Suggestions for Planning a Migration-Monitoring Network Based on the Experience of Establishing and Operating the MAPS Program[1]

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Abstract

Based on the experience of creating and implementing the Monitoring Avian Productivity and Survivorship (MAPS) program, I suggest that, to be successful, a migration-monitoring network must: (1) provide strong justification for the data it proposes to collect; (2) provide direct links between those monitoring data and both research and management goals; (3) provide critical information useful at both small (local) and large (regional) spatial scales; (4) utilize standardized protocols for all aspects of data collection; (5) provide electronic data verification programs to be used by cooperators; (6) utilize state-of-the-art analytical models for making inferences; (7) have a central repository for all data and an organization responsible for timely analysis of data and publication of results; (8) provide frequent and substantive feedback and results to its cooperators; (9) undergo peer review after an appropriate pilot period; and (10) adequately budget for program development, data management and analysis, publication of results, and outreach. I discuss how MAPS has achieved, or attempted to achieve, each of these suggested requirements.

Discussion

Considerable discussion has occurred recently regarding the establishment of a continent-wide network of migration-monitoring stations. The purpose of this paper is to suggest and discuss ten requirements that I believe are crucial for the successful establishment of such a network. These suggestions are based upon 14 years of experience with the establishment and operation of the MAPS (Monitoring Avian Productivity and Survivorship) Program. For each of these requirements, I discuss how the MAPS Program fulfilled, or attempted to fulfill, the requirement.

Requirement 1: Provide a clear definition of the program and its monitoring goals, and a strong justification for the data the network proposes to collect. The MAPS (Monitoring Avian Productivity and Survivorