

# Bird populations and environmental changes: can birds be bio-indicators?

*Stanley A. Temple and John A. Wiens*

**A** CLEAR MESSAGE OF THE SUMMARIES of Regional Reports and Christmas Bird Counts published each year in *American Birds* is that bird populations change. Some of these changes consist merely of extralimital occurrences of a few individuals, but others involve large-scale changes in the abundance or distribution of species. Can such changes be used to monitor changes in the environment, especially aspects of environmental degradation that may not yet be apparent to us? To use bird populations as indicators of environmental changes, we must be confident that the population changes we have recorded are real and not artifacts of sampling, and we must be able to link those changes to specific perturbations in the birds' environment.

To address these issues, the Cornell University Laboratory of Ornithology and the Johnson Foundation sponsored a two-day symposium in May 1987 at Wingspread in Racine, Wisconsin. The participants focused on a number of basic points. The first deals with whether the changes we detect in populations can be linked in a cause-and-effect fashion to specific environmental perturbations, while the second involves assessing how well existing programs that monitor birds detect changes at the population level. We summarize here the proceedings of that symposium, comment on the prospects for using birds as indicators of environmental changes, and suggest what needs to be done to improve our knowledge of this subject.

## Establishing cause-and-effect relationships

Birds live in an environment that is subject to both regular and irregular fluctuations, and bird populations respond to these changes in predictable ways. They do so, however, on several scales of magnitude and with varying degrees of directness. We often imagine the cause-and-effect link between an environmental change and birds to be a direct and simple one. In some instances, this appears to be true, but to expect such clear-cut relationships to be commonplace is wishful thinking. The effects of environmental changes on bird populations are more often influenced by one or more intermediate factors, or the population changes are caused by any one or more of many interacting effects. The existence of intermediate stages in the cause-and-effect link not only complicates our attempts to understand what is going on, but also acts to produce time lags in the appearance of the effects. An episode of unusually high rainfall in the desert, for example, may take some time to be translated into greater growth of plants that provide food for the insects on which birds feed, and for the insect populations to increase in abundance takes still more time. By the time these events result in greater production of young or in higher population densities in birds, the rainfall event that started the sequence may be long forgotten.

Site fidelity of breeding birds may

also produce time lags in response to environmental changes. Thus, when a large area of sagebrush habitat was destroyed and replaced by crested wheatgrass in a "range improvement" program in southwestern Oregon, breeding populations of Sage Sparrows (*Amphispiza belli*) and Brewer's Sparrows (*Spizella breweri*) remained relatively stable for at least two years because established breeders returned to their former territories, even though the habitat changed and was no longer suitable (Wiens and Rotenberry 1985).

In such cases, the environmental change that causes a population change at some later time may be identified if the situation has been monitored for a sufficiently long period, with attention to delays in cause-and-effect relationships. In other situations, identifying the important causal link among a large number of possibilities may be quite difficult.

Environmental effects on birds are typically assayed by recording changes in population density, abundance, or distribution. These are frequently the most evident sorts of changes, but they are not necessarily the ones most closely tied to changes in the environment. Birds may respond to environmental changes on several levels. The most immediate and direct responses are behavioral and physiological, involving changes in the characteristics of individuals. These changes, in turn, affect several basic population rates: birth rate, death rate, and rate of dis-

persal Changes in these three primary population parameters can then generate changes in several secondary population parameters, such as density, population size, geographic range, habitat occupancy, age structure, sex ratios, or the proportion of birds that breed.

Fluctuations in basic population rates are probably the most appropriate responses to measure when looking for evidence of environmentally induced changes in bird populations, because there is likely to be both spatial and temporal coincidence between these primary responses and the underlying environmental change. This temporal and spatial coincidence simplifies the difficult task of establishing a cause-and-effect relationship between an environmental event and an observed change in a bird population. On the other hand, changes in secondary population parameters are often spatially and temporally removed from the environmental trigger.

Both primary and secondary population parameters show normal year-to-year and local variations that may have little or no long-term bearing on

the population's overall well-being and stability. Ricklefs (1973) reviewed many long-term studies of bird populations and found that primary population parameters tended to vary more from year to year than did secondary population parameters, especially local population size and density. This pattern is a consequence of the buffering of fluctuations in local population size and in density by density-dependent processes. Increased survival and immigration, for example, can mask the impact of a local reduction in fecundity on population density. A result of this density-dependent buffering is that significant changes in primary population parameters can occur without causing concomitant changes in local population size or density. It may require several consecutive seasons or the widespread occurrence of unusually poor reproduction or survival before local population size or density are affected.

Even among various environmental factors that can cause a change in a single primary population parameter there is a dynamic buffering effect that can obscure their individual impacts.

Many of the major mortality factors that affect birds act in a compensatory fashion: an increase in the rate of mortality caused by one factor can result in a compensatory reduction in the rate of mortality caused by other factors. The result is that no change in the population's overall mortality rate occurs, merely a redistribution of the relative impact of the individual factors that are components of overall mortality. Recently, for example, the United States Fish and Wildlife Service intentionally varied annual rates of hunting mortality for Mallards (*Anas platyrhynchos*) by altering harvest regulations. Although major annual changes in mortality due to hunting resulted, an analysis of band-recovery data showed no correlation between the overall annual mortality rates of Mallards and the annual mortality rates due specifically to hunting (Anderson and Burnham 1978).

