Avian Conservation

Research and Management

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CHAPTER 7

What Do We Need to Monitor in Order to Manage Landbirds?

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Conservation Issues and Previous Research

A major issue in environmental biology concerns the worldwide decline of migratory landbirds (Robbins et al. 1989; Terborgh 1989; Kaiser and Berthold 1994; Martin and Finch 1995). Among northern-hemisphere species, long-distance migrants (i.e., those that breed in temperate and winter in tropical latitudes) appear to be declining most severely. For example, thirty years of data (1966–95) from the North American Breeding Bird Survey (BBS) indicate that 55 percent and 69 percent of Nearctic-Neotropical migrant species are declining in eastern and central North America, respectively, compared to 47 percent and 53 percent, respectively, for short-distance migrant species, and 45 percent and 56 percent, respectively, for permanent resident species (Peterjohn, Sauer, and Link 1996). Similarly, twenty-two years of migration-monitoring data (1972–93) from the Mettnau-Reit-Illmitz Program of the German Ornithological Institute "Vogelwarte Radolfzell" indicate that fifteen (71 percent) of twenty-one trans-Saharan migrant species decreased significantly while only two (4 percent) of the fourteen European-wintering species declined significantly (Kaiser and Berthold 1994). In addition, by 1990, data from the British Common Bird Census and Waterway Bird Survey showed that thirty of Britain's passerine species were experiencing long-term declines, as opposed to seventeen species whose populations appeared stable and eighteen species that showed population increases (Stroud and Glue 1991; Newton, this volume). In addition, seventeen (57 percent) of the thirty declining species were long-distance migrants, while only five (28 percent) of the eighteen increasing species were long-distance migrants (Stroud and Glue 1991).

The data that were used to describe the above temporal patterns were generated from broadscale, retrospective monitoring programs. Monitoring has been defined in many ways (e.g., Goldsmith 1991); here we refer to monitoring as the temporal assessment of demographic parameters of bird populations. A critical goal of any population monitoring program should be to identify the state of the population, that is, estimates of desired attributes, such as density, average productivity, or average survival rates for a given time period. Although detection of environmental influences on animal populations is difficult, especially considering the nature of time-series data, such as estimated population trajectories (Botsford and Brittnacher 1992), the detection process can provide information on changes in population parameters (Nichols, in press) and can be considered a preliminary search for patterns to be tested in detailed field studies (Holmes and Sherry 1988; Botsford and Brittnacher 1992). In this sense, monitoring facilitates applied research. Furthermore, monitoring, if done in an experimental or quasi-experimental manner (Nichols, in press), is necessary to determine the effectiveness of management actions designed to reverse population declines or bring about the recovery of small or threatened populations (Noon 1992).

Large-scale, long-term monitoring programs, such as those referenced above, are necessary to detect declining population trends over large geographic regions. Such programs require both large-scale coordination and cooperation. Generally, they rely on large numbers of trained volunteers and have only been implemented successfully in developed countries. Even there, many species are too rare or locally distributed to permit reliable identification of population trends. Moreover, interpretation of large-scale, long-term population data is not always straightforward; indeed, controversy still exists regarding interpretation of data from even the well-established BBS Program (Sauer and Droege 1990; James, McCulloch, and Wiedenfeld 1996; Peterjohn, Sauer, and Link 1996). This controversy exists largely because the probability of observing an individual bird, which potentially varies among observers, geographic areas, habitat, species, and time, is unknown. Clearly, the implementation of large-scale, long-term, population-trend monitoring is not a simple exercise.

Despite the general success of avian population-trend monitoring programs in identifying potentially declining species in certain well-studied countries, such monitoring programs provide little information as to factors responsible for population declines and even less direction as to appropriate management actions to reverse declines (Peterjohn, Sauer, and Robbins 1995). This is because they provide no information on the primary demographic parameters (productivity and survival) of the species monitored (DeSante 1995). Indeed, population-trend data by themselves provide no information at all as to the stage(s) in the life cycle that control(s) the population declines (Temple and Wiens 1989) and thus fail to distinguish problems caused by birth-rate effects from those caused by death-rate effects (DeSante 1992). As a result, the factors responsible for declining landbird populations have generally remained unclear (O'Connor 1992).

Features of Research That Improved Conservation

Broadscale, retrospective monitoring projects, such as the BBS, have heightened our awareness of possible population declines in landbirds. Although the magnitude of the declines is often not well estimated and even the direction of the changes is sometimes controversial (James, McCulloch, and Wiedenfeld 1996), these programs have provided the primary data used by decision makers to allocate additional effort toward further investigation of the potential declines or toward implementing conservation plans. The examples presented in this section highlight how monitoring has been used to aid conservation efforts.

Comparisons of BBS population-trend data among species having various life-history traits (i.e., migration strategy, habitat preferences on breeding and wintering grounds) provided indirect evidence that destruction and degradation of forested tropical wintering habitat could be a major cause of population declines in some species of eastern North American landbirds (Robbins et al. 1989). Other studies on some of these same species (i.e., Wood Thrush [*Hylocichla mustelina*] and Ovenbird [*Seiurus aurocapillus*]), however, suggested that reduced breeding success caused by high levels of brood parasitism by the Brown-headed Cowbird (*Molothrus ater*) caused, in turn, by fragmentation of temperate forest breeding habitat, could be a major cause of population declines in midwestern North America (Robinson et al. 1995; Faaborg et al., this volume). Obviously, both breeding-ground and wintering-ground processes could adversely affect population trends, and management actions could be suggested that would tend to mitigate against each of these processes (e.g., requiring overstory shading in tropical coffee plantations or implementing extensive cowbird-control programs on temperate breeding grounds). Because such management actions will likely be expensive and will involve major policy changes, public agencies and private organizations are reluctant to undertake them without considerable assurance that they will be successful. Knowledge of the rates of primary demographic factors throughout a species' range can facilitate the identification of key factors controlling its observed population trends. Monitoring demographic parameters helps achieve this latter knowledge.

A major advance in this direction was provided in a seminal paper by Baillie (1990) in which he advocated an "integrated population monitoring scheme" whereby various monitoring programs would address different aspects of the population dynamics of a suite of species over the same geographic area. In this scheme, which has been implemented by the British Trust for Ornithology (BTO), population trends are tracked by several programs, including the Common Bird Census and Waterways Bird Survey (Baillie 1990). Information on the potential proximal demographic causes of observed population trends in several habitat types is provided by the British Constant Efforts Sites (CES) Scheme (Peach, Buckland, and Baillie 1996), which monitors changes in productivity indices and survival-rate estimates through constant-effort mist netting. Finally, detailed, habitat-specific information on various aspects of reproductive success, including timing of clutch initiation, clutch size, brood size, and nesting success, are provided by the BTO's Nest Record Scheme (Baillie 1990).

Peach, Baillie, and Underhill (1991) and Baillie and Peach (1992) have used integrated population monitoring to better understand the potential causes of population declines in several trans-Saharan migratory species of European landbirds. They found, for example, using key-factor analysis (Varley and Gradwell 1960; Blank, Southwood, and Cross 1967; Krebs 1970; Southwood 1978), that variations in mortality of full-grown birds (individuals that have reached independence from their parents) explained most of the population fluctuations in all seven of the species investigated. Mortality of young birds during their first year of life was implicated as the key factor causing population declines in Sedge Warblers (*Acrocephalus schoenobaenus*) and Willow Warblers (*Phylloscopus trochilus*), while mortality of adult birds after their first year of life was implicated for Whitethroats (*Sylvia communis*). Moreover, for Sedge Warblers, Whitethroats, and Swallows (*Hirundo rustica*), fluctuations in mortality of full-grown birds were correlated with conditions on the wintering grounds. In the case of the first two species, both survival of full-grown birds and total population size were highly correlated with rainfall patterns on the species' sub-Saharan (Sahel), west African wintering ranges. Populations of these two species appear to be limited by competition for resources on the wintering grounds, and these resources are strongly dependent on rainfall during the preceding wet season. Thus, the population declines in British Sedge Warblers and Whitethroats appear to have been caused directly by the extensive Sahel drought. Conservation measures for these species, therefore, should be directed toward ameliorating the causes of drought in the Sahel or, at least, mitigating the effect of these droughts. These results suggest that conservation efforts that target the breeding ranges of these species may do little to reverse their population declines.

