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THE EFFICIENCY OF THE MAPPING METHOD—A COMPUTER SIMULATION BASED ON FIELD DATA

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ABSTRACT.—A program CENSUS has been developed to simulate a population of stationary Willow Warbler males and its censusing by an observer using the mapping method. The song activity of the simulated birds was based on field data without any modification. Census efficiency increased with shorter distances between observer stops, longer listening time per stop, and greater hearing range of the observer. For comparable circumstances, good agreement was found between field and simulated census efficiencies: a census of 10 surveys under favourable conditions (many stops, long listening time, great hearing range) records 80 to 90% of the true population. It is concluded that the so far purely deterministic simulation can be regarded as a reliable base for further extensions including the introduction of stochastic factors such as bird movements, recording and mapping errors, etc.

Methodological research into bird census techniques is complicated by the fact that conditions in the field during a census can be controlled only to a very limited extent. The usual procedure of scientific experiments—to keep all factors constant except the one under investigation—can hardly be followed in the field: it is impossible to vary only one factor, e.g., the observer's speed, while keeping constant all other conditions such as time of day, time of year, weather, bird activity, etc. Thus, exact replications of a survey are not feasible.

To bypass these difficulties, we have developed a computer program for simulating the mapping method. (For a detailed description of this method see, e.g., the study of Enemar (1959), which also shows by a "provisional calculation" that song activity can influence census results.) In our simulation, we can vary systematically the factors under consideration without changing the other conditions. A further advantage is that the true size of the simulated population is known a priori, whereas in field studies the final result of the census itself often yields the only available 100% value used as a "yardstick" in efficiency calculations.

An essential feature of our approach has been to base the simulation on data as realistic as possible, and on a minimum number of generalizations and assumptions. In the construction of many ecological models, assumptions are introduced at an early stage, which often increases the range of results and applications. We felt, however, that the need for clarification in bird census methodology makes a completely empirical approach more desirable, and that—at least as a first step—"trivial" results on a safe basis are to be preferred over more "interesting" ones based on assumptions the validity of which is difficult or impossible to judge.

METHODS

FIELD DATA

In 1973, 1974, and 1976 through 1978, breeding passerine bird censuses were conducted using the mapping method. The study area was the "Donatusfeld," a reforested former opencast brown coal mining area, 25 km southwest of the city of Cologne, Federal Republic of Germany. The Willow Warbler (*Phylloscopus trochilus*) was chosen for a more intensive study of singing behaviour and census efficiency: males of this species sing loud and regularly and can easily be observed on their singing posts. About 50% of the stationary males in the study area were banded with individual combinations of colour-rings. The population size ranged from 30 to 55 stationary males in different years. These numbers were obtained from many census surveys (16 to 39 per breeding season), from color-banding, and from additional field observations; they can be regarded as very reliable estimates. In 1978, song activity of Willow Warbler males was measured during the four hours after sunrise by recording "song" or "no song" of individual birds for every half-minute interval. Most of the recorded males could be identified afterwards by their colour-rings. Song patterns, i.e., sequences of "+" and "−" signs, were obtained from 14 different males, and for a total of 52.3 hours.

SIMULATION

The program CENSUS was written in SIMULA, a programming language for simulation purposes which has been developed from ALGOL (for an introduction see Birtwistle et al. 1975). We simulated a population of 42 Willow Warbler males, which is in the range of real numbers for the study area. The spatial distribution of the birds was copied according to scale from the census maps; so was the observer's route. As we had to follow pre-established tracks during the surveys in the field to minimize disturbance, a somewhat irregular route resulted (Fig. 1). To keep the simulation as realistic as possible, we decided not to alter this route layout. However, other routes can also be simulated by simply changing the program input parameters. Each simulated bird was assigned an individual song pattern. We used the patterns exactly as recorded in the field, i.e., the sequences of "+" and "−" signs, without modifying or processing them by calculating average song probabilities or similar generalizations.