Two hypothetical examples further illustrate the differences between primary and secondary population parameters. If one monitored the density of breeding individuals on a study area (a secondary population parameter) and found a sudden drop in one

Photograph/Jerg Kroener.



year, the underlying proximate cause of that decline could (among other possibilities) have been a reduction in the birth rate during the previous year's breeding season, a lowered survival rate during the intervening non-breeding season, a dispersal movement of individuals away from the study area, or some combination of these. In any event, the change in the density of the breeding population would probably have lagged so far behind most of these underlying events that it might be difficult, in retrospect, to establish the environmental cause or to know exactly when and where it exerted its effect.

Similarly, one might monitor the density of the breeding population on a study area and detect no change in response to a suspected environmental threat, such as a local application of a highly toxic pesticide. One might, therefore, conclude that there had been no impact on the bird population because the before-and-after densities were similar. However, if one had monitored mortality rates among local territorial individuals, one might have found that there was a brief but major episode of mortality immediately after the chemical application and that the resulting losses were promptly recouped by rapid recolonization of the vacated territories by previously nonbreeding "floaters." Conflicting conclusions about the impact of the chemical application might be reached, depending on the response variable that had been monitored.

These two examples illustrate the point that, when looking for responses to environmental change, primary population parameters may provide a better indication of a response than secondary population parameters. The last example also illustrates how the risk of concluding that there is no effect of an environmental perturbation when there really is one may be increased by using secondary rather than primary population parameters.

All this is not to say, however, that primary population parameters are necessarily the most "important" measures of the response to an environmental change. One can argue that, because various population rates are to a degree compensatory, it is only an overall change in a population's size that matters. If an environmental change increases the mortality rate of a population, but fecundity

also increases so that there is no overall, long-term change in population size or density, one might conclude that although the environmental change had an effect on the population, this effect was not really important in the long run. By the same token, very short-term behavioral or physiological adjustments to environmental perturbations may not be important if they have no effect on rates of mortality, fecundity, or dispersal. It would be a mistake, however, to conclude that, because an environmental change has no apparent effect on some population parameter (either primary or secondary), it has no effect on the population at all.

Whether the effects of environmental perturbations translate into "important" consequences is to some degree a matter of one's objectives. If the objective is to maintain viable populations of birds over a long period in particular habitats or regions, we must regard persistent declines in population sizes (a secondary population parameter) as "important." On the other hand, if one's interest is in sensitive, proximate indicators of a population-level response to some environmental disruption, primary population parameters may be "important" in their own right.

#### **Existing sources of bird population data**

Ornithologists have monitored North American bird populations in an organized fashion since 1900, when the National Audubon Society's annual Christmas Bird Count was inaugurated. In the years since 1980, many other monitoring schemes have been established. A few of these programs are continent-wide, include coverage of most taxa, and are intended to be long-term ventures (*e.g.*, the Breeding Bird Survey and Nest Record Program); most, however, are more restricted in geographic, taxonomic, and temporal scope. The scale of each program has its own inherent advantages and disadvantages. Broad-scale programs are well suited to detecting changes in bird populations that occur slowly over many years and over large geographic areas, but they often lack the precision needed to detect subtle population changes at the

local level promptly, before the population has experienced a major tilt. Narrowly focused studies are far better at quickly detecting small, subtle changes in local bird populations and identifying their causes, but there are often uncertainties in extrapolating the results to a wider arena. The results from some monitoring programs are not readily accessible whereas other programs maintain data in such a way that they are easily available on request to interested parties. Monitoring schemes of the latter type can provide valuable information to a variety of potential users and are most likely to be examined first when looking for evidence of environmentally induced change.

Existing monitoring schemes measure a variety of response variables. Fecundity (generally indexed as the number of fledglings per nesting attempt), for example, is measured on a broad scale by the Nest Record Program. On a narrow scale, fecundity estimates are typically obtained in local, short-term studies of the nesting biology of a particular species, and a plethora of such studies exists for various species and locations. For several species of special interest, such as migratory waterfowl or endangered species, investigators have collected data on fecundity that span several decades, as in the annual Waterfowl Production Surveys of the United States Fish and Wildlife Service and the Canadian Wildlife Service.

Mortality and survival rates for many species can be estimated from band-recovery data maintained by the Bird Banding Laboratory of the United States Fish and Wildlife Service. Several analytical procedures are used to estimate mortality and survival rates from data on recaptures or resightings of marked birds (Seber 1982, Brownie *et al.* 1985). Local, short-term studies based on recaptures or resightings of individually marked birds have also been carried out by individual researchers for a variety of species, localities, and durations.

The results of programs that monitor mortality rates differ greatly in precision. The low rates of band recovery for all except a few heavily hunted species prevent the Bird Banding Laboratory from calculating survival rates for birds in areas smaller than broad regions of North America, such as major migration flyways, or

over periods of less than a year. Major effects on mortality in a population often occur within a small region over a period of weeks or even days. However, only narrowly focused, intensive studies are able to detect these responses to environmental changes.

Dispersal can only be studied by following the movements of individually marked birds. Data maintained by the Bird Banding Laboratory are, therefore, a potential source of insights on dispersal (e.g., Houston 1978). Local studies of color-marked or radio-tagged individuals also produce useful information.

It seems that information on the important primary population parameters is most likely to be obtained in intensive, local, species-specific studies. Such studies are difficult and time-consuming, however, data on these parameters are scant, and data banks containing them are few. The information that has been produced by these studies, although of great value, is rarely stored in a data bank; rather, it is typically published in summarized form in scientific journals.

