Studies in Avian Biology No. 6:17–23, 1981.

THE CHRISTMAS BIRD COUNT AND AVIAN ECOLOGY

CARL E. BOCK[1] AND TERRY L. ROOT[1]

ABSTRACT.—The Christmas Bird Count (CBC) is an enormous but weakly standardized avian count. Observers spend thousands of hours annually, counting as many species and individuals as possible inside hundreds of 15 mile (24 km) diameter circles in North America. CBC data are an inappropriate substitute for more controlled census work associated with local projects. Scientists probably would ignore CBC data altogether, were it not for their potential application to large-scale studies. CBC results have proven to be good descriptors of continent-wide patterns of avian geographical ecology—patterns which otherwise often would remain undetected. Nevertheless, CBC data should be used with caution. Large sample sizes are very important. The data are better indicators of real patterns among common and well-dispersed species than for rare and/or highly social species. For species spread relatively evenly across count circles, CBC results should be standardized by dividing raw numbers by total party-hours of count effort. Species which are social and restricted to unusual habitats (e.g., waterfowl) are likely to be counted or estimated totally regardless of the overall count effort. The best standardization for these birds probably is to compute raw numbers per count. Most CBC studies have been concerned with population trends, but the data are equally valuable indicators of spatial abundance patterns. Application of clustering techniques to CBC data results in a numerical biogeography, the power of which lies in its being quantitative, objective, and based upon abundance patterns.

Certainly the largest and oldest bird census in the New World is the annual Christmas Bird Count. Each CBC is a day-long tally of birds seen inside a circle 15 miles (24 km) in diameter just prior to or following Christmas Day. Results, published in *American Birds*, include latitude-longitude coordinates of each census, lists of species seen and their numbers, numbers of observers, party-hours and party-miles as indices of effort, and information about weather and habitats surveyed. Each year thousands of observers participate in hundreds of counts across North America. We estimate that just in the decade 1962–71 Christmas counters spent well over one million hours afield and recorded about 635 million birds.

If the CBC ranks as the world's largest bird-population count, it probably is the least structured. Since they are involved in a type of birding contest, participants will do what they can to see as many species and individuals as possible. This can involve staking out rare birds ahead of time and sowing bird seed in likely places. Counting birds at backyard feeders is common. Organizers try to assure uniform coverage, but observers naturally spend most of their time in the best spots.

Given these conditions of data collection, scientists might be expected to avoid CBC's altogether. Doubtless this would be the case, were it not for the potential that they offer to students of avian ecology. With CBC's we can at least *ask* questions about winter bird-population fluctuations and about bird-abundance patterns on a geographic scale not possible for any other organisms.

This, of course, presumes that CBC data are realistic indicators of winter bird-population distribution and abundance. There is no way to test the quality of the data, except as they conform to expected patterns or are confirmed by independent sources of information. In this regard, however, results have been quite good. CBC data revealed an unexpected synchrony and cyclic regularity to southward eruptions of normally boreal birds (Bock and Lepthien 1976d), a finding subsequently supported by banding data (Kennard 1976, 1977). Many apparent and generally recognized population changes have been documented with CBC data (e.g., Davis 1937, 1974; Wing 1943; Brown 1973, 1975; DeHaven 1973; Bock and Lepthien 1976c; Larson 1980; Pruett-Jones et al. 1980). CBC patterns of species richness and diversity are strongly correlated with certain climatic variables (Tramer 1974; Bock and Lepthien 1975b). Recent comparisons of CBC data with results of migration studies at the Long Point Observatory led Hussell and Risley (1978:98) to conclude that "Christmas Bird Count indices can be used to monitor populations of many species with greater precision than had previously been suspected."

Despite these encouraging results, it is obvious that CBC data must be used with great care and caution (Arbib 1967). They can be a powerful analytic tool; but there are circumstances under which they ought not to be used; and there are some methods of analysis that are much more effective than others. The purposes of this paper are to discuss: (1) means of standardizing CBC data, (2) effects of weather on count results, (3) the problem of adequate sample sizes, (4) the problems presented by rare and by highly social species, and (5) the application of cluster analyses to CBC data.