The concept of integrated population monitoring is beginning to be pursued in North America (see also Hejl and Granillo, this volume). Population trends are monitored by means of roadside point counts through the BBS (Robbins, Bystrak, and Geissler 1986; Peterjohn, Sauer, and Robbins 1995; Peterjohn, Sauer, and Link 1996). Productivity is monitored by means of constant-effort mist netting through the Monitoring Avian Productivity and Survivorship (MAPS) Program (DeSante et al. 1995; DeSante, Burton, and O'Grady 1996) and by means of direct nest monitoring through the Breeding Bird Research

Database (BBIRD) Program (Martin and Geupel 1993). Finally, adult survivorship is monitored by means of mark-recapture data from the MAPS Program.

The integration of BBS and MAPS data from the Sierra Nevada has shed light on the potential proximal causes of population decline in the Willow Flycatcher (*Empidonax traillii brewsteri*), a species that has shown drastic population declines in the Sierra over the past fifty years (Gaines 1988). In contrast, two similar species of Sierran flycatchers, Hammond's Flycatcher (*E. hammondii*) and Dusky Flycatcher (*E. oberholseri*), both show positive BBS population trends in the Sierra. MAPS data from ungrazed meadows in the Sierra, where all three species breed, show that both the productivity index and the annual adult survival rate estimate for Willow Flycatcher is as high or higher than those of the other two species (DeSante, unpublished data). It has been suggested from localized research efforts in the Sierra (Serena 1982; Gaines 1988) that the grazing of montane meadows, which results in defoliation of the lower portion of the willows, causes the habitat to become unsuitable for nesting Willow Flycatchers. MAPS data is consistent with this hypothesis by providing data to reject competing hypotheses such as low productivity in general (in ungrazed as well as grazed meadows) and low survivorship due perhaps to problems on the wintering grounds. MAPS data thus support research and management efforts for Willow Flycatchers aimed at reducing the impact of grazing Sierran montane meadows.

Research Needed to Further Conservation

An effective integrated monitoring program for landbirds should be able to accomplish three objectives: (1) identify species with declining population trends and describe these trends at multiple spatial scales; (2) identify reasonable hypotheses for the proximal demographic causes of population declines and suggest research activities to test these hypotheses; and (3) evaluate the effectiveness of local management actions and larger-scale conservation strategies implemented to reverse the declines. These objectives emphasize that the results of an integrated monitoring program will be most effective if reasonable hypotheses, backed by knowledge of demographic patterns derived from monitoring, can be formulated so that rigorous tests of the hypotheses can follow. In this sense, monitoring facilitates research.

In the past, monitoring, research, and management have generally been treated as independent activities. Only the first objective outlined above typically was considered to lie within the domain of monitoring. Objective 2 was more often considered to lie within the province of research, while objective 3 was relegated to the domain of management. Two major shortcomings of this traditional approach have been: (1) a general paucity of research efforts designed to investigate causes of population declines over large spatial scales; and (2) a lack of effective integration between monitoring, research, and management at both large and small spatial scales. Most research and management efforts directed at understanding and reversing declining populations of landbirds have focused on small or local scales (e.g., a particular refuge) or on particular habitats. This is not to disparage such research and management efforts; many such studies have added important information regarding factors influencing habitat choice and nesting success that has assisted in developing effective management actions. The real failure of such efforts, however, lies in the paucity of management actions following on the heels of successful research and the lack of follow-up monitoring of the effects of the management actions actually implemented. Too often, good research and well-intentioned management actions end up in a relative vacuum and are not integrated with each other or with continued monitoring. The interaction of monitoring, research, and management must be structured into an interactive loop for adaptive decision making.