In contrast to the general dearth of data on primary population parameters, there is a relative abundance of

information on secondary population parameters, especially local population densities. Bird censuses, in their many and varied forms (Ralph and Scott 1981), typically attempt to count all individuals in a specified area over a specified time. Although they rarely achieve this ideal (Verner 1985), censuses often do provide a reasonably precise and accurate estimate of population size or density at a particular time and place. Several large data banks maintain information ranging from simple records of presence or absence to complex estimates of density on broad geographic

## The National Audubon Society's Christmas Bird Count

The National Audubon Society's Christmas Bird Count is the most popular, voluntary, early-winter, continental bird inventory in the world. This annual project, conducted in the Americas, involves a one-day count of the individuals of all species observed within a count unit known as a Christmas Bird Count circle. Count circles are discrete, having no parts in common, and each is defined as that area contained within a circle of 24.1 kilometer (15 mile) diameter. Each count must be conducted on a single calendar day within the official Christmas Bird Count period, which is roughly two weeks centered around Christmas Day. Searching the count circle is accomplished by parties of observers of varying numbers, and every individual bird encountered is included in the inventory. The results of each count unit are reported on standardized forms, which also solicit details on weather, methods of canvassing the area, numbers of participants, hours afield and at feeding stations, and miles covered. Count statistics have been published for the last 88 years, and represent the most extensive, longest term, continuous, and most geographically compre-

hensive data set in American ornithology.

The Christmas Bird Count was initiated in 1900 by ornithologist Frank M. Chapman, who for thirty five years was the editor of *Bird Lore* magazine, the first official organ of the National Audubon Society and the great-grandparent of *American Birds*. The first count, in 1900, had a mere twenty five circles with a total participation of twenty seven birders. Over the past eight decades the survey has grown dramatically, so that in the 1988-1989 count period there were 1543 counts involving more than 42,000 people. Today birders participate in the Christmas Bird Count in the United States, Canada, the West Indies, and Middle and South America. All birders are welcome to participate in Christmas Bird Counts or, if they have special expertise and credentials and live in an area not already covered by an existing Christmas Bird Count circle, can start a new count by selecting and delineating a circle and getting approval from *American Birds*.

The complete results from each Christmas Bird Count season have been continuously published for the past 88 years. To-

day the Christmas Bird Count issue of *American Birds* runs to over 700 pages.

The Christmas Bird Count provides the empirical basis for an increasing number of research studies involved with the relative abundance of species and their dynamics, and their definition and spatial relationships on their early-winter ranges. The Christmas Bird Count is an enormously rich data source which may be useful for estimating population parameters provided that researchers are aware of its limitations. Its strength lies in its quantity. There is no other branch of field zoology which has any sample comparable in size, scope, and regularity. No group of paid professionals could ever mobilize the time or dollars to gather this much data. Analysis of them in isolation, even by the most sophisticated and rigorous statistical methods, will not indicate avian population trends, but in combination with other avian monitoring techniques, they certainly appear to be surprisingly good indicators of spatial and temporal patterns in avian geographical ecology.—Susan Roney Drennan, Editor, *American Birds*, 950 Third Ave., New York, NY 10022.



and temporal scales

Censusing bird populations is popular and widespread because it can be a relatively straightforward activity that can be easily mastered by those who often enjoy birdwatching with a purpose. Of all the population monitoring schemes in North America, the National Audubon Society's Christmas Bird Count, with its simple censusing methods, remains the most popular program in terms of numbers

of participants. At a broad scale, it provides useful information on distributional patterns and population trends (Bock 1984). Other programs that involve greater individual effort and follow a more detailed study design attract fewer participants but have the potential to provide information of sufficient precision to monitor population size on both broad and local scales.

In all of these sorts of investigations,

the data that are produced are most likely to be useful in gauging bird responses to environmental perturbations if they are included in a data bank that is readily accessible and standardized. Recognizing the subtle but persistent changes in either primary or secondary population parameters that may indicate the onset of an environmental change often requires the statistical analysis of long-term data sets, and such analyses are not

## Bird population studies at the Cornell Laboratory of Ornithology

The four primary goals of bird population studies at the Cornell University Laboratory of Ornithology are to encourage birders to collect bird population data, to manage computerized databases on North American birds, to conduct research using these databases, and to communicate the results back to birders and the general public. We are responsible for maintaining and promoting the North American Nest Record Program, the Colonial Bird Register, and two new programs, Project Birdwatch and Project FeederWatch. In addition, we maintain computerized databases for three programs sponsored by the National Audubon Society: the Christmas Bird Count, the Breeding Bird Census, and the Winter Bird-Population Study.

Data for the North American Nest Record Program are recorded on cards, which are then edited and computerized. Nest records contain data on avian breeding biology, such as the nesting season, clutch size, incubation period, nestling period, and nesting success. Three hundred thousand nest records have been completed for 555 species, of which 150,000 cards have been computerized. One of the major justifications of the program is its potential to monitor the reproductive success of birds on an annual basis. Annual monitoring of avian reproduction using nest records would serve as

an "early warning system" to detect reproductive failure. Annual variation in reproductive success has never been analyzed for any species with data from the nest record program, although the program has enough cards for some species to justify such an analysis.