[1] Department of Environmental, Population and Organismic Biology, University of Colorado, Boulder, Colorado 80309.

STANDARDIZING CHRISTMAS COUNT DATA

MEASURES OF COUNT EFFORT

CBC results must be normalized to be meaningful indicators of winter bird population sizes (Kenaga 1965, Raynor 1975). Davis (1974 and earlier papers cited therein) divided total birds seen by the number of counts per year in his studies of Northern Shrike (*Lanius excubitor*) eruptions. Birds per census would be a reliable index of population trends, as long as average effort per census did not change over the years or areas being considered. Most authors have been unwilling to make this assumption, although it probably holds if enough counts are considered at once. Some workers have divided bird numbers by party-miles (Brown 1971, 1973) or by numbers of observers (Raynor 1975), but most have chosen party-hours as the best measure of count effort (e.g., Schreiber and Schreiber 1973, Bystrak 1974, Stahldecker 1975, Plaza 1978).

DeHaven (1973) found that dividing by party-hours and party-miles gave essentially the same picture of Starling (*Sturnus vulgaris*) population growth in California. Raynor (1975:628) concluded that "it probably makes little difference which measure of effort is used to normalize count data," since all are strongly correlated. Falk (1979) analyzed 15 count sites in the north-central United States and found that, overall, total party-hours was the best predictor of both the number of species and the number of individuals recorded on those counts. Party-hours seems to be the best and most widely accepted factor for CBC standardization.

THE PROBLEM OF UNUSUAL HABITATS

One of the greatest difficulties with CBC data concerns their application to aquatic species or other birds restricted to special habitats inside count circles. Observers will be aware of these areas and will cover them each year regardless of overall count effort. If there is one pond in an otherwise terrestrial count circle, it will be covered for ducks each year. If total party-hours doubled over a 10-year period, then "ducks per party-hour" would fall to one half its original value over the same period, despite a stable duck population on the pond. Raynor (1975) recommends calculation of "effective party-hours" for such circumstances, which in the above example would be the party-hours actually spent at the pond counting ducks. This solution has several problems. First, it is not possible to determine just where a particular species was seen. Published count results include lists of habitats visited (by percent of total count time spent in each), but the birds are not listed by those habitats. Even if one could logically connect the species of interest with a particular habitat type, and then calculate effective party-hours spent in it, such calculations would soon become prohibitively tedious in any study involving large numbers of counts. Most importantly, we have found it very difficult to compare lists of habitats from one count to another, since there is no standard terminology in use.

Morrison and Slack (1977) found no correlation between raw numbers of Olivaceous (*Phalacrocorax olivaceus*) and Double-crested Cormorants (*P. auritus*) and any measures of effort among Gulf Coast CBC's. They used actual numbers per count as the best measure of population trends. This probably is the simplest and most meaningful way to standardize CBC data for birds which are restricted to aquatic habitats, which are social, and which therefore are easily censused.

STANDARDIZATION BY COMPARISON OF SIMILAR SPECIES

A less-used but potentially powerful approach to CBC analysis is to use the number of birds themselves as a means for data standardization. Suppose, for example, we are interested in comparing abundance patterns of Eastern (*Sturnella magna*) vs. Western Meadowlarks (*S. neglecta*). We simply divide the raw numbers of the eastern species by the total number of meadowlarks of both species. No additional standardization is necessary. The problem of unusual habitats is eliminated by this method, since dividing by total meadowlarks presumably compensates for the fact that different counts involved different amounts of time spent in meadowlark habitat.

This method of calculating relative abundance tells us nothing about absolute changes in numbers, but it does tell us a great deal about patterns of geographic complementarity among related or similar species, and it should be as applicable to readily counted species (e.g., waterfowl) as to species spread more evenly across count circles. Bock et al. (1977) and Root et al. (in press) used this approach in studies of the geography of flickers (*Colaptes*), juncos (*Junco*), meadowlarks (*Sturnella*), bluebirds (*Sialia*), phoebes (*Sayornis*), and thrashers (*Toxostoma*) across the central U.S. in winter. The technique dates to the work of Wing (1943), who examined ratios of Mallards (*Anas platyrhynchos*) and Black Ducks (*A. rubripes*) across the eastern U.S. between 1900 and 1939. We have computed similar ratios for the 1962–71 counts, grouped in five degree blocks. Figure 1 shows blocks in which Mallards and Black Ducks were most abundant. Wing's line of equal ratios is superimposed, showing how the Mallard has expanded its numerical dominance eastward in the past 30 years (see also Johnsgard and Di-Silvestro 1976).

