2 min at another is not likely to yield density estimates reflecting the true situation. This tendency is a natural one among observers. It can be prevented by dividing among observers the responsibilities for counting common species, or by varying the species counted from station to station in a pattern that still gives ample coverage for the common species (Scott and Ramsey 1981a).

Factor D2 can be reduced by using a field form for each station that is essentially a map consisting of concentric circles drawn around a point (the station) on a line representing the transect. The observer turns around while surveying but keeps the form aligned with the transect at all times. As each bird is detected, its distance and direction are estimated and the observer enters on the form a four-letter species code at the resultant estimate of its position. If desired, the code may be underlined if the detection is by call, circled if by song, or unmarked if the detection is visual.

Factor D3 may be reduced by training the observers and impressing upon them the importance of their job (Kepler and Scott 1981). Another means to reduce boredom is to have two observers making simultaneous counts at the same or nearly same station. If an observer knows that his observations will be directly comparable with those of another observer he will tend to be more alert throughout the count period (Scott and Ramsey 1981b, Kepler and Scott 1981). Factor D5 can be minimized by instructing observers to move quietly between stations and to make as little noise as possible while on station.

This leaves D1 as the principal constraint on the selection of long count periods. The effects of D1 can be minimized by using different length count periods for species that vary widely in rate of movement and conspicuousness.

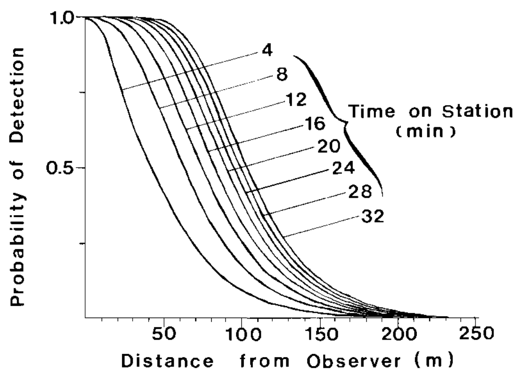

FIGURE 3. Detectability curves for surveys of different durations.

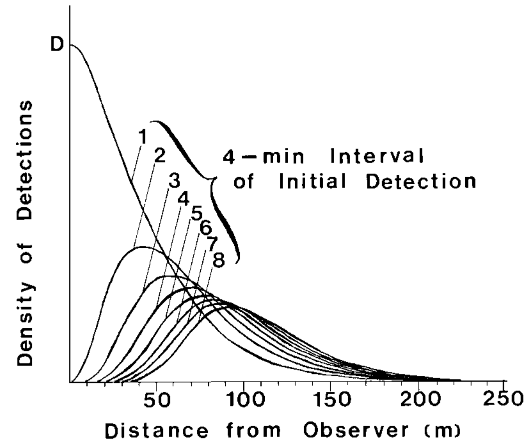

FIGURE 4. Theoretical densities based on initial detection distances, by 4-min periods in a 32-min survey.

How might we expect the movement of birds to affect survey results? As suggested in D1, an obvious consequence of longer count periods is that too many birds will be detected. Not only are those birds detected that were initially near station, but also new birds will approach near enough to the station to be detected. The 'Apapane in Figure 2 demonstrates this effect. What may not be obvious is where these recruits will first be detected and thus recorded for distance. At one extreme, if a species is highly detectable throughout a broad region around the station, we might expect that detection distances of recruits would all fall near the outer limits of the range of high detectability. This would create a "donut" pattern of higher observed density in a distance range removed from the station than exists near the station, where new recruits do not penetrate prior to detection. Such a pattern of detections could be discerned in data and appropriate corrections could be applied.

At the other extreme, fast moving species of low detectability would likely get quite near station before being detected. In this case detections of recruits might have the same distance patterns as do birds initially present and detected within the observer's range. No recognizable pattern of detections exists to distinguish this effect of bird movement, so corrections must be based solely on biological information. In the next section we will examine some simulated examples to see how movement might affect survey results.