Creation of an integrated monitoring effort must include the monitoring of productivity and survivorship as well as the population trends that result from the interaction of these primary demographic parameters (Hejl and Granillo, this volume). It is important to note that monitoring cannot, by itself, identify ultimate environmental causes of population change. Monitoring primary demographic parameters will, however, allow a temporal assessment of changes in these vital rates that, through correlation analyses, can identify hypotheses for further evaluation. Carefully controlled research efforts are then needed to test the hypotheses generated by monitoring in order to determine the environmental factors causing the observed changes (or differences) in the primary demographic parameter(s) responsible for the population changes (Nichols, in press).

Monitoring of primary demographic parameters also may be the most judicious way to determine whether or not management actions are working effectively (DeSante, in press). This is because management actions affect primary demographic parameters directly, and these effects can potentially be observed over a short time period (Temple and Wiens 1989). Because of buffering effects of floater individuals (Smith 1978) and density-dependent responses of populations, there may be substantial time lags between changes in primary parameters and resulting changes in population size or density (DeSante and George 1994). Moreover, because of the vagility of most bird species, local variations in population size may often be masked by recruitment from a wider region (George et al. 1992) or accentuated by lack of recruitment from a wider area (DeSante 1990). Thus, density of a species in a given area may not be indicative of population health, due to source-sink dynamics (Van Horne 1983; Pulliam 1988). Knowledge of primary demographic parameters is thus critical for understanding population dynamics and is directly applicable to population models that can be used to assess land-management practices (Noon and Sauer 1992), particularly when these parameters can be related to specific habitats or landscape features.

What Needs to Be Monitored and How Should it Be Done

Population Trends

An effective large-scale monitoring program must be able to provide reliable estimates of relative abundance and population trend over the entire ranges of many species. In general, the BBS currently has the capability of providing these estimates for a large number of North American species (Peterjohn, Sauer, and Robbins 1995; Peterjohn, Sauer, and Link 1996), although there is controversy as to how reliable the estimates are (Sauer and Droege 1990; James, McCulloch, and Wiedenfeld 1996).

A major shortcoming of the BBS program is that habitat-specific relative-abundance and population-trend data are not obtained. This could be rectified by a coordinated program of habitat-specific off-road point counts (Hutto, this volume) or area searches; or, perhaps, by incorporating remote-sensed habitat data associated with each BBS survey point. However, because of different detection rates in different habitats (Schieck 1997), relative abundance among habitat types will be difficult to estimate reliably, even for a single species.

Productivity

Productivity and survivorship are the major primary demographic parameters that provide critical information for understanding patterns of population change. Productivity has a number of components, including clutch size, egg and nestling survival, fledgling survival, and number of nesting attempts. Information on the component that most affects overall reproductive success will be very useful in assessing potential management actions designed to increase productivity.

Habitat- and site-specific estimates of several of these components (e.g., clutch size, egg and nestling survival) can be obtained from direct nest monitoring through the BBIRD Program (Martin and Geupel 1993), although these estimates may be difficult to obtain. Near the time of fledging, daily nest monitoring may be necessary to get the best estimate of nest success. If the birds are individually color marked and all nesting attempts are monitored, the number of nesting attempts per pair can be estimated as well. Direct nest monitoring, however, cannot provide an estimate of fledgling survival, which may or may not be correlated with survival of eggs or nestlings. Moreover, observer effects may bias the results of direct nest monitoring, especially if daily monitoring is necessary.

Indices of post-fledging productivity (the number of young per adult that reach independence from their parents) that integrate all of the individual components of reproductive success can be obtained from constant-effort mist netting through the MAPS Program (DeSante et al. 1995; DeSante, Burton, and O'Grady 1996). Data collected by mist netting are probably better suited for estimating productivity on a regional, rather than site- or habitat-specific, basis than are data from direct nest monitoring. Productivity indices obtained from constant-effort mist netting are likely to be biased, however, because of the lack of a well-defined sampling area and because of habitat- and species-specific biases in the capture probability of young compared to adults (DeSante et al. 1995). DeSante (1997) showed that habitat-specific biases indeed exist, but that consistent station operation and extensive sampling lessen their effect. DeSante (1997) also provided evidence that species-specific biases in productivity indices caused by differences in dispersal characteristics or foraging height between young and adults may be relatively small.