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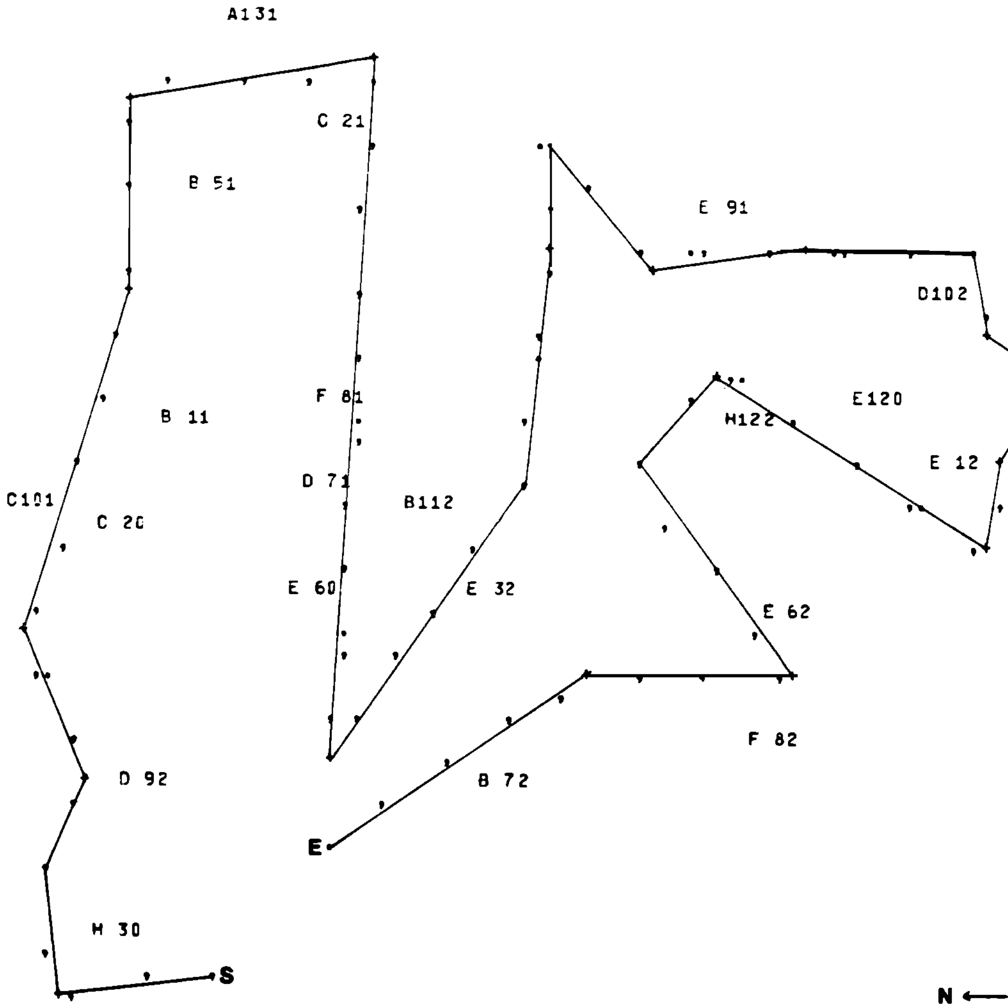

FIGURE 1. Computer output of simulated census. (Line: observer route; S, E: start and end points of route (walking direction alternated on successive surveys); full stops and commas: observer stops for both walking directions, respectively; figures: identification numbers of "males," e.g., 102 = second copy of bird no. 10; letters A, B, C, etc.: bird has been recorded on one, two, three etc. surveys; N: north direction of original study plot).

However, as data were available for 14 individuals only, we created two additional copies of each song pattern to obtain a total population of 42 birds. We made sure that birds with identical patterns were located far apart. Thus, the observer meets the original and the copies at different times and therefore has to deal with quite different sections of the full song pattern.

The procedure of a simulated survey is as follows: The observer starts at one end of the route, alternating start point and walking direction for successive surveys. He stops at fixed intervals and listens for a certain period. During this time, all males of the population are checked for occurrence within the observer's hearing range, and for their song activity. If they are within hearing range and are singing during the observer's stop, they are noted by the program as recorded for this survey. Each census consists of several surveys, the number of which can be varied. The computer output corresponds to the species map of the mapping method and shows the cumulative results of all census surveys (Fig. 1). Numbers identify individuals and letters indicate how often the bird has been recorded and where it is located. Further output shows the efficiency (number of recorded males as percentage of the true population) for each single survey as well as for the final result of the census after all surveys. As in the evaluation of real species maps, it is possible to set a lower threshold for acknowledgment of a stationary male; e.g., all recorded males with only

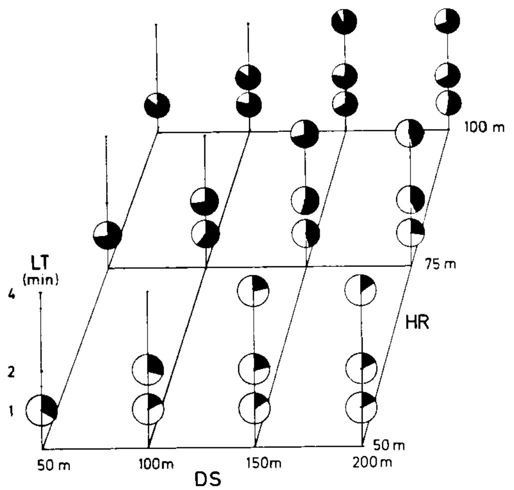

FIGURE 2. Efficiencies of simulated censuses with ten surveys, between 0 and 4 hours after sunrise. (DS: distance of observer stops; HR: hearing range of observer; LT: listening time per stop; black circle sectors: recorded proportion of total stationary male population).

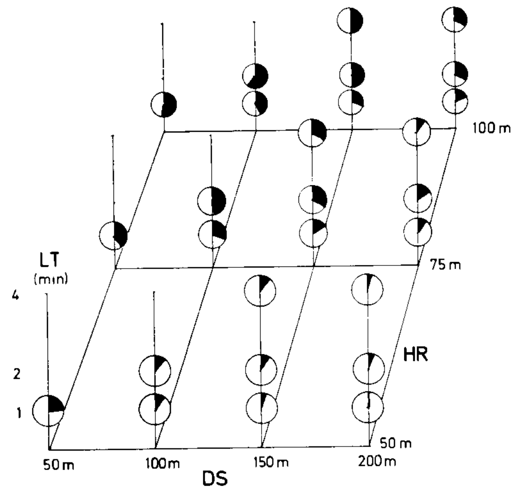

FIGURE 3. Efficiencies of simulated censuses with five early surveys, between 0 and 2 hours after sunrise. See Fig. 2 for abbreviations.

one or two registrations can be excluded from the final result as suspected migrants or floaters. Note that the simulation does not allow the birds to move around. The program has been designed to include this possibility; however, no field data were available on movement patterns of Willow Warblers, and for the reasons stated above, we did not want to introduce hypothetical assumptions at the present stage of the simulation. Neither did we include background noise by setting the recording probability below unity for singing birds within hearing range: every bird that can be recorded will be recorded. So far, the program is completely deterministic.

The following input parameters of the program can be varied: size of stationary male population; location of males; shape of observer's route; distance between observer's stops; listening time at each stop; hearing range of the observer; number of surveys per census; starting time of day for surveys; and minimum number of recordings for acknowledgment of a stationary male (as opposed to floaters).

As the sequence length of the available song pattern field data is limited, not all possible parameter combinations could be run: if, for instance, there are too many stops and too long listening times, the song data are used up before the observer has finished his survey.

The program was run on a Control Data Corporation Cyber 72 computer at the Regional Computing Center Cologne.

RESULTS

As the program CENSUS requires relatively large amounts of computer time and storage, only a limited number of runs could be conducted up to now. Additional runs with different parameter combinations will be necessary to allow a more precise investigation including regression analysis, etc. The results obtained so far are summarized in Figures 2 through 4. The recorded proportions of the true population range from 14 to 88% for censuses with 10 surveys (all on different days, between 0 and 4 hours after sunrise; Fig. 2); from 2 to 62% for censuses with 5 early surveys (0 to 2 hours after sunrise; Fig. 3); and from 0 to 52% for censuses

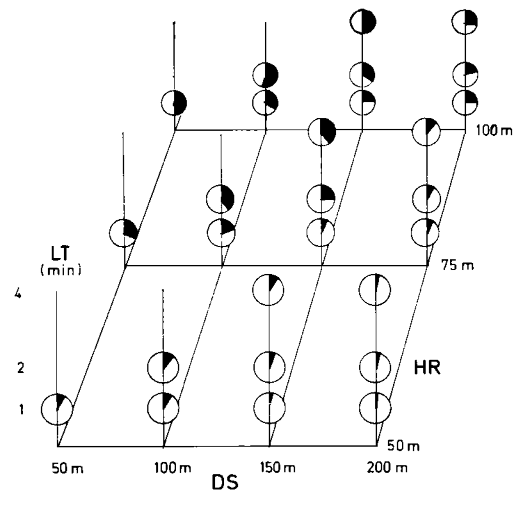

FIGURE 4. Efficiencies of simulated censuses with five late surveys, between 2 and 4 hours after sunrise. See Fig. 2 for abbreviations.

with 5 late surveys (2 to 4 hours after sunrise; Fig. 4). The mean efficiencies over all runs for the three groups of censuses are 49.8, 25.1, and 19.7%, respectively. These are not true averages, of course, since the parameters have been varied between runs. The figures can be used for comparison, however, because in all three sets of simulations the same parameter combinations have been used.

DISCUSSION

As our field surveys were conducted very thoroughly, their results are comparable to those parameter combinations with many stops and long listening time. The hearing range in our study area was about 100 m, due to a rather low vegetation height (less than 6 m), and due to the Willow Warbler's habit of singing from conspicuous tree tops. Ten surveys under these conditions yielded a census efficiency of 80 to 90% in the field. The census efficiency of the simulations with comparable parameter sets lay in the same range.

In agreement with intuitive expectations, census efficiency is increased with shorter distances between stops, longer listening time at each stop, and larger hearing range, which all increase the probability of spotting a bird while it sings.

The effect of the time of day on census results in general is also well known. The simulations confirm that even such minor shifts in survey time as from the first to the second two-hour period after sunrise can lead to a slight decrease in census efficiency. This result for the Willow Warbler, a marked morning singer, will also be true for other passerine species with similar daily song activity patterns.

A general argument against the usefulness of such a simulation might be that it does not lead to any new insights, as it only "can put out what has been put in." This is true inasmuch as the simulation is a deterministic one up to now. However, it renders possible a quantitative and replicable analysis of census efficiencies. Moreover, we considered as necessary the step of calibration against field results before proceeding towards a more realistic model. Only after having found—as we did—good agreement between results from the field and those of a simple, deterministic simulation, the introduction of stochastic factors such as movements of birds, background noise, mapping errors, etc., seems justified and worthwhile.

ACKNOWLEDGMENTS

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