In the mid-1970s the National Audubon Society and the Laboratory of Ornithology organized the Colonial Bird Register to establish a computerized database for the collection and dissemination of information concerning colonial waterbirds. Most CBR data come from state and federal survey projects and can be used to monitor the size and location of colonies over time.

The Christmas Bird Count, described in more detail elsewhere in this article, is the main database being used to monitor the distribution and abundance of birds in the winter.

The Breeding Bird Census, initiated in 1937 by the National Audubon Society is a monitoring program in which the density of territorial males is estimated on a plot of homogeneous habitat. Quantitative sampling methods are frequently used to measure the vegetation of the plot. Much of the data from the 50 years of the Census is stored in computer files at the Cornell University Laboratory of Ornithology.

The Breeding Bird Census has proven to be a useful source of information on the density of

bird species in particular habitats and for determining population variation of a species within a site over time. Breeding Bird Censuses also have provided important information about bird population changes that accompany plant succession in a plot and about how the habitat use of a bird species changes geographically.

The Winter Bird-Population Study is the winter analogue to the Breeding Bird Census. Although much attention has been given to overwinter survival in bird populations, the bird-habitat relationships described in the Winter Bird Population Study are greatly underused.

The Laboratory of Ornithology is initiating two new programs to monitor populations of birds. For Project FeederWatch, weekly lists of birds compiled by participants from watching their feeders during the winter months will be sent to the Laboratory of Ornithology for processing. We hope that these data can be used to track movements of birds during the winter. Project Bird-Watch, currently a pilot project, is based on weekly lists of birds compiled by participants. The data will be used to enhance our knowledge of geographical distributions and seasonal patterns of abundance.—*R. Todd Engstrom and Gregory S. Butcher, Cornell Laboratory of Ornithology, 159 Sapsucker Woods Road, Ithaca, NY 14850.*

likely to be done unless the data are readily available.

### What can population data tell us?

There are two types of questions that we can ask of bird population data: Has a significant change occurred in a monitored population parameter, and what temporal and spatial correlates of that change may help us identify the underlying cause? The existence of data banks containing information on North American bird populations does not by itself ensure that the data they contain are adequate to address either of these questions. We need to know what types of changes are important enough or unusual enough to warrant further investigations into their possible causes, and we must have some basis for associating the population changes with some alteration in environmental conditions.

How much change in monitored population parameters must occur before one becomes alarmed and seeks a specific cause? Given the fact that primary population parameters normally vary more than secondary population parameters, it might be appropriate to adopt a more liberal criterion for some population characteristics, like fecundity and mortality rates, than for others, such as density, population size, or geographic range. The criteria must be developed on a situation-specific basis, however; a 50% swing in population size might not be of concern in a cyclic species like the Northern Goshawk (*Accipiter gentilis*), but in a species such as the Peregrine Falcon (*Falco peregrinus*) it would be most alarming.

It is also possible that the duration of a trend in a population parameter is more important than the magnitude *per se* of the change. A slight but recurring annual drop in fecundity or population size would be more alarming than an annual drop of similar or even greater magnitude that continued for only a year or two. The simulation models of Ford and his colleagues (1982), for example, indicated that populations of marine birds such as murres (*Uria* spp.) might be more sensitive to slight but continuous depressions of reproductive success caused by chronic, low-level oil pollution than to acute, large-scale mor-



Peregrine Falcon (*Falco peregrinus*). Photograph/P. McLain/VIREO/M15/2/021.

tality caused by occasional massive but isolated oil spills.

In some instances, the geographic extent of a change in population parameters determines its significance. A deviation in one local population of a species while other populations remain stable is less alarming than a change that is experienced over a broad region or over a species' entire range. Thus, Holmes and his co-workers (1986) were able to associate the decline in Least Flycatcher (*Empidonax minimus*) abundance in a New Hampshire forest with local forest succession rather than with events in wintering areas largely because other nearby breeding populations of this species did not exhibit a parallel decline.

Whether we are interested in the magnitude, the duration, or the geographical extent of a population change, it is difficult to know how much change in a population parameter should be taken as an indication that something in the birds' environment may have changed. One way to explore such questions is through computer simulation models of population dynamics, in which one may systematically vary certain parameters by a given amount over a given length of time or a given area to determine what effects such variations might possibly have on measures such as long-term population stability. Only a

few investigators (e.g., Ford *et al.* 1982; Temple and Cary 1988) have used these techniques, however, and their potential remains largely unexploited.

Once one has established criteria for determining the sorts of population change that should concern us, the available population data must be evaluated to see whether or not they are actually capable of detecting the sorts of changes we have deemed important. A hypothetical example may illustrate the problem. We know that DDT contamination of aquatic food chains can and did reduce the average annual fecundity of some populations of the Bald Eagle (*Haliaeetus leucocephalus*) by about 30%. We also know that Bald Eagle fecundity has a normal annual variation (expressed as a coefficient of variation) of about 50%, mostly owing to vagaries of weather and food (Grier 1974). Suppose we wish to use North America's primary data bank on fecundity, the Nest Record Program, to detect a 30% deviation from average Bald Eagle fecundity in a certain year with a 90% certainty at the 0.05 level of significance. It is possible to calculate the sample size (number of nest records) that would be required to detect such a reduction in fecundity with the expected certainty. In this case, the results of such a calculation (Zar 1984:134) indicate that it would take



*Male Bald Eagle (Haliaeetus leucocephalus). Photograph/Jerg Kroener.*

nest records from at least 120 eagle nests per year to detect a 30% deviation from average fecundity. Unfortunately, the Nest Record Program currently receives information on fewer than 40 nests each year. Furthermore, these nests are scattered over North America, while an important environmentally induced change is most likely to occur at the local or regional level, where sample sizes are even smaller.

