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BREEDING BIRD CENSUSES USING SPOT-MAPPING TECHNIQUES UPON SAMPLES OF HOMOGENEOUS HABITATS

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ABSTRACT.—Breeding bird censuses using spot-mapping techniques upon samples of homogeneous habitats are widely used. Large scale measurement programs have been undertaken in Sweden, Great Britain, Canada and the United States. The method is rapidly becoming adopted as standard practice in a broad range of environmental planning and environmental impact assessment projects.

Several major underlying problems occur with the technique. First, the final result is not an arithmetic summation of the individual censuses. Therefore, after much field and analytical research time, only one "sample" results. Therefore, standard statistical tests can not be applied. Second, we do not have definitive experimental data on the effectiveness of this technique in measuring the actual avian population. Most researchers assume that a high percentage of the population is measured. Also, most assume that an underestimate of the actual population occurs. But, we are unsure of ourselves on this critical point. Up to now, no well defined definition of the term homogeneous has been given. A number of more minor sources or error are discussed.

Resolution of the major problems will require the development of innovative experiments that have not as of yet been undertaken.

Breeding bird censuses using spot-mapping techniques upon samples of homogeneous habitats have been conducted widely in both North America and Europe. The methodology has become relatively standardized over time due to its extensive use by avian population biologists (Williams 1936, Kendeigh 1944, Pough 1947, Pough 1950, Udvardy 1957, Enemar 1959, Williamson and Homes 1964, Hall 1964, Robbins 1970 and Van Velzen 1972). The method appears to be used with a considerable amount of confidence by many researchers.

A census is defined as a complete count of animals over a specified area at a specified point in time (Overton 1971). This technique might be more appropriately called a survey because at no time is the entire population measured.

The traditional applications of the technique for the study of various aspects of the population biology of birds have been recently augmented with the advent of environmental impact assessments. In many governmental jurisdictions the need for the ecological assessment of land use change has spurred field biologists in the search for census methods that offer the most advantageous combination of high accuracy and low cost. This method appears to offer such a combination to many environmental impact practitioners.

The method has been used in nationwide programs of population measurement in Britain (Batten and Marchant 1976), Sweden (Svensson 1978) and well as the United States and Canada (Van Velzen 1980). Examples of the use of this methodology for environmental assessment include: the measurement of the effects of residential development on avian populations (Aldrich and Coffin 1980), the species that reinvade reclaimed surface-mined land (Whitmore 1980), and the disturbances that affect breeding populations during the development of a new provincial park (Eagles 1976).

Because of the importance of the breeding period in the life cycle of most avian populations a detailed knowledge of the community at that time is often desirable.

The objectives of this paper are: to briefly summarize the methodology, to comment briefly on some census results, to critique its effectiveness, and to encourage the development of field experiments that will help clarify the various issues raised.

METHODS

The spot-mapping technique involves the repeated censusing of a sample of homogeneous habitat through the breeding season. The research plot, with a recommended minimum area of 10 ha, is traversed by an observer walking along transect lines on a 100 m grid in open habitats, such as fields, or a 50 m grid in denser habitats, such as thick forest. A minimum of eight censuses are done.

Each contact with a bird is marked as a registration on a map of the plot. Registrations that are indicative of territorial behavior, such as male song or boundary aggression, are particularly important. Each map registration contains coded information on the bird's identity, sex (if this can be determined), song (presence and type) and behavior. Standard behavioral observations include the giving of alarm reactions, the feeding of young, any aggressive reactions, the type of vocalizations and the type of activity (perching, flying, hopping, feeding, etc.). In the vast majority of cases it is male bird detection that occurs either by visual or aural means. Registrations of females help to confirm that a breeding pair is present. Constant effort is made to not include an individual as multiple reg-

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TABLE 1
SUMMARY OF H', S, J' FOR EASTERN NORTH AMERICA WITH MEANS ±2 STANDARD ERRORS FOR BREEDING-BIRD POPULATIONS IN NINE COMMUNITY TYPES (FROM TRAMER 1966)

