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MEASURING RESPONSES OF AVIAN COMMUNITIES TO HABITAT MANIPULATION

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ABSTRACT.—Increasing concern for the need to conserve our renewable natural resources, including birds, has resulted in the enactment of laws and the involvement of federal agencies to protect these resources. Past assessments of the effects of management activities on avian communities, and of the sampling procedures used, have been limited in approach and unsatisfactory in result. Recent research suggests that, in addition to sampling bird communities, relevant habitat features must be sampled. Multivariate statistical analyses of many sample plots is usually a preferred technique, trend estimates are usually preferable to density estimates, and the variable-diameter circular plot method is usually best suited for the inventory analyses needed by management.

Human activities of many sorts bring marked changes in the natural habitats of birds, resulting in changes in species composition and population densities. A growing concern that some of the ways we use land may result in irretrievable losses of some renewable resources, including birds, has led to the enactment of laws, at many levels of government, intended to assure wise stewardship of all renewable natural resources. At the federal level, for example, these laws include the Multiple Use-Sustained Yield Act of 1960, the Endangered Species Act of 1973, the Forest and Rangeland Renewable Resources Planning Act of 1974, and the National Forest Management Act of 1976. The laws recognize all wildlife, including birds, as valuable, renewable natural resources.

Because of these laws, many federal agencies are involved in a variety of bird studies (Hirsch et al. 1979). The studies have at least two common goals—to enable us to predict the effects of land or resource management projects on the composition of bird communities, and to monitor bird population trends in the community before and after project completion. It is impossible, of course, to monitor every management project adequately, but our ability to predict the effects of projects will improve in proportion to the monitoring accomplished. I believe it is imperative to ensure coordination among those involved in the effort, to minimize duplication, and to employ standardized methodologies.

This paper reviews and evaluates the state-of-the-art for predicting or assessing the effects of management activities on bird communities. The problems are assessed from the viewpoint of an applied ecologist constrained by the needs of management to find reliable and cost-effective methods for achieving goals.

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PREDICTING AND ASSESSING PROJECT EFFECTS ON BIRD COMMUNITIES

Our ability to predict the effects of projects on bird communities is limited. This is particularly true in North America where, until recently, systematic, standardized, and continent-wide inventory programs encompassing all habitats and sampling both animal communities and their associated habitat elements have not been supported. Sampling has been disorganized, noncomprehensive, and has used different sampling procedures. The state-of-the-art is more advanced in Europe, especially in Scandinavia, where nationwide inventory and monitoring programs have received more attention (Lack 1937; Oelke 1966; Järvinen and Väisänen 1973, 1976c, 1977b; Sharrock 1976).

LIMITED SITE COMPARISONS

Until recently, the most common method for assessing and predicting project effects on bird communities has been to compare species' densities on treated and untreated sites. Sample sizes have typically been small, usually only one treated and one untreated site; or, for studies of successional changes, only one site each in several seral stages. Also, most of those earlier studies were done only after habitat treatment. Comparison was made between the treated site and a different, but usually nearby, untreated control site. This design assumes that prior to treatment the control site had an avian community not significantly different from that of the treated site in any sampling season. This may or may not have been true, but no test of this assumption can be made once a treatment is completed.

The optimal design, if a limited number of sites is to be sampled, involves both pre- and post-treatment sampling of the treated site and

> "an identical, untreated control area . . . The null hypothesis in this case would state that changes in bird species abundance in

the treatment area over time would be identical to changes occurring in the control area. Contained within this design are controls for both space and time" (Conner and Dickson 1980).

The key assumption is that the control and treatment sites are identical. Each site should be sampled several years (my intuition suggests at least 5 years) prior to treatment to establish that patterns of annual variation do not differ between sites. Even then, the researcher has no measure of within-treatment variance, so valid generalizations to other similar habitats are limited.

The necessity for comparing communities before and after treatment has not been met because, until recently, no strong mandates to maintain all renewable resources were in force. Consequently, managers did not include in their decision-making process alternatives to incorporate a wide variety of resource needs. And researchers generally failed to provide managers the kinds of information required to accommodate the needs of birds, mammals, and other renewable resources considered in management prescriptions. This has resulted in a general lack of communication between researchers and managers. Researchers have not sought information on future projects, and managers have not brought projects to the attention of researchers. Fortunately, this situation is changing rapidly, and the result no doubt will be mutually beneficial.