A more positive example illustrates the potential of existing data banks for detecting changes in certain species. The Nest Record Program currently receives more nest records per year (about 1500) for the Eastern Bluebird (*Sialia sialis*) than for any other species. Given this sample size and other pertinent information on bluebird reproduction, it is possible to calculate the minimum change in fecundity that could be detected with 90% certainty at the 0.05 level of significance. In this case, we should be able to use the existing records to detect a 4%

deviation from average bluebird fecundity throughout the species' range. At the local population level, where annual sample sizes for some bluebird populations may reach 200 nests, it should be possible to detect a 15% change in fecundity from the existing information. These detection capabilities are certainly within standards that might be adopted for a monitoring scheme.

These examples serve to illustrate two important points. First, our ability to draw reasonably firm conclusions about whether or not a change in a particular population parameter has actually occurred is restricted by the adequacy of the data available. In many cases, it may not be possible to detect anything other than relatively large-scale shifts in population features from the sorts of data sets that currently exist. Second, the size of samples and the precision of measurement of population parameters are related to the level of change that we wish to detect. If, for a given objective,

it is sufficient to be able to detect population shifts of 25%, gathering samples or conducting studies with an intensity that permits one to detect changes of 5% may be unnecessary. We must define standards for the minimum changes that we need to detect and for the certainty with which we wish to be able to detect such changes, but these decisions have rarely been made. Examples such as those for eagles or bluebirds provide important insights into the sampling effort that is required to allow a particular data bank to serve its intended purposes.

Once one understands the power and limitations of a data bank used to detect changes in population parameters, the next question is what might have caused a given change. In the absence of direct experiments (which are often impossible, given the temporal and spatial scale of population changes of interest and the status of the bird populations involved), cause-and-effect links must be determined by finding environmental factors that might be expected produce a change in the population by direct or indirect pathways and that have changed in a way that is correlated with the population changes. A wide variety of factors in the environment may affect important population parameters in birds. The list of such factors is not only long, but many different environmental changes can cause the same response in bird populations. Indeed, one of the most vexing challenges to using bird populations as bio-indicators is determining how to isolate the actual cause of an observed change in a bird population from among all the possibilities.

Establishing a cause-and-effect relationship between environmental changes and population responses is an essential but often elusive, goal of many population-monitoring programs. Unless one can establish an unambiguous statistical connection between an environmental change and an observed change in a bird population, little more than speculation is possible. Establishing a statistical correlation between the occurrence or magnitude of an environmental perturbation and a change in a bird population, however, does not necessarily prove a cause-and-effect relationship.

The most effective way to establish cause-and-effect relationships between changes in bird populations and

## The question of causality

In spite of the limitations of some of the sampling methods used in the large-scale monitoring programs, data can now be used to provide estimates of regional and long-term variation in the clutch size and fledging rate of birds (Nest Record Card Program), dispersal (Bird-Banding Laboratory), density and species richness of birds by habitat (Breeding Bird Census and Winter Bird-Population Study), wintering range (Christmas Bird Count), and breeding range and relative abundance (Breeding Bird Survey). The value of this information, especially for common species, is tremendous. However, once regional variation or annual trends have been identified, the task of identifying a cause, or a combination of causes, can be very difficult. Is the decline in the American Black Duck population, for example, due to overhunting, ingestion of lead shot, decline in invertebrate food for ducklings in lakes that are now acidified, or hybridization with the Mallard? If neotropical migrants are really declining, is it mostly because of the destruction of suitable habitats on their wintering grounds, on the breeding grounds, or in places used during migration? Sometimes the answers seem obvious. Six of the species that are apparently declining in numbers in Florida are cavity nesters. At least along roadsides, where the Breeding

Bird Survey is conducted, there are probably fewer trees suitable for these species than there were 15 years ago. But until other possibilities are checked (disease, parasites, decline in bark-dwelling insects), any conclusion about causes is mere speculation. For sorting out the cause of an effect, the ideal situation is a controlled experiment in which individuals can be assigned randomly to treatments and then treatments are compared. With observational studies, the best solution is to incorporate some principles of experimental design at the analysis stage. One example would be to use time-series analysis. Did the decline occur all at once, and if so what environmental factor changed at that time? In this quasi-experimental design the annual censuses would be used as replicates. Or one could compare regions in which the various potential causes occur at different levels and then see which regions have concordant population effects. Such comparisons permit weak inferences about causes. Other applications of principles of experimental design, such as blocking and matching, have been very useful in the analysis of large data sets in the fields of medicine, education, and sociology. Applications in ornithology are overdue.—*Frances C. James, Department of Biological Science, Florida State University, Tallahassee, FL 32306.*

on the environment. Because these bird and environment data sets are not coincident in time and space, it is difficult to make any but the coarsest or broadest kinds of correlations between them. Still, for a few of the major environmental variables that are known to affect population parameters, such as climate and habitat conditions, there are readily accessible data that can be used in conjunction with information on bird populations.