WEATHER

It is common for users of CBC data to be concerned about weather, not as it affects the numbers of birds present in a count circle, but as it might influence their detectability and/or observers' enthusiasm (Arbib 1967). Compensation for the weather may be necessary in some cases. For example, W. H. Brown (1971) found that more Red-shouldered Hawks (*Buteo lineatus*) were counted on clear than on cloudy days. Morrison and Slack (1977) found that numbers of cormorants counted varied inversely with cloud cover and wind. However, Falk (1979:689) analyzed 15 counts in the north-central U.S. and found that (1) "weather conditions do not consistently affect measures of count effort," and (2) "there are relatively few significant values when selected weather conditions are correlated with number of bird species and individuals."

THE PROBLEM OF SAMPLE SIZES

The best safeguard against spurious effects of weather or any other stochastic event, such as observer skill and numbers, or movements of flocking birds, is to analyze a sufficient number of counts over a sufficient number of years so that these variables will cancel out or equilibrate. What is a sufficient sample size? We can give no universal answer except to state the obvious: the more counts that are analyzed, the greater the confidence that can be placed in any emerging trend or pattern. Bock and Smith (1971) analyzed population trends for 20 selected species in Colorado for the years 1940 to 1970. Most species curves fluctuated wildly until about 1950, when the sample size per year jumped rapidly from four or fewer counts to eight or more counts. Schreiber and Schreiber (1973) found a similar pattern in Florida counts.

The importance of large samples is illustrated by the following simple but real examples. Root et al. (in press) analyzed 124 count sites in Texas, Oklahoma, and eastern New Mexico for abundances of bluebirds. They found that the Eastern Bluebird (*Sialia sialis*) was significantly more abundant east of the 100th meridian than it was to the west. Yet, between 1962 and 1971 three east Texas CBC's (Ft. Worth, Dallas, Travis County South) together counted fewer Eastern Bluebirds per party-hour than did three west Texas counts (Davis Mts., Lubbock, and San Angelo). This does not mean that the six counts in question were "wrong," but neither does it invalidate the general conclusion about bluebird geography in Texas.

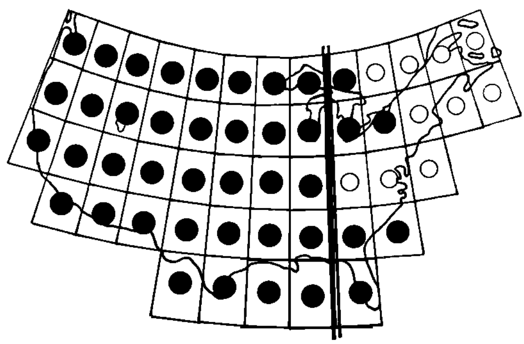

FIGURE 1. Geographic blocks in which Mallards (dots) or Black Ducks (circles) were most common on 1962–1971 CBCs. Between 1900 and 1939 Black Ducks outnumbered Mallards east of the heavy double line (Wing 1943).

Bock and Lepthien (1976d) found that, between 1962 and 1971, synchronous and continent-wide southward eruptions of boreal seed-eating birds occurred in the winters of 1963–64, '65–66, '68–69, '69–70, and '71–72. Sample size for this study exceeded 7000 counts. CBC's in a 5 degree block including parts of Minnesota and Wisconsin (Block 7 in Fig. 6A) showed this pattern clearly for the strongly eruptive Common Redpoll (*Carduelis flammea*); yet, in that block, the Duluth count conformed to the continental pattern only in some of those years (Fig. 2).