Community	n[a]	H'[b]	S[c]	J'[d]
Marshes	15	1.79 ± 0.34	6.33 ± 1.32	0.718 ± 0.080
Grasslands	38	1.93 ± 0.24	5.74 ± 1.00	0.842 ± 0.034
Shrublands	26	3.14 ± 0.16	14.08 ± 2.31	0.848 ± 0.024
Deserts	6	3.25 ± 0.60	14.17 ± 5.68	0.884 ± 0.048
Coniferous forests	51	3.53 ± 0.14	17.43 ± 1.92	0.880 ± 0.014
Upland deciduous forests	62	3.82 ± 0.08	20.94 ± 1.34	0.879 ± 0.012
Mixed forests	30	3.92 ± 0.14	21.87 ± 2.76	0.893 ± 0.016
Floodplain deciduous forests	18	4.07 ± 0.16	24.22 ± 2.84	0.898 ± 0.020
Tropical woodlands	21	5.23 ± 0.24	55.14 ± 11.24	0.921 ± 0.012

[a] n = number of censuses in sample.
[b] $H' = -\Sigma p_i \log_2 p_i$.
[c] S = number of species.
[d] $J' = H'/\log_2 S$.

istrations without indicating that factor. During the analysis, a territory is assigned if there is a minimum of three valid registrations, that is, registrations on 37.5% of the site visits (3 out of 8).

The numerous details of the standardized methodology can be found in Hall (1946), Robbins (1970), Van Velzen (1972) and Eagles and Tobias (1978).

A large number of individual censuses, using this methodology, have been undertaken in North America. Many have been published through the years in *American Birds*. In Canada specifically, the Canadian Wildlife Service has published nearly comprehensive compilations of the Canadian studies (Erskine 1971, 1972, 1976a). Therefore, the original survey results are usually readily available for secondary analysis.

In order to look for similarities or patterns amongst the measured avifaunal populations in similar community types over broad geographical areas, the published results of these censuses were collected. An analysis of the number of species, diversity index, relative abundance and density in a variety of community types was done. The diversity index was calculated using the Shannon-Weiner formula (Tramer 1969).

This analysis, consultation of the literature and the author's personal experience with the methodology in the field, have been used as a basis for the critical analysis.

RESULTS

Tramer (1969) analyzed the results from 267 breeding bird censuses from eastern North America in a variety of vegetation community types (Table 1). A similar compilation of 70 censuses from southern Ontario (Table 2) revealed a pattern quite similar to that found by Tramer.

These analyses show that the number of breeding species (S), the diversity index (H') and the relative abundance (J') increase progressively along a sequence of community types. Figure 1 shows the diversity indices at a 95% confidence interval for each of the community types given in the tables. It appears that the avian populations in each of the vegetation community types can be structurally differentiated in this way. The confidence interval describes the situation for the final census results of a number of studies. That is, the single study is the sampled area and variation is the site-to-

TABLE 2
SUMMARY OF H', S, J' AND DENSITY FOR SOUTHERN ONTARIO WITH MEANS ±2 STANDARD ERRORS FOR BREEDING-BIRD POPULATIONS IN EIGHT COMMUNITY TYPES

Community	n[a]	H'[b]	S[c]	J'[d]	Average density in males/100 ha
Fields, pasture	11	1.85 ± 0.52	6.7 ± 1.8	.70 ± 0.15	184 ± 87
Sand dunes	6	2.42 ± 1.30	8.5 ± 5.3	.82 ± 0.25	79 ± 58
Urban	5	2.66 ± 0.43	8.4 ± 2.6	.88 ± 0.05	152 ± 269
Fields with trees	13	3.07 ± 0.34	14.5 ± 3.2	.81 ± 0.05	361 ± 96
Deciduous forest in urban ravines	7	3.57 ± 0.43	14.6 ± 4.1	.94 ± 0.01	230 ± 46
Upland coniferous forest	1	3.75	20	.87	356
Upland forest	15	3.82 ± 0.20	23.3 ± 2.8	.85 ± 0.04	601 ± 146
Lowland mixed forest	12	4.24 ± 0.34	26.8 ± 6.2	.91 ± 0.01	590 ± 86

[a] n = number of censuses in sample.
[b] $H' = -\Sigma p_i \log_2 p_i$.
[c] S = number of species.
[d] $J' = H'/\log_2 S$.

site and study-to-study variation. Presumably, the interval derives from the standard Student's t statistic.