In some cases, these environmental data banks may provide information that can be convincingly related to an observed change in a bird population. For example, in Great Britain it was possible to establish a strong correlation between the extraordinarily severe winter weather of 1978–1979 and changes in several population parameters for selected bird species: increased rates of dispersal movements during the winter and lowered population densities and increased fecundity during the subsequent breeding season. In this case, the bird population data from the British Trust for Ornithology's Ringing Scheme, Common Birds Census, and Nest Records Scheme were used in conjunction with climatic information from data banks maintained by the British government (Cawthorne and Marchant 1980).

Thus, although the most convincing documentations of cause-and-effect relationships will usually come from narrowly focused, carefully controlled, intensive field studies, some indications of important causal links may also be obtained from comparisons using broad-scale data banks. Moreover, and perhaps more importantly, these data sources may provide the foundation for initial, exploratory analyses that provide the insights necessary to know what might be investigated most effectively through more intensive work.

### Prospects and priorities

We end up agreeing with Morrison (1985) that the prospects for using birds as sensitive bio-indicators are not especially good. Bird populations change, to be sure, and many of these changes are related in one way or another to underlying changes in the environment, but knowing exactly what has caused the population changes is too often beyond our im-

environmental changes is to relate the bird population data to parallel data on changes in the environment. In most narrowly focused studies of bird populations, the researchers who study the birds also simultaneously measure environmental variables on their study areas. By relating changes in these simultaneously measured variables to one another, causal links may be established with at least reasonable certainty if (and it is a big "if") the events affecting the bird populations actually operate at the same

temporal or spatial scales on which the variables were measured.

In contrast, most broad-scale monitoring schemes that rely on data collected by volunteers do not require that the observers collect detailed information on the condition of the local environments in which they observe the birds. As a result, information from large data banks must typically be paired with environmental information from a completely independent source, often another broad-scale data bank containing data



## Some environmental databases

Of the many environmental factors that can affect bird populations, habitat features and weather are two for which accessible databases exist. The United States Fish and Wildlife Service's National Wetlands Inventory Project collects information on the location, extent, status, and trends of United States wetlands, a critical but threatened habitat for many birds. Maps are available for 51% of the lower 48 states, 14% of Alaska, and all of Hawaii. Copies of these maps can be ordered by calling 1-800-USA-MAPS. A national assessment of the status and recent trends in United States wetlands has been completed. The results are published in the Fish and Wildlife Service report, *Wetlands of the United States: Current Status and Recent Trends*. Between the mid-1950s and the mid-1970s, the conterminous United States lost 9 million acres of wetlands at an annual rate of 458,000 acres, a loss that must have had serious consequences for wetland birds. The trend analysis study will be periodically updated; the next update will be completed by the end of 1990. The National Wetlands Inventory Project is also producing other products, such as state wetland reports, that provide basic data on the status of wetlands throughout the country.

Weather has pronounced effects on many parameters of bird populations, and excellent nationwide data on weather are available to ornithologists. Useful data are contained in the *Weekly Weather and Crop Bulletin*. Annual subscriptions are \$25, payable to NOAA. Write to WWCB, NOAA/USDA, USDA South Bldg., Room 5844, Washington, D.C. 20250.

The total precipitation (and percent of normal) and average temperatures (plus departures

from the 30-year mean) are presented on a seasonal, monthly and weekly basis in map form for the 48 contiguous United States and Alaska. Observed minimum and maximum temperatures for the week, a biweekly drought severity chart, and monthly status of the nation's rivers and reservoirs are included. Thus, the possible impact of varying periods of unusual heat or cold and dryness or wetness can be analyzed using the data in this inexpensive publication, with the added advantage that the user may freely reprint any of the data and maps, provided proper credit is given.

Severe storms or winds may influence a particular species' migration, breeding or feeding patterns, WWCB highlights significant storms with both satellite pictures and text. When conditions warrant, feature articles on topics like severe drought or heat and cold waves in places like Africa and Europe, as well as on this continent, will appear. Even the path of air parcels responsible for transporting radioactive debris from Chernobyl was discussed on a timely basis. In short, any weather or climate anomaly having a noticeable impact on human and other biotic systems will receive attention.

Historical data are also available from The National Climatic Data Center, Federal Building, Asheville, NC 28801-2696. One is advised to call (704) CLI-MATE to discuss data needs with NCDC's meteorologists. Those wishing to delve much deeper into potential data sources should request the "Selective Guide to Climatic Data Sources".—Ralph W. Tiner, Jr., U.S. Fish and Wildlife Service, National Wetlands Inventory, Newton Corner, MA 02158 and Douglas A. Paine, Biometeorology Unit, Cornell University, Ithaca, NY 14853.

mediate grasp There are too many complicating variables, it is too difficult to associate cause with effect, and it is too problematic even to know what sort of population change might be an indication that something in the environment is really awry. Responses to persistent, long-term changes in the environment generally can be detected over time, but by then the environmental degradation that caused the population changes may be far along or worse, irreversible. Responses to short-term environmental changes are much harder to detect and interpret unless the change is really massive and the response of the bird populations immediate.