Some workers have attempted to improve the "quality" of CBC data by accepting only those counts with certain ranges of party or observer numbers (e.g., Graber and Golden 1960, Stahldecker 1975). Others have included only those counts conducted continuously for the span of years being considered, or only counts occurring in some minimum number of years (e.g., DeHaven 1973, Brown 1975). Such selectivity may be necessary for studies involving a small number of years, a restricted geographic area, or a rare and/or flocking species. *A priori* exclusion of counts is a legitimate step, but it can lead to a powerful and dangerous urge to exclude certain counts *a posteriori,* when those counts are obscuring an otherwise clear trend.

RARE AND FLOCKING SPECIES

Problems associated with very rare species may be so severe that no meaningful CBC analysis is possible. Observers will work hard to find at least one individual of any rare species which might occur in a count circle. The result is that some rare species appear to occupy the country

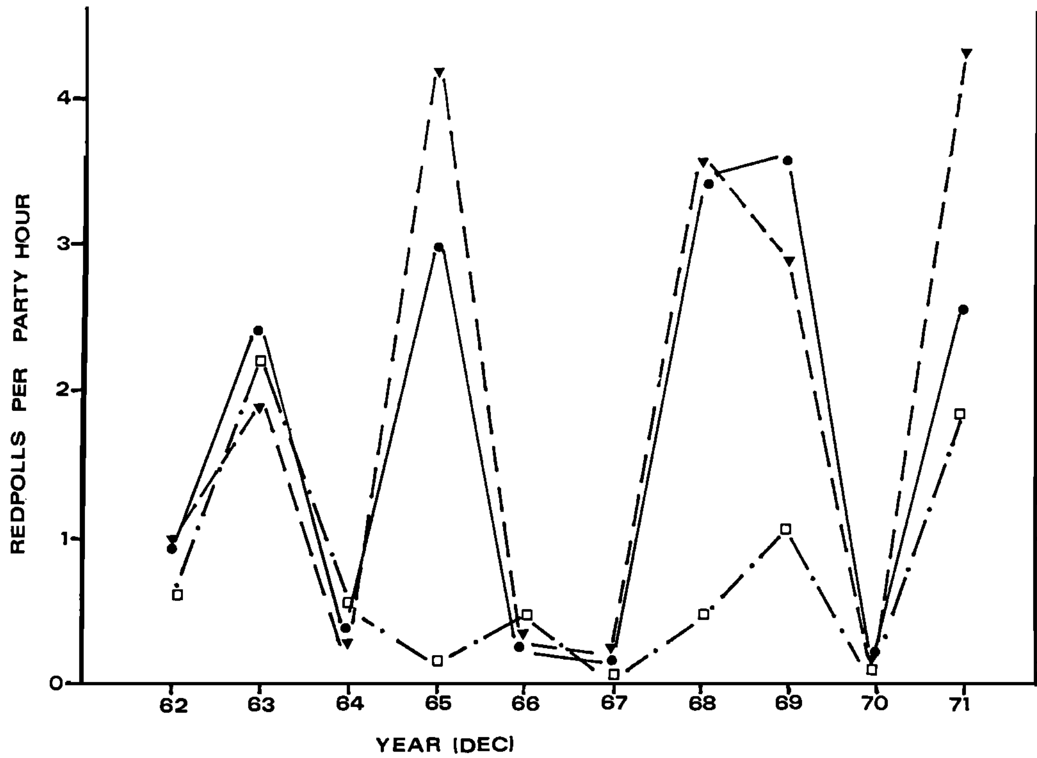

FIGURE 2. Number of Common Redpolls counted per party-hour on all counts (solid line), Block 7 counts (dashed line), and on the Duluth, Minnesota, count (broken line). See Figure 6A for location of Block 7. Multiply abundance scale by five for Block 7 and Duluth count data.

in the ornithological equivalent of a monomolecular layer. Chance encounters of rare and narrowly distributed species can significantly affect results. We found no correlations between carefully considered population estimates of the California Condor, *Gymnogyps californianus* (Sidney et al. 1968) or Whooping Crane, *Grus americana* (Olsen 1980) and our computerized 1962–71 CBC data for these species.

Flocking and communally roosting species can be equally difficult. One of the first projects we attempted with our CBC data bank was an examination of nationwide population changes in the Starling. We discovered that three or four individual counts in the Southeast, if they occurred in a particular year and if observers found roosts, could double the average number of Starlings counted per party-hour for the entire country. Our data for blackbirds and grackles are equally variable and appear beyond any sort of meaningful analysis.