Multiple Site Comparisons

The extensive literature on habitat selection by birds has been reviewed (Hildén 1965), and the value of an understanding of habitat selection in effective management of bird populations was summarized by Verner (1975). Factors important in habitat selection include food sources, nest sites, song posts, shelter, available water, nesting materials, watch-posts for insect hawking species, and general features of the terrain or vegetation. The data

> "generally demonstrate a great range of variability among bird species with respect to habitat selection. The data also show that for nearly all species our knowledge of specific factors eliciting positive habitat selection responses is woefully meagre. While I believe we must continue to research this problem on a species-by-species basis, I suggest that this is not the most fruitful approach to the immediate problem of managing wild lands in a manner that will minimize detrimental effects on populations of . . . birds. Studies most likely to yield information widely applicable in habitat management are integrative, multivariate analyses of bird species abundance and habitat variables" (Verner 1975:51).

This view is widely held (Anderson 1979, Niemi and Pfanmuller 1979, Rotenberry and Wiens in press and Shugart in press).

Assuming sufficient information on habitat selection by the bird species of a region, it should be possible to predict avian community composition for any site. This can be done by measuring habitat variables that provide proximal cues for habitat selection. Applications of multivariate statistical analyses to avian communities and their associated habitats show this to be a viable alternative to limited site-comparison methods. This is not to say, however, that it can take the place of intensive, individual species studies, especially rare species or those with very large home ranges. Detailed life history investigations must remain a vital part of our overall research effort to be fitted in where necessary. And we may not permit our confidence in the multivariate approach to dull our insistence on the need to test predictions.

The trend in North America toward applying multivariate statistics to avian community and habitat studies goes back to the work of Cody (1968), James (1971), and Anderson and Shugart (1974). Cody (1968) used discriminate function analyses to identify interspecific differences in habitat selection among species in grassland bird communities, and to identify those habitat variables contributing to the differences. James (1971) sampled 15 vegetational variables on 0.1 acre plots centered on 401 song perches of 46 species in a variety of habitats in Arkansas. Principal component and discriminate function analyses were used to establish habitat ordinations of the species along three dimensions representing gradients in vegetation structure. Anderson and Shugart (1974) used discriminate function analysis to order habitat variables "according to their strength in separating abundance categories for 13 of the more abundant bird species" in a primarily deciduous forest in Tennessee. They concluded that their results provided a basis for predicting changes in bird species composition as a result of habitat alterations.

Several multivariate techniques have been used recently by researchers studying the relationships of avian communities to habitats (Capen in press). Discriminate function analysis, principal components analysis, and cluster analysis have been used most often. But this field is in a dynamic state. The best methods are surfacing. Also, researchers need more experience in interpreting results from these sophisticated techniques—both the statistics and the biology.

If a time-efficient counting method is used to sample bird communities, a large number of sites can be included, and key habitat variables measured at each. Some standardization is desirable, as suggested by James and Shugart (1970). Multivariate approaches can yield information beyond that needed to evaluate effects of a management project on the bird community at a given site. As these data accumulate, our ability to predict impacts will improve. Significant insights into habitat selection by individual bird species will emerge, leading to understanding of the bases for regional differences in habitat selection within species. Clearly, such results can make profound contributions to basic knowledge, while still generating data needed by applied ecologists.

PRACTICAL CONSIDERATIONS

The task of maintaining all bird species, providing wise stewardship of other renewable resources, and also accommodating demands of resource users, is formidable. Managers need tools to do the job effectively within the constraints of tight budgets and limited personnel. For management considerations, trend estimates in bird populations may need to be the rule, because reliable trend data are more cheaply and quickly accumulated than reliable density data. And rather than intensive analyses of vegetation composition and structure on a study site, managers may be able to afford to measure only those parameters critical to predicting whether or not a site will be optimum, suitable, or only marginal for certain species. Parameter selection must, therefore, consider the speed and objectivity with which measurements can be taken. For example, diameter-at-breast-height (dbh) may be the preferred measurement as an index of tree height, foliage volume, or canopy diameter (Young 1977, Verner 1980b), even though bird species richness is more directly affected by tree height or volume.

However these challenges are met, it is obvious that much basic research remains to be done. This research needs to include:

- Quantitative sampling of bird communities and habitats;
- Identification of the habitat needs or preferences of birds on a species-by-species basis;
- Identification of effective habitat predictors of species richness and species occurrence; and
- The role of patch size, shape, and position in determining the make-up of avian communities.