Direct nest monitoring and constant-effort mist netting thus provide information on different components of productivity at different spatial scales. As such, they provide complementary information; both methods, therefore, should be included in an effective integrated population monitoring scheme.

Survival Rates

Estimates of annual survival rates of adult birds can be obtained from mist netting (e.g., MAPS) using modified Cormack-Jolly-Seber (CJS) mark-recapture analyses (Clobert, Lebreton, and Allaine 1987; Pollock et al. 1990; Lebreton et al. 1992). Potential biases caused by including nonresident (transient) individuals in the sample of newly banded adults can be reduced using various transient models (Peach, Buckland, and Baillie 1990; Pradel et al. 1997). It is important to note that estimates of adult survival rates obtained in this way are actually estimates of apparent survival that include an unknown component of emigration (DeSante 1995).

Survival rates of young are difficult to obtain from capture-recapture studies because young birds typically have relatively large dispersal distances. Estimates of post-fledging, premigration survival rates and dispersal characteristics have been obtained by radiotelemetry for Wood Thrush (Anders et al. 1997), and such methods should be applied more broadly (Walters, this volume; Faaborg et al., this volume).

Considerations of Spatial Scale

An important aspect of monitoring is the ability to detect trends in selected parameters and investigate the scale at which they may be occurring. Regional trends in avian demographic patterns may occur due to large-scale weather changes or changes in the landscape that affect areas large enough to affect many local populations similarly. Local changes or trends, such as may occur in a specific national forest, may occur due to changes to habitat quality, for example, from tree harvest. If the pattern of local environmental change is pervasive, similar regional patterns may result. Understanding the scale of trends will thus be informative for determining future research needed to identify problems, and, once they are identified, to determine management solutions. Processes that affect patterns in demographic rates are likely to be scale dependent; management policies and activities often respond to relatively local issues, although concern over small-scale patterns may be motivated by documentation of larger-scale phenomena. Thus, monitoring must be effective at multiple scales ranging from "local" (e.g., national forest or park) through "regional" (e.g., physiographic strata) to "large" (e.g., eastern North America or the entire range of the species).

Avian populations vary spatially and temporally in regard to demographic parameters such as density (Brown 1995), productivity (Robinson et al. 1995; DeSante, Burton, and O'Grady 1996), and survivorship (Johnson, Nichols, and Schwartz 1992; Burnham, Anderson, and White 1996). Describing patterns of variation in primary demographic parameters is important for understanding dynamics of populations and for interpreting trends in population size that may reflect reduced viability (Wilcove and Terborgh 1984). Lack of knowledge on the spatial scale and the magnitude of temporal variation in demographic parameters often leads to incorrect conclusions regarding population health and makes it difficult to argue that specific population declines are noteworthy and deserve additional attention.

Although there is a tremendous effort to obtain data to monitor wildlife population trends at small spatial scales (e.g., an individual refuge), there are few programs that attempt to monitor trends at larger geographic scales (e.g., western North America). Understanding patterns at small scales is critical in guiding research and management actions to address local concerns. However, it is difficult to isolate reasonable hypotheses for the observed patterns when larger-scale patterns are unknown. The challenge is to design monitoring programs to provide estimates of parameters of bird populations at larger geographic scales, while maintaining adequate precision at smaller spatial scales to address local issues. Given a finite sampling effort, allocation of this effort can be extensive, intensive, or a combination of both approaches (figure 7.1). Unfortunately, there is a trade-off between precision of local estimates and potential bias of large-scale estimates when effort is fixed (figure 7.2): increasing the effort at a given site will increase precision of local site-specific estimates, but because the effort is apportioned into fewer sites, there is likely an increase in bias of average estimates across a large geographic area. The degree of bias is relative to the degree of geographic heterogeneity of the parameter of interest. The single most important consideration regarding allocation of sample effort in an integrated monitoring program should be that of geographic scale.