DISCUSSION

The Census Summaries

Tables 1 and 2 and Figure 1 show quite clearly that the avian populations, as measured by this methodology, can be discriminated from one another according to the vegetative community type in which they occur. It is of course intuitively obvious to any student of avian populations that different species and populations are found in different vegetative complexes. What is surprising is the degree of similarity between some parameters of avian populations in similar vegetation communities in different areas.

These tables show the confidence interval around the means for a number of parameters. But these factors say nothing about the degree of statistical error found in each individual survey.

A few examples may serve to highlight the information found in the tables. The degree of similarity between the diversity index of upland deciduous forests in eastern North America (3.82 ± 0.08) and southern Ontario (3.82 ± 0.20) is striking. It appears that this forest type holds a certain avian species diversity, across a wide geographical area. The diversity found in tropical woodlands (5.23 ± 0.24) is significantly different from any other community type.

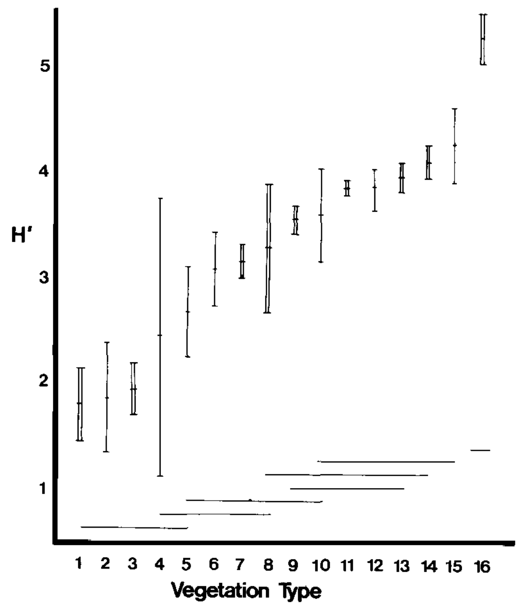

FIGURE 1. Diversity index means plotted against vegetation type. This figure graphically represents the data found in Tables 1 and 2. $H' = -\Sigma p_i \log_2 p$. Vegetation types represented by numbers: 1—marshes; 2—fields and pastures; 3—grasslands; 4—sand dunes; 5—urban; 6—fields with trees; 7—shrublands; 8—deserts; 9—coniferous forests; 10—deciduous forest in urban ravines; 11—upland deciduous forests; 12—upland deciduous forests; 13—mixed forests; 14—floodplain deciduous forests; 15—lowland mixed forests; 16—tropical woodlands. Means given with ±2SE. Means not signficant at 95% confidence level, according to Scheffe's Test, underlined together. Means with double lines from Table 1. Means with single line from Table 2.

Major Problems

The final compilation of the avian population involves data from at least eight censuses that were done during the breeding season. During each census visit the avian activity evidence is marked as registrations on a field map. Later this information is transferred to a master map, one for each species. The evidence found on each successive visit is added to the master maps. The result of all the visits is one map for each species that represents the situation, which is assumed to be stable, prevailing during the time period of the study. The final result is not an arithmetic summation of the individual censuses. It is a temporally oriented, cumulative collection of the registrations for each species. The overall result is the number of territories, or the number of pairs, that occur on the research plot. Since, after considerable field and analytical research time, the result is essentially one "cumulative" sample, then standard statistical tests of variance and significance cannot be applied.

It is usual to consider that each master map is complete and accurate. But it must be recognized that each map has a statistical error attached to it, which represents the difference between the map and the actual situation. Presently we have no way of estimating the size of this statistical error.

This problem could be remedied if a larger number of censuses were conducted so that a number of compilations could be done independently. If 32 censuses were done, then four "samples," each composed of eight censuses, would be present. Statistical tests could then be conducted on the four "samples." This approach would involve the significant problem that the preconceived notions of territorial integrity that the researcher developed during the many hours spent on the research plot could spill over from one sample to the next. Also, the 32 trip level negates the use of the method if time and money are restricting factors.