SIMULATED MOBILITY: THE MODEL

We use a model developed by Ramsey et al. (in press), where an observer is stationed at the origin of a plane. A bird is randomly positioned in the plane. During a count period of 32 min, the bird is allowed to move along a straight line with speed, S, the direction of the line being chosen at random. Speed of movement is expressed as a proportion of the speed needed to travel one effective detection distance in 4 min. Every 20 sec., the observer performs a visual scan as follows: the distance, y, from bird to observer is measured and the observer has a chance for visually detecting the bird equal to

$$g_V(y) = 1 - \{1 - \exp[-(y/15)^2]\}^{1/24}.$$

Furthermore, each bird emits calls according to a random Poisson time process with an average of θ calls per min. The observer has a chance of making an audio detection of any call equal to

$$g_A(y) = \exp\{-(y/30)\}.$$

Here y is the distance at the time of its call, measured in meters.

A bird may be detected either visually or aurally at some time during the count period. If it is detected, its species and distance are recorded. This procedure is then repeated many times to simulate species densities.

It is possible to discuss the model's features in the absence of movement ($S = 0$), and assuming that we ignore multiple detections. The probability of a bird's being detected increases with time, regardless of its distance from the observer. Figure 3 displays eight of the detectability curves, corresponding to 4 min increments. Thus the cumulative number of detections is expected to increase with time (cf. Fig. 2). This would increase the corresponding estimate of density, were it not for the fact that the approaching birds, detected in the latter stages of the census, have greater average detection distances and therefore increase the estimate of effective area surveyed. (See Ramsey and Scott

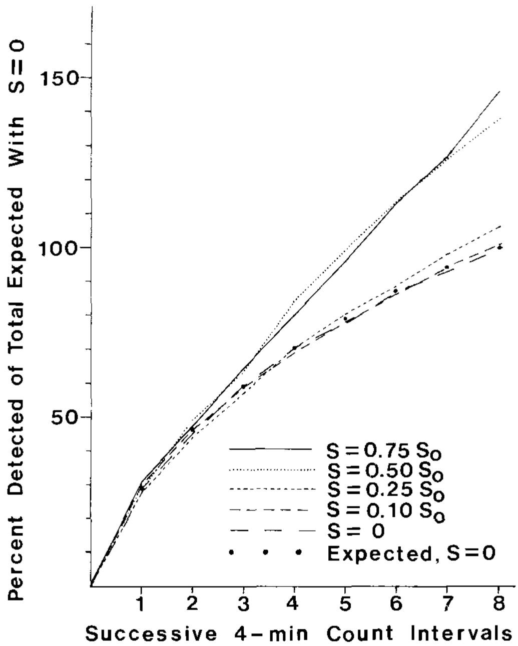

FIGURE 5. The effect of mobility on cumulative numbers of detections over successive 4-min count periods. The simulated speed of movement is expressed as a proportion of S_0, the average speed needed to travel one effective detection radius in one 4-min interval.

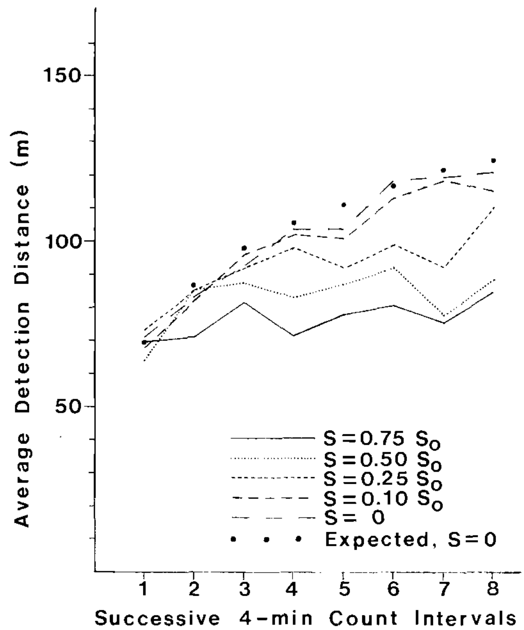

FIGURE 6. Simulated effect of bird mobility on average detection distance during successive 4-min counting periods. S is calculated as for Figure 5.

1981, for a description of the density estimation procedure used.) The theoretical situation is presented in Figure 4, where we show the density distributions of the birds detected in each of the 4 min. intervals. Note in particular how the average detection distance increases with longer census periods.