Considerations of Temporal Scale

Monitoring, by definition, is an assessment of specified parameters as a function of time. Any monitoring program must define the time frame of interest, as the success of the monitoring will be defined by the ability to detect changes. The probability of detecting change, if it is in fact occurring, is a statistical power issue (Steidl, Hayes, and Schauber 1997). Larger effect sizes (i.e., the magnitude of change from a null hypothesis) will require a shorter time frame for monitoring than would a smaller effect size given an equivalent statistical power. Statistical

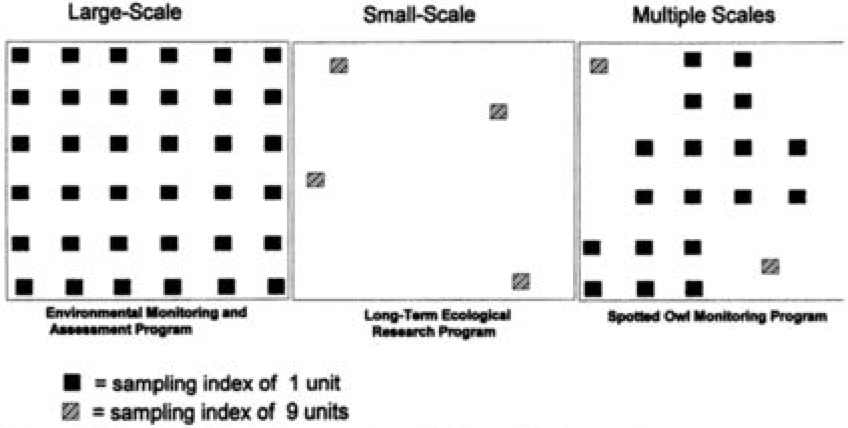

Figure 7.1. Hypothetical sampling strategies with finite effort. A sampling scheme can be envisioned in which samples are located systematically or with a probability-based scheme throughout a large landscape. In this large-scale approach (left panel), which is similar to the scheme initially used by the Environmental Monitoring and Assessment Program of the U.S. Environmental Protection Agency (NRC 1995a), many sites are sampled but with limited effort per site. In a small-scale approach (center panel), local sites are selected and sampled intensely. This scheme is similar to the National Science Foundation's Long-Term Ecological Research Program. In a multiple-scale approach (right panel), there are elements of both a large-scale approach in which many sites are sampled with limited effort, and a small-scale approach in which several sites are sampled intensively. This type of scheme was suggested for monitoring Spotted Owls (*Strix occidentalis*) in the Pacific Northwest (Bart and Robson 1992).

power also is a function of sample size. For example, the ability to detect a declining trend in survivorship is a function of the number of years of sampling (monitoring), the number of individuals sampled, and the effect size (percent annual change) given set recapture and survival probabilities (figure 7.3). Clearly, the spatial scale becomes important, as this dictates the ability to acquire large samples for a long period of time, the two critical factors for detecting trends in the demography of landbird populations.

Site Selection

A further issue relating to the effectiveness of extensive monitoring programs to provide unbiased estimates of large-scale trends is the representativeness of the samples, especially for large geographic areas. BBS attempts to sample randomly, although because all routes are along roads, there is a roadside bias. Most demographic monitoring programs, such as BBIRD and MAPS, use a nonrandom sampling framework. Sites selected are usually a function of local or habitat-specific interest or sites with large numbers (high density) of birds. Since most bird populations seem to be distributed with a high degree of heterogeneity, with most sites having few individuals of a given species and only a few sites with high densities (Brown 1995; Rosenberg 1997), it may not be feasible to have a prob-