SAMPLING BIRD COMMUNITIES

Many methods have been used to sample the composition of bird communities and to estimate densities of species in those communities. These topics have been dealt with in various papers presented at this symposium. We are far from consensus on which method is most appropriate in any given situation. The International Bird Census Committee recommended the mapping method as preferable for sampling communities of breeding birds (Svensson and Williamson 1970). The same procedure is standard for the National Audubon Society's annual Breeding Bird Census, with more than 100 censuses being reported annually in the pages of *American Birds*.

Various forms of transect counts are used widely including fixed-width and variable-width strips (review in J. T. Emlen 1971, 1977a). French scientists, for more than two decades, have made extensive use of timed counts from fixed points with unlimited boundaries (Ferry 1974; Blondel 1975, 1977). More recently, a method involving variable-diameter circular plot counts has been developed (Ramsey and Scott 1978, Reynolds et al. 1980) and tested extensively (J. M. Scott, pers. commun.). Nearly all bird species in most terrestrial habitats can be sampled by variations of these basic methods. However, the particular needs and constraints of land managers make some methods more appropriate than others.

The mapping method is applicable only to territorial populations. Moreover, it is poorly suited to large-scale inventories mandated by recent legislation. Resource agencies lack funds and manpower to sample enough plots to generate a sufficient data base for statistical analysis. Although many researchers believe the mapping method is the most accurate sampling procedure in wide use (but Berthold's [1976] thorough review casts much doubt on that belief), the small sample sizes possible mean that no confidence limits can be established. This could put the manager in an untenable position if a management decision based on such data comes under legal challenge.

The patchiness of vegetation makes it difficult to locate large, homogeneous areas of habitat. But large plots are needed to reduce the potential for a bias in the mapping method resulting from territories overlapping the edge of the study plot (Berthold 1976). The relationship be-

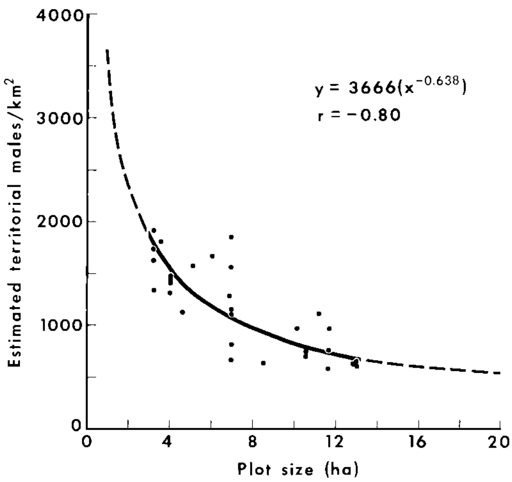

FIGURE 1. Relationship between plot size and estimated density of territorial males in California oak woodlands (Verner 1980a). Dashed portions of the curve are calculated extrapolations from the data.

tween mapping plot size and estimated density of birds in California oak woodlands (Fig. 1) is based on counts reported in *Audubon Field Notes* and *American Birds* from 1944 through 1976. Data were fitted to linear, exponential, and power curve regression models. Statistically significant ($P < 0.001$) negative correlations were found in each case ($r = -0.80$, -0.81, and -0.80, respectively). Figure 1 shows the power curve fit to the data, as this gave the best visual fit. These results suggest that bird density on 3.2 ha plots is about 2.7 times the density of birds on 13 ha plots, which may be true if the smaller plots are isolated patches that tend to attract a disproportionate share of birds. If, however, the data in Figure 1 reflect an overestimate of density on smaller plots, then plots of at least 20 ha appear to be required in California oak woodlands to escape this small plot effect. The character of most managed land does not provide homogeneous patches of habitat that large.

Transect methods lend themselves better to sampling more sites, because usually several transects can be counted in the same period of time required to complete one mapping survey. Conner and Dickson (1980) recommend fixed-width transects as the preferred technique to detect effects of habitat treatments on birds. I believe J. T. Emlen's (1971, 1977a) variable-width transect method is superior to a fixed-width method, however, because it compensates for species with variable detectability and for observer biases. Comparisons of density estimates obtained by mapping and by the variable-width strip transect method generally show lower estimates with the transects (J. T. Emlen 1971, Franzreb 1976, Dickson 1978). No method, however, yields completely accurate censuses of birds. Effective management *can* be based on reliable estimates of population trends, but those estimates should come from the same sampling method year-after-year (Conner and Dickson 1980).