SIMULATED MOBILITY

The average speed with which a bird moves about its home range influences the probability of its coming within detection range of an observer. Figure 5 displays results of various simulated rates of movement on numbers of detections in successive 4 min counting intervals, in relation to expected numbers of detections with no movement. It is clear that increasing mobility increases the numbers of detections in later counting periods. With $S = 0.75\ S_0$, for example, the total simulated number of detections after 32 min of counting exceeded the number expected without bird movement by 45%. The effect of this, of course, is to overestimate bird densities.

The overestimate of density might be partially compensated for if birds that move into detection range are first detected farther away than expected for stationary birds. Figure 6 shows results of simulated effects of rates of movement on detection distances in successive 4 min. census intervals. Although average detection distances of moving birds increased in successive intervals, they did not keep up with expected values for stationary birds. And the effect decreased with increasing rates of movement. We tried simulations using several faster call rates with similar, but less marked, results. Apparently bird mobility at all rates simulated here allowed birds to get nearer to the observer than expected before detection. This effect would also tend to inflate density estimates of birds, and especially so for the higher mobility rates.

Next we combined the effects of mobility on numbers of detections on average detection distances to compute density estimates shown in Figure 7. For slower rates of movement (up to $S = 0.25S_0$), the combined effects of mobility do not appear to result in a marked overestimate of density compared with the expected for stationary birds. As the rate of movement increases, however, the net result is an increasing overestimation of density.

CONCLUSIONS

The results of simulation studies presented here show that bird mobility may seriously bias density estimates derived from variable circular

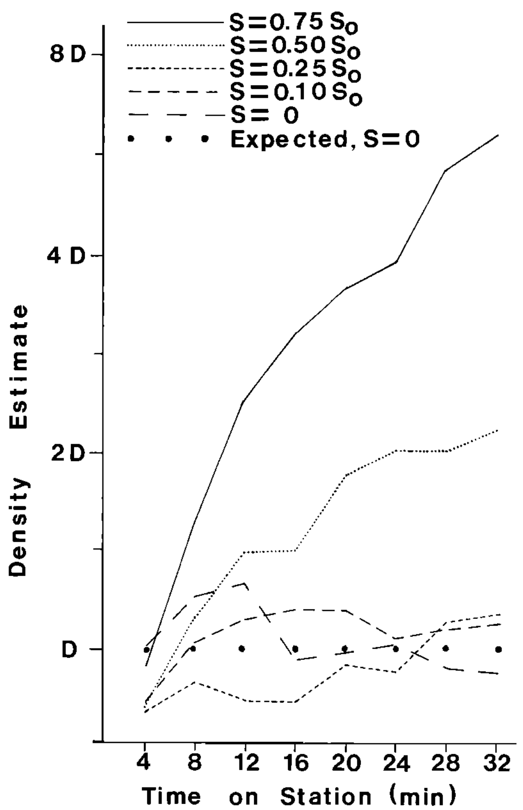

FIGURE 7. The simulated effect of bird mobility on estimates of density with increasing duration of counting period. *S* is calculated as for Figure 5.

plot surveys, especially for counts of longer duration. Because of bird mobility, an observer essentially surveys a much greater area than is indicated by detection distance information. The bias is even more serious for circular plots with a fixed radius, because density computations do not benefit from greater average detection distances that accompany longer count periods. Count periods of different lengths are required for species with dramatically different rates of movement. This may be handled by counting only birds of a similar mobility during a count period or not counting individuals of a species after a certain period, e.g., 1 min for swifts and swallows.

Counts of long duration are generally advantageous for sedentary species, particularly if they are rare or inconspicuous. The same may be true for territorial species, if the average defended area is small compared with the effective area surveyed from a given station. However, without considerable information on average rates of movement within a home range, and on call and song rates, it is not possible to use such counts for accurate estimates of the density of a very mobile species, or of a species with a territory that is large compared to the area effectively surveyed. The next logical step in our studies requires collection in the field of the information on mobility rates, song rates, and so on, needed to examine these relationships empirically.

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