This lack of statistical testing does not appear to have lowered the effectiveness of this method in the opinion of many researchers. This is obvious from its widespread use. But, it does leave an undesirable element of doubt.

Unfortunately, we do not have definitive experimental data on the effectiveness of this technique in the field. We do not know the actual percentage of the population that is being measured. Nevertheless, some researchers have used this method as a control for evaluating the accuracy of other census techniques (Stewart et al. 1952).

DesGranges (1980) plotted the cumulative number of species found in successive trips for six different community types. In all cases a similar curve resulted. The number of new species encountered was large in the first few visits and decreased in each consecutive visit. The curves levelled out from between 4 to 7 visits with an average of 5.8. Performance of a survey method for a bird can be defined according to the percentage of visits in which this individual was encountered. The overall performance is the average performance of six research plots. These values varied from 38.3% to 57.8%, with an average of 47.6 ± 6.8%. Therefore, it can be calculated that on the first visit to these research plots 47.6% of the observed population would be recorded. On the second visit more of the observed population would be recorded so that 72.5% could be considered to have been found. Therefore by the fourth visit 92.5% would be recorded and 99.8% by the tenth. These percentages deal with the observed individuals only. The total population, of which the observed is a part, is unknown.

Best (1975) did a comprehensive inventory of the individuals in a population of Field Sparrows (*Spizella pusilla*). Each individual was captured and marked and all nests were followed carefully. A standard spot-mapping census was undertaken and was submitted to five other ornithologists for analysis. Their compilations from the data estimated the population from 53 to 87% of the actual population. These analysts did not do any censusing in the field and therefore lacked any backup field knowledge. They relied solely on the field maps provided by the field observer. This study may indicate more about the significance of observer knowledge and memory of the plot than it does about census or analysis efficiencies.

Francis (1973) found that area counts underestimated the true population of Red-winged Blackbirds (*Agelaius phoeniceus*) by 27%. Since this species is relatively conspicuous on its breeding territories, it is suggestive that the underestimation may be even larger with inconspicuous and secretive species.

Stewart et al. (1952) estimated the accuracy of the method to be above 90% for most species, with an average of over 95%. Svensson (1979a) has calculated that the daily census results must be at least 40 to 60% efficient if the final compilation, using the 3 out of 8 rule, is to be considered acceptable.

Davis (1965) found a 30% difference between two aural censuses of male song in Rufous-sided Towhees (*Pipilo erythrophthalmus*) that were done in the same area but were approximately 15 minutes apart. This note reinforces the point that the starting points and the transect directions should be varied so as to "capture" portions of the plot at different times during the census period. Speirs and Orenstein (1975) and Best (1975) mention the importance of recording data on all the activities and behaviors of the birds in the research plot, not just the singing male registrations.

DesGranges (1980) maintains that this methodology is very accurate. Blondel (1969) states that if the methods are properly applied the margin of error will be 10% at the maximum.

Odum and Kuenzler (1955) studied four species in the field, Eastern Kingbird (*Tyrannus tyrannus*), Eastern Wood Pewee (*Contopus virens*), Eastern Meadowlark (*Sturnella magna*), and Orchard Oriole (*Icterus spurius*). They found that between 2 and 8 hours of field observation were required to reach the 1% level on the smoothed effort/yield curve. Beyond this point, each additional observation produced less than a 1% increase in the measured territory size. The average spot-mapping census which consists of 3 hours in the field, on eight separate occasions, will entail a period of 24 hours spent in the field. This is well above the time found to be necessary by Odum and Kuenzler. But it must be recognized that many species are much less conspicuous than the four studied by Odum and Kuenzler and the average census taker must deal with at least 15 species or more singing simultaneously on the research plot.

Preston (1979) discusses the theoretical basis of bird observation in the field. He suggests that bird-spotting can be considered to be a matter of chance. That chance is mediated by elements such as lighting, distance from the bird, foliage density, chance bird movement, and many other factors. He points out that the number of birds seen per hour increase proportionally with the square root of the number of observers. Preparatory work for the atlas of breeding birds in Great Britain and Ireland (Sharrock 1976) pointed out that in an area of 100 sq. km that 50% of the birds could be found after two hours, 75% after 10 hours, 87% in 16 hours and 100% could not be found even after 200 hours of field work. Both these works point out that even after 8 census visits (32 field hours) one observer will not reach the 100% detection level.