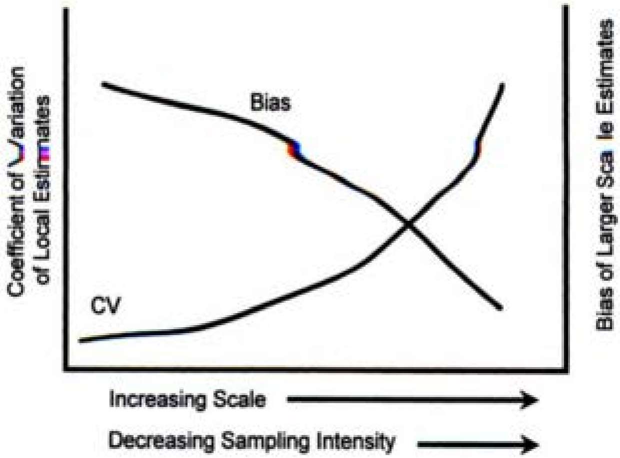

Figure 7.2. Trade-off in precision of local estimates and bias in large-scale estimates of parameters of bird populations. Given a finite sampling effort, there is unfortunately a trade-off in obtaining precise estimates for a given sampling area (e.g., a particular national forest) and obtaining unbiased large-scale (e.g., western North America) estimates. With a sampling scheme focused for estimating parameters of bird populations at small spatial scales (figure 7.1), precision for the local estimates will be much greater (and the coefficient of variation [CV] much lower) than under a large-scale approach in which the sampling intensity at a single site is minimal and thus produces estimates with larger CV. However, if average estimates over a large region are desired, sampling only a few sites may produce a region-wide estimate with large bias. The magnitude of the bias will be positively associated with the degree of spatial heterogeneity of the parameter being estimated.

ability-based sampling strategy over a large geographic area for demographic monitoring because of the large amount of effort required at each site. However, the nonrandom nature of the samples must be considered when making inferences on the larger-scale population parameters.

That few sites contribute most of the information for many species suggests that estimates from demographic monitoring programs that have a nonrandom type of sampling regime are unlikely to be representative for spatial scales larger than the actual study sites, and perhaps may be representative only of the study area of the few stations that contributed the majority of the data. Thus, if the average rate of a specified parameter for a given geographic area is the parameter of interest, then the estimate may be biased; the percent bias is unknown, although it is probably related to the level of geographic or habitat-specific variation in the parameter. If there is little or no variation, then estimates of the average rate may be unbiased. The bias in the average rate for a geographic area is primarily a concern because of the nonrandom sampling strategy. If a probability-based design were used, then it could be argued that the dominance of a few stations represents the true distribution of abundance; hence, there may be little bias in the average rates since they reflect the overall population. If there were common traits among study sites, then perhaps suggestive inferences

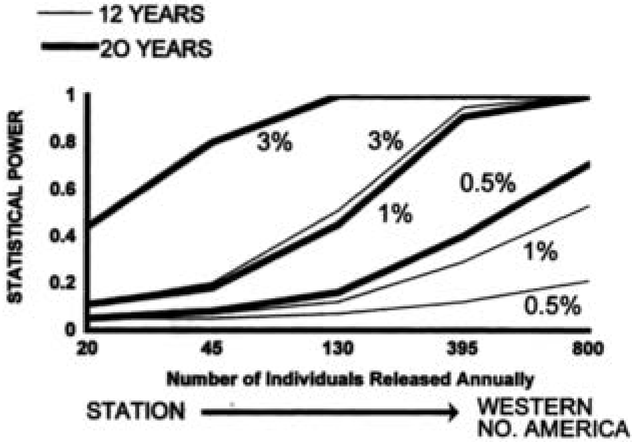

Figure 7.3. Simulation analysis of the statistical power to detect exponentially declining survivorship in relation to the number of individuals released annually, number of years of monitoring, and percent annual decline. The spatial scale reflects the average number of birds released annually in a geographic unit within a particular spatial scale (e.g., individual station). Data were simulated to reflect field data collected on Swainson's Thrush (*Catharus ustulatus*) from the MAPS Program (Rosenberg, De Sante, and Hines, in press). Initial survival rates used in the simulations were 0.45, and recapture probability was 0.54.