BIOGEOGRAPHY

Species' Abundance Patterns

Most CBC ornithology has been concerned with temporal changes in species populations. The data are equally valuable for studies of the spatial abundance patterns of birds.

Biogeography traditionally has considered only the presence and absence of species on continents, since these are the only data available on such a scale. Yet presence versus absence is recognized to be a grossly simplistic

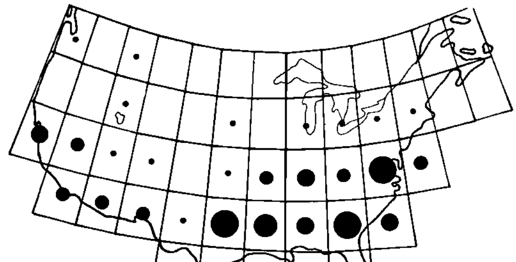

FIGURE 3. Numbers of vultures counted per 100 party-hours, 1962–1971 CBC data. Five sizes of dots represent <1, 1–33, 34–65, 66–100, and >100 birds/100 party hours. Open blocks = no vultures counted.

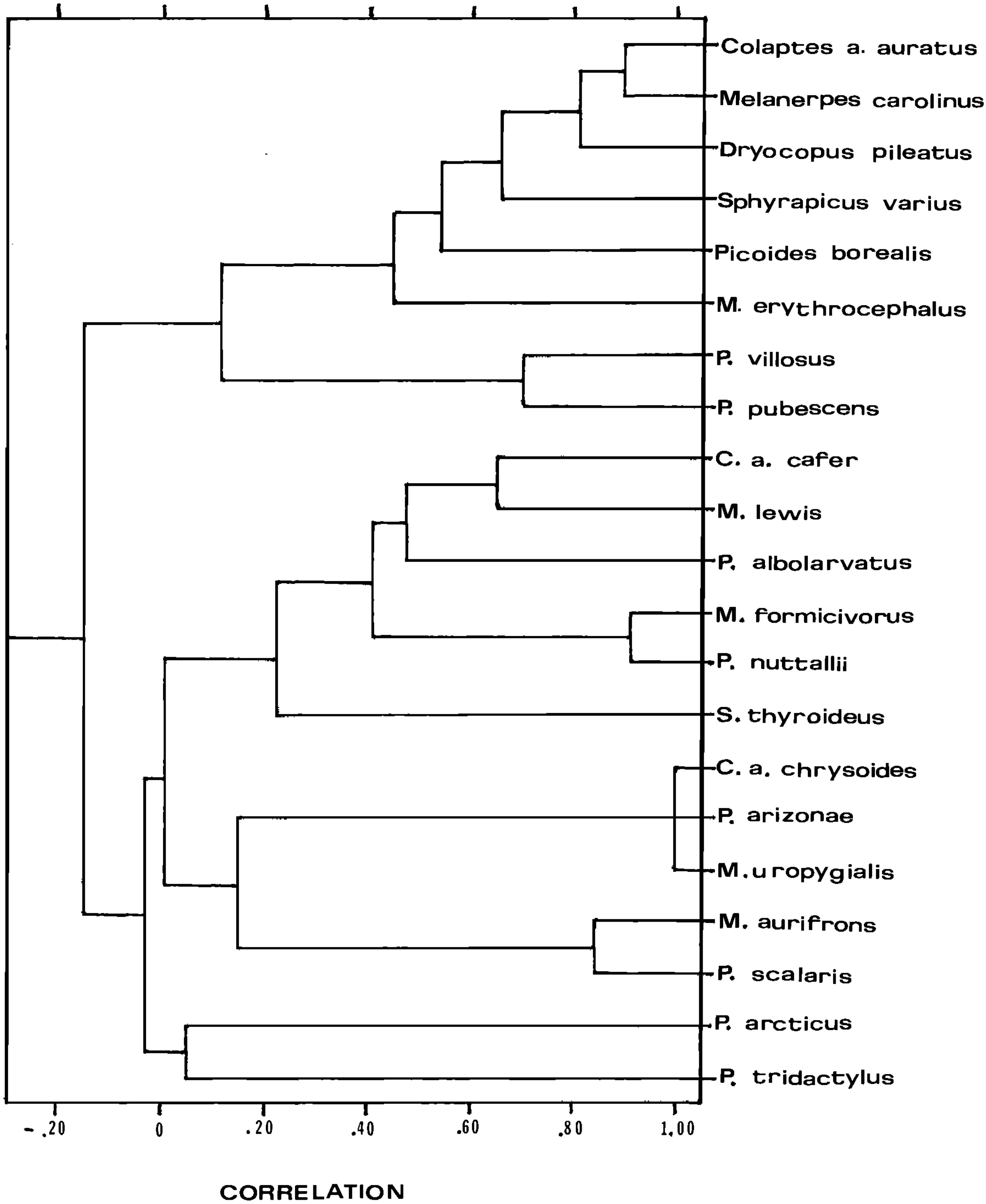

FIGURE 4. Dendrogram showing relationships among 21 taxa of woodpeckers, based upon their CBC abundance patterns in 51 latitude-longitude blocks (Fig. 6A). Matrix correlation = 0.891.

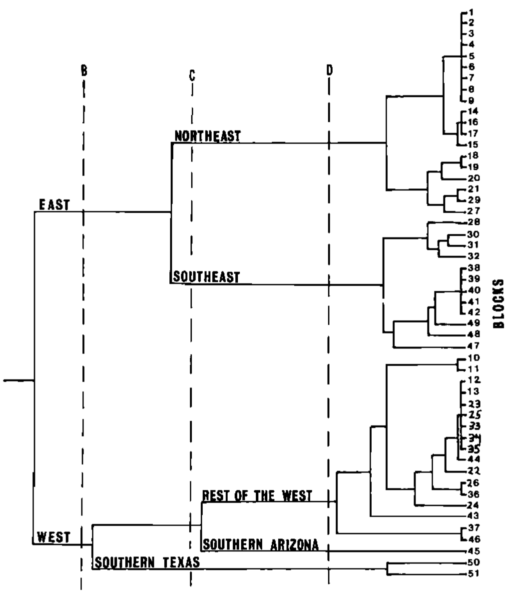

FIGURE 5. Dendrogram of 51 latitude-longitude blocks, based upon CBC abundance patterns of 21 woodpecker taxa. Matrix correlation = 0.917.

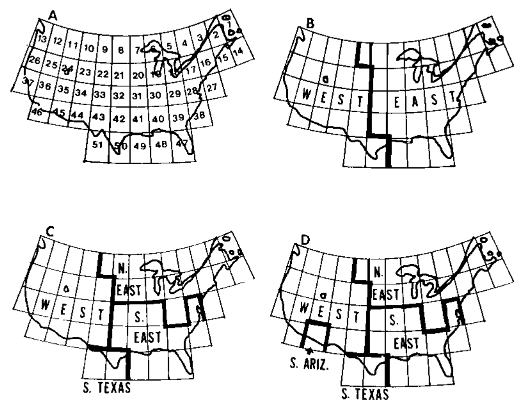

FIGURE 6. A. Locations of 51 5-degree latitude-longitude blocks. Maps B–D show geographic positions of clusters of blocks corresponding to branches of dendrogram transected by dashed vertical lines B–D in Figure 5.

view of the reality of species distributions (e.g., Udvardy 1969, Rotramel 1973). Simply stated, species are common in some places and rare in others. There is good reason to suspect that the last outpost of a species' range tells us less about what is environmentally important to it than would data showing us where, inside its range, that species switches from being abundant to being scarce. With CBC's we anticipate that we can plot a species position in space in terms of contours of declining density away from centers of abundance (Grinnell 1922). We could then compare these with known patterns of climate, topography, and vegetation and learn what factors of the environment are important to the bird populations of interest.

One common criticism of CBC data is that they are collected in early winter, before some species have fully settled on their wintering grounds (Arbib 1967). If we used CBC's as indicators of the limits to winter ranges of species, this would indeed be a problem. But the unique aspect of CBC information is that it shows us where species concentrate in winter, so that the occurrence of stragglers becomes largely unimportant.