In practice, the same route is run in opposite directions by the same observer. This person develops an expectation of where the birds will be found and therefore distributes subsequent effort unevenly. This kind of variation is impossible to quantify. The results presented by DesGranges (1980), for example, are based on such a situation and therefore are potentially suspect because of the lack of independence between measurements.

Confidence intervals could be calculated for a single study if the field visits represented true replications based upon a random selection procedure (Ramsey, pers. comm.). This might necessitate the use of randomly selected observers.

Vegetation Analysis

There is no standard definition used for the concept of homogeneous habitat. A general trend seems to be developing, that groups vegetation communities into a number of quite generalized classes (Tables 1 and 2) (Van Velzen 1980). But it is obvious that any of these classes can be seen as being composed of a large number of different community types. In southern Ontario, Hills (1952) has shown that there are nine predominant forest types that vary according to the microclimate and soil moisture regimes. Recent work by Maycock and Beechey (pers. comm.) has expanded Hill's system into 150 vegetation types that occur in all of Ontario. But the breeding censuses tend to lump the vegetation types into only a few basic categories (Table 2).

This clumping of vegetation types need not be of concern as long as the detailed vegetation community composition data is included with the avian census data. This information can then be used to reclassify the vegetative community if it proves to be necessary at some future date.

A standardized vegetation analysis technique has been recommended for forested communities (James and Shugart 1970) but no such standard has yet come to the fore for non-forested communities.

Homogeneity can be considered to be a problem of mapping scale. Basically, the existing general community categories are those that are mapable at a 1:5000 scale. At a larger scale, the various sub-communities become visible. But it must be recognized that the bird population measurement is done on the ground at a 1:1 scale. If the vegetation communities are approached at this scale, definition becomes much more difficult because of the obvious lack of homogeneity.

This aspect of vegetation community mapping has not been systematically treated by avian population biologists up to now. In the future it would prove valuable to have general community categories defined for each of the North American biomes. This would result in the standardization of the reporting of the vegetation component of avian censuses and hopefully, in the development and acceptance of standard vegetation analysis methodologies.

Sources of Error

A number of sources of error are known with the spot-mapping technique. The most important ones are discussed below.

The territories of individuals may move through the time of the breeding season (Wiens 1969). Individual birds may die or otherwise abandon territories (Best 1975). The possibility of territorial infractions where individuals trespass on another territory raises the possibility of considerable confusion at the time of analysis if such an infraction was observed. There is always the problem of the presence of transient and non-breeding males on the research plot.

A variety of territory types occur in different species of birds (Schoener 1968). Each must be dealt with separately. Some species are non-territorial, such as Brown-headed Cowbird (*Molothrus ater*). Colonial nesters, such as the Great Blue Heron (*Ardea herodius*), pose unique problems. Species with very large territories, that is territories that are many multiples of the total plot size, can cause overestimates of population density if the entire plot is counted as one territory and not as just part of a territory. Small research plots, that is ones below the recommended minimum size, can cause this inflated density effect for even the intermediate-sized species such as the Eastern Meadowlark. These problems are discussed in Eagles and Tobias (1978).

The amount and intensity of singing and the overall conspicuousness varies considerably between species. After the incubation of the clutch begins, or the young hatch, the song level of the adults of many species decreases and therefore the males become less conspicuous. The conspicuousness may increase again briefly after fledging of the young occurs.

Any breeding census methodology of this type must be capable of dealing with those species that nest early or late in the season. When these species are well known in the community under study, then specific census can be done in the appropriate time of year. But the incubation time varies considerably between species and those that breed quickly. For example, these species may be under-sampled if censuses are widely spaced in time. Therefore considerable care must be exercised by the researcher in selecting dates.

Polygamous individuals obviously negate the assumption that the method measures the number of pairs on the plot.

As with any population sampling technique, it must be recognized that the entire population is not being measured. It is to be hoped that in the future field researchers will take on the job of finding the answers or suggesting solutions to the deficiencies pointed out in this paper. Most of them should be amenable to experimental investigation.

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