Does this mean that the symposium was a failure and that we should do nothing? Of course not. Although bird populations may not normally provide an ideal "early warning system" of environmental deterioration, they can tell us much about what happens to their (and thus our) environment over the long run. Attention to several points will enhance our ability to draw meaningful conclusions from our studies of bird populations:

We must continue to monitor the status of bird populations, using a combination of programs, sites, and scales. General programs such as the Christmas Bird Count, the Breeding Bird Survey, the Nest Record Program, and the Breeding Bird Census can continue to provide important broad-scale information, but these activities should be supplemented with more intensive studies conducted over a series of specified study sites. It is especially important that long-term monitoring of both primary and secondary population parameters be conducted at locations that are not susceptible to haphazard disruption by human activities. This is because in order to assess population changes that are due to subtle or widespread environmental changes, it is necessary to have baseline or "control" information from locations at which these effects are not overwhelmed or distorted by large-scale but local perturbations. In this regard, the National Environmental Research Park sites administered by the Department of Energy or National Parks and Wilderness Areas may hold special promise. It would be especially valuable if standardized studies, in which several critical primary and secondary popu-

lation parameters are measured with a specified level of precision, could be initiated at these sites.

Observers participating in any of these programs, whether broad or narrow in scope, should gather basic information on the status of key environmental features such as climate, habitat conditions, or human activities as part of their censuses of birds. For formally structured programs, this environmental information should be gathered following carefully standardized procedures.

The information obtained in these studies should be promptly transferred to computer-accessible data banks, and the information in these data banks should be subjected to continual analysis to maintain close monitoring of population trends or changes in population parameters. The information in these data banks should be readily available to both amateurs and professionals; accessibility will be enhanced if the data banks are maintained in a few central locations.

Analyses of the data should be combined with computer modeling to determine the sensitivity of populations to changes of varying magnitudes and duration in key population parameters. Such investigations may help to define the sorts of changes that should be of concern for particular species. Computer modeling may also be used to determine the sample sizes or levels of precision required to interpret population changes of a given magnitude.

If the major bird population data banks are to achieve their intended purposes, they must include samples of population data that are adequately large. Participants should be actively recruited rather than passively attracted to the programs.

#### ACKNOWLEDGMENTS

Participants in the symposium that formed the basis of this paper included: Rex J. Bates, P. Dee Boersma, Richard E. Bonney, Jr., I. Lehr Brisbin, Gregory S. Butcher, David Call, Eileen Chambers, Catherine B. Cleary, Alan Crawford, Jr., Noel J. Cutright, David G. Davis, Susan Ronney Drennan, John T. Emlen, Todd Engstrom, Ann Gaylord, Anne N.

Gromme, Owen Gromme, Thomas M. Hampson, Joseph J. Hickey, James F. Hobson, Frances James, Dianne Johnson, Gene Johnson, Samuel C. Johnson, Richard E. Keyel, Spencer Knight, Robert H. Larkin, Thomas S. Litwin, Harold Mahan, John McCarthy, Barnabas McHenry, G. Michael McHugh, J. P. Myers, Raymond J. O'Connor, Douglas A.

Paine, David B. Peakall, William H. Rickard, Barbara Rickard, Chandler S. Robbins, Margaret Rostker, Sir Peter Scott, Lady Philippa Scott, Stanley E. Senner, Steven C. Sibley, Michael Slimak, Bill Smith, Charles R. Smith, Rollin D. Sparrowe, Randall R. Stauffer, William R. Stott, Jr., Scott Sutcliffe, Stanley A. Temple, William H. Thompson, Ralph W. Tiner, Jr.,

## Use of bird population data by the Environmental Protection Agency

Among federal agencies, the United States Environmental Protection Agency has the broadest mandate to promote efforts which will prevent or eliminate damage to the environment and biosphere. One important way the Environmental Protection Agency uses bird population studies is the preparation and review of environmental impact analyses. The preparation and review of Environmental Assessment or Environmental Impact Statements is the major mechanism by which the environmental impacts of major federally-sponsored projects are assessed. Environmental Impact Statements are often required for such projects under the National Environmental Policy Act.

The Environmental Protection Agency's review of Environmental Impact Statements is intended to identify and minimize impacts to the environment. These impacts can include direct and indirect effects on bird populations, and Environmental Impact Statements typically discuss the bird populations occurring in the affected environment.

Access to avian population data is important to both the preparers and reviewers of Environmental Impact Statements in determining the true impacts of projects and activities that affect wildlife resources. The types of data of greatest value are:

1. Breeding bird data and habitat-use data for specific sites (e.g., data from Breeding Bird Surveys,

- Breeding Bird Censuses, and Colonial Bird Register).

2. Information on life histories and habitat affinities for bird species (e.g., data from the Nest Record Program, Breeding Bird Census, and Winter Bird Population Study). Frequently baseline studies for Environmental Impact Statements involve only a single year of field data. Long-term data are especially valuable when available.

3. Population data that indicate trends in populations and guilds by watershed, ecoregion, or other landscape scale unit (e.g., Breeding Bird Surveys, Christmas Bird Counts, Breeding Bird Censuses, and Colonial Bird Register). The Environmental Protection Agency and other natural resource agencies need a geographically-based data system that allows them to draw upon information at many scales.

Obtaining and using more accurate and complete information on bird populations will help the Environmental Protection Agency and other regulatory agencies more effectively implement environmental protection laws and regulations. The Environmental Protection Agency needs to make use of existing information resources, many of which are described here, and develop new ones to increase its ability to assess the total impact of proposed activities.—Thomas A. Muir and David G. Davis, U.S. Environmental Protection Agency, Washington, D.C. 20460.