The major limitation of the transect method is that, as for the mapping method, it is difficult to find large enough blocks of homogeneous habitat to contain the transects. Any given transect count commonly yields results reflecting considerable variation in habitat characteristics. This is incompatible with multivariate statistical analysis. Anderson et al. (1977) have attempted to minimize this problem by subdividing transects into 150-m segments and treating each segment as a separate sample. The obvious shortcoming of this solution is that bird counts in adjacent segments, and even some measured habitat variables, are not independent.

Counting of variable-diameter circular plots is probably the best compromise as a method for the enormous task facing land and resource managers. It is time-efficient, applicable to small patches of habitat, and can supply the trend data suited to management. It can also provide some information on species' densities. I agree with Shields (1979) that it is preferable to use a method having some potential for indexing absolute, rather than relative, abundance. Such information can be important to managers in the case of some species, and further work with the method should give us a better understanding of the relationship between real field densities and densities as computed by the method. Furthermore, we can gain the density information by this method with little or no more time than is required to obtain acceptable estimates of population trends by sampling only relative abundance.

The variable-diameter circular plot method is also well-suited to multivariate statistical analyses, because sampled plots are small enough that habitat structure can be kept reasonably uniform, and many sites can be counted in a short time. Statisticians recommend sample sizes five to ten times greater than the number of independent variables to be considered. Agencies constrained by limited time or personnel should be guided by the rule: results from multivariate analysis will be more valid if more time is given to accurate sampling of the independent variables, even if less accurate estimates of the dependent variables result (David Sharpnack, pers. commun.). In other words, sampling many sites a few times is better than sampling a few sites many times.

The variable-diameter circular plot method is not without its sources of error and bias in estimating bird densities. For example, one assumption of the method is that "The count period is short enough . . . that objects occupy fixed locations during the count" (Ramsey and Scott 1978). This, of course, is not true. If a bird is detected in the count area and leaves during the count, it is not deleted from the total of birds recorded. But if a bird that is not within detectability when the count begins later moves within detectable range during the count, it will be recorded. The effect of this according to S. L. Granholm (pers. commun.) is to inflate the count relative to ideal fixed locations assumed by the model. It also tends to create a "donut" effect in the distribution of detection distances relative to the observer, because such incoming birds generally are first detected some distance away, as they near the plot center (Ramsey and Scott 1978).

Finally, none of the methods considered here is well suited to sampling rare species, or species with large home ranges, because they yield insufficient numbers of observations to assess the effects of management on them. At least some of these species are among those recognized as especially sensitive to the sorts of changes humans have brought to natural ecosystems. The diurnal and nocturnal raptors are examples. An obvious solution is to apply a variety of census techniques.

CONCLUSIONS

In addition to sampling bird communities, it is essential to sample relevant habitat features. Research must focus attention on identifying habitat features that are good predictors of bird species presence. This process should consider the ease and accuracy with which selected features can be measured.

Analysis of the effects of habitat treatments on avian communities, based on pre- and post-treatment measurements on a limited number of treatment and control sites, has limited general application. With about the same time input, and well within the time constraints of a challenging Ph.D. dissertation, it is possible to carry out a study of many sites across a wide range of habitat conditions and to apply to the results a variety of multivariate statistical analyses. This can provide insights into habitat selection by birds and, at the same time, generate information upon which to base general predictions of a wide range of project impacts on bird communities. Given the probable course of secondary succession on a site disturbed by management, it should be possible to predict avian community structure well into the future. This is rapidly becoming an indispensable part of the planning process for public land management agencies.

Because no counting method equivalently samples the densities of all species, and because accurate density estimates of few, if any, species can be readily obtained, most assessments of management effects ought to rely on trend estimates only. Any well-conceived method is suitable for this, so long as sampling is standardized from plot-to-plot and from year-to-year.

The variable-diameter circular plot method of estimating bird densities is the best suited to most of the inventory work so badly needed by management agencies today. Even though the method may be used by management primarily for obtaining trend information, some density information may prove to be invaluable. Other methods may be superior in certain situations, and we must keep in mind the fact that some sensitive species are not adequately sampled by this or any other common census method. Intensive life history studies may be the only solution for some such species.

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