The most extensive geographic analysis to date using CBC data has been the winter-range-mapping project (Bystrak 1971, Bystrak et al. 1974), which resulted in publication of abundance maps for 140 species, each prepared by a volunteer. The maps are of good quality for the most part. If they have a weakness, it is that they usually were based on only one year's data. Recently, Plaza (1978) has shown the potential of applying computer mapping programs to CBC information.

We have built a computerized data bank containing the results of 7891 counts occurring between the winters of 1962–63 and 1971–72. We combined the counts into 5-degree blocks of latitude and longitude, then computed the mean number of birds seen per party-hour for each block, for each of the ten winters, for 627 species. Figure 6A shows locations of the blocks, by number; sample sizes were very uneven across blocks, ranging from 11 in Block 48 to 864 in Block 16.

CBC abundance maps are interesting and valuable indicators of species' centers of abundance. Through correlation analysis we have compared species' abundance patterns with climatic variables (e.g., Lepthien and Bock 1976), and with vegetation (e.g., Bock and Bock 1974). Figure 3 shows the combined 10-year mean winter abundance pattern of the North American vultures (*Cathartes aura* and *Coragyps atratus*). Applying environmental data to the same grid, we find that this pattern is positively correlated with estimates of primary productivity (r = .601), number of frost-free days (r = .746), and annual precipitation (r = .458).

CBC's and Numerical Biogeography

By applying techniques of cluster analysis to CBC data (Sneath and Sokal 1973), it is possible to describe geographic patterns for whole groups of species in a quantitative manner. Beginning with a raw-data matrix of *n* species by *n* geographic areas, we can group species which share centers of abundance (e.g., Bock and Lepthien 1976a), or recognize groups of blocks which are highly correlated in terms of their winter avifaunas (Bock et al. 1978). We present here a single-linkage cluster analysis (Sneath and Sokal 1973) of the family Picidae to illustrate the value of this approach. Figure 4 is a cluster of 21 taxa of woodpeckers, based upon correlations of their abundances in 51 latitude-longitude blocks (Fig. 6A). We can cluster the blocks by inverting the matrix, so that the characters become the objects to be classified. The resulting dendrogram (Fig. 5) shows groups of blocks with high faunal similarities, but which differ from one another. The dashed vertical lines labelled B, C, and D in Figure 5 transect stems of the dendrogram which include groups of blocks shown geographically in Figures 6B, C, and D, respectively. The maps then show areas of high internal avifaunal homogeneity, and the boundaries between them. The strengths of this approach to avian biogeography are that (1) it is quantitative, repeatable and objective, and (2) it is based upon the abundances of species and not simply their presence or absence.

CONCLUSIONS

Eugene Odum (1950:227) said of the CBC: "One has the feeling that there is more gold buried in the mass of data than has yet been uncovered." There has been considerable mining activity since then, and some rich veins have been explored. Clearly the strength of Christmas count data lies in their quantity more than in their quality. There may be ways to improve the nature of CBC information (Stewart 1954, Arbib 1967, Arbib 1981), but we agree with Hickey (1955) that one ought not to tamper with the event very much, lest the thousands of volunteers who make it happen, and who do it largely for fun, stop *having* fun and quit. Also, any change in CBC rules which would make it impossible to compare past and future results would defeat the very purpose of the census.

Christmas count data do not appear to work well until they include a critical mass of years and count circles, but it is only in pursuit of such long-term and continentally scaled patterns that we need them. Christmas count data should not be substituted for careful local censuses in environmental impact studies, or in any other sort of field ornithology within the strategic capabilities of an individual investigator. For large-scale studies, CBC analysis is very cost-effective. The petroleum has already been combusted, and the hours have been expended in the field. No group of paid professionals could ever mobilize the time or dollars to gather such data. CBC's appear to be surprisingly good indicators of pattern in avian geographical ecology, if they are used carefully and conservatively, and especially if they are used in large numbers.

ACKNOWLEDGMENTS

Research for this paper was supported by NSF grants GB 36860 and DEB 79-10784. We thank Michael Grant and Larry Lepthien for assistance with statistics and computer analyses, and Joseph J. Hickey for reviewing the manuscript.