## Lands for long-term research on bird populations

If birds are to be used as indicators of environmental change, there is often a need to have baseline, control areas on which bird populations that are isolated from certain environmental changes can be studied. This need is not unique to bird population studies. The need to establish a network of relatively extensive land holdings on which "baseline" ecological studies can be conducted over extended periods of time has been recognized by many environmental scientists. Although there are a number of kinds of public lands on which long-term bird population studies can be conducted (e.g., national parks, national forests, national wildlife refuges, and various state and local parks) the purposes for which such lands are held often involve priorities and management practices (e.g., timber harvest and/or the grazing of domestic livestock) that may produce extensive environmental alteration over time and thereby decrease the value of the site as a constant "reference point" against which population changes in other altered environments can be compared.

There are, however, two major networks of land-holdings in the United States which specifically include long-term baseline ecological surveys among the activities for which they were designed. These networks include the Long-Term Ecological Research sites of the National Science Foundation and the National Environmental Research Parks of the United States De-

partment of Energy. The lands held and managed under both of these programs should, thus, be considered as sites where long-term studies of bird populations could be undertaken.

One major difference between the Long-Term Ecological Research and National Environmental Research Park sites is that the NERP sites are generally larger ( $X^- = 96,596$  ha for National Environmental Research Park sites vs.  $X^- = 13,292$  ha for Long-Term Ecological Research sites). The larger National Environmental Research Park sites also include within their boundaries various sources of human-caused environmental perturbations, whereas Long-Term Ecological Research sites exist almost wholly for ecological research and are little perturbed except by natural disturbance.

In the case of some National Environmental Research Park sites, on-site environmental research activities have continued over long periods of time. At the Savannah River National Environmental Research Park, which is located near Aiken, South Carolina, studies of the site's bird populations date from 30 years ago. Over that time, over 80 studies of the site's bird populations have been published. Databases from these studies are available to researchers who may now wish to use these sites to either initiate or expand studies of the site's bird populations.—I. Lehr Brisbin, Jr., Savannah River Ecology Laboratory, Department of Energy, Aiken, SC 29801.

David L. Trauger, Charles Walcott, Edward Weidner, John A. Wiens, Jane Hance Woods, and David A. Wustner.

### LITERATURE CITED

ANDERSON, D. R., and K. P. BURNHAM. 1978. Effect of restrictive and liberal hunting regulations on annual survival rates of the Mallard in North

America. *Trans. N. Amer. Wildl. Nat. Res. Conf.* 43: 181-186.

BOCK, C. E. 1984. Geographical correlates of abundance vs. rarity in some North American winter landbirds. *Auk* 101: 266-273.

BROWNIE, C., D. R. ANDERSON, K. P. BURNHAM, and D. S. ROBSON. 1985. Statistical inference from band recovery data: a handbook. U.S. Fish and Wildl. Serv., Resource Publ. No. 156.

CAWTHORNE, R. A., and J. H. MARCHANT. 1980. The efforts of the 1978-79 winter on British bird populations. *Bird Study* 27: 163-172.

DeSANTE, D. F., and G. R. GEUPEL. 1987. Landbird productivity in central coastal California: the relationship to annual rainfall, and a reproductive failure in 1986. *Condor* 89: 636-653.

FORD, R. G., J. A. WIENS, D. HEINEMANN, and G. HUNT. 1982. Modeling the sensitivity of colonial breeding marine birds to oil spills: guillemot and kittiwake populations on the Pribilof Islands, Bearing Sea. *J. Applied Ecol.* 19: 1-31.

GRIER, J. W. 1974. Reproduction, organochlorines, and mercury on northwestern Ontario Bald Eagles. *Canadian Field-Nat.* 88: 469-475.

HOLMES, R. T., T. W. SHERRY, and F. W. STURGESS. 1986. Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook. *Ecol. Monogr.* 56: 201-220.

HOUSTON, C. S. 1978. Recoveries of Saskatchewan-banded Great Horned Owls. *Canadian Field-Nat.* 92: 61-66.

MILLSAP, B. A. 1986. Status of wintering Bald Eagles in the conterminous 48 states. *WILDL. SOC. BULL.* 14: 433-440.

MORRISON, M. L. 1986. Bird populations as indicators of environmental change. Pp. 429-451 in R. F. Johnston (Ed.), *Current Ornithology*. Plenum, New York.

RALPH, C. J., and J. M. SCOTT (Eds.). 1981. Estimating numbers of terrestrial birds. *Studies in Avian Biology* No. 6.

RICKLEFS, R. E. 1973. Fecundity, mortality and avian demography. Pp. 366-434 in D. S. Farner (Ed.), *Breeding Biology of Birds*. Natl. Acad. Sci., Washington, D.C.

SEBER, G. A. F. 1982. The estimation of annual abundance and related parameters. Macmillan, New York.

TEMPLE, S. A., and J. R. CARY. 1988. Modeling dynamics of habitat-interior bird populations in a fragmented landscape. *Conserv. Biol.* (in press).

VERNER, J. 1985. Assessment of counting techniques. Pp. 247-302 in R. F. Johnston (Ed.), *Current Ornithology*. Plenum, New York.

WIENS, J. A., and J. T. ROTENBERRY. 1985. Response of breeding passerine birds to rangeland alteration in a North American shrubsteppe locality. *J. Appl. Ecol.* 22:655-668.

ZAR, J. H. 1984. *Biostatistical Analysis*. Prentice-Hall, Englewood Cliffs, NJ.

—Department of Wildlife Ecology, University of Wisconsin, Madison, WI 53706 (Temple); Department of Biology, Colorado State University, Fort Collins, CO 80523 (Wiens).