(hypotheses) could be made relevant to the common trait (e.g., a specific habitat type for BBIRD or landscape-level habitat information, such as extent of forest fragmentation, for MAPS). Such determinations potentially could be made with vegetation data from the study area (BBIRD) and from the landscape surrounding the station (MAPS).

Making Research Effective for Conservation

An effective integrated avian monitoring effort will be able to identify declining species, identify potential demographic traits responsible for the declines, and attempt to relate those traits to habitat and landscape characteristics. An integrated approach will also provide useful information to aid in identifying conservation strategies and management actions to reverse the declines, and will provide a means for evaluating the effectiveness of the strategies and actions implemented. Foremost will be the description of the temporal and geographic patterns of bird population parameters: relative abundance, productivity, and survivorship. Untangling the processes responsible for the observed patterns will require an experimental or quasi-experimental approach (Nichols, in press), which hopefully will be facilitated by knowledge of the temporal and geographic patterns found from monitoring.

Successful efforts to reverse population declines of landbirds will require an intimate integration of monitoring, research, and management. We believe that monitoring must play a central role in such an integrated process. Thus, it is the monitoring of population trends that defines the species of interest (i.e., declining species). It is the integrated monitoring of population trends and primary demographic parameters that provides information regarding the spatial and temporal patterns on which hypotheses of proximal demographic causes of population change are generated and intensive research at the local scale is based. Results from monitoring, coupled with the results of the implemented research, must then lead to suggested management actions at the local scale, and conservation strategies at larger scales, to reverse the population declines in species of concern. The integrated monitoring of population trends and primary demographic parameters, when done in an experimental framework, will then provide the means for evaluating the effectiveness of the implemented management actions and conservation strategies. We strongly recommend that each implemented management action be required to provide suggested monitoring efforts to evaluate its effectiveness at reversing the population declines in the species of concern. In this way, monitoring, research, and management truly can be integrated into an interactive sequence of activities.

An example of the operation of such an integrated monitoring, research, and management effort could be as follows. Assume BBS data show that a target species is declining in area A but has a stable population trend in area B. Assume that MAPS data show that survival rates for the species do not differ between areas A and B, but that productivity indices in area A are significantly less than those in area B and that the difference in productivity is sufficiently large to account for differences in population trends between areas A and B. Such a situation would suggest that low productivity is the proximal demographic cause of the population decline in area A. Habitat-specific information from BBIRD on nest success of the species in area A could provide information on the stage(s) in the nesting cycle that may be causing the low productivity (i.e., clutch size, number of nesting attempts, survival of eggs or young). This latter information would lead to research efforts to test hypotheses regarding the cause of the low productivity and to additional efforts to identify appropriate management actions to increase productivity at the local scale and to identify larger-scale conservation strategies to increase productivity over the entire range of the species where it is in decline. Continued integrated monitoring of population trends and primary demographic parameters would then determine the effectiveness of the management actions and conservation strategies implemented. This assessment would not only evaluate whether the declining population trend is lessening, but also whether productivity itself is being enhanced by the implemented actions and strategies.

Although the concept of integrated population monitoring is reasonably straightforward and analytical methods are well developed, implementation of integrated population monitoring is not a simple matter, especially over large geographic areas. Real-world issues of sample size (affecting precision of estimates), sampling strategy (affecting bias of estimates), and spatial scale are difficult and complex. The bottom line, inevitably, is that a large number of samples collected over a long time period will be necessary to provide precise and unbiased estimates of demographic rates and population trends. Coordination among the various programs will also be required for an integrated approach. Currently, there is little overlap of sampling sites among BBS, BBIRD, and MAPS.

A real commitment to continued, long-term monitoring on the part of agencies charged with the responsibility of managing bird populations is crucial. In addition, the large samples required can likely be obtained only by substantial volunteer effort. The recruitment, training, and maintenance of a network of volunteers is thus also crucial to the success of any large-scale, integrated, population-monitoring scheme. Ultimately, an interest in and appreciation of birds at the grassroots level must be cultivated if we are to succeed in identifying and describing avian population changes and in developing successful conservation strategies for reversing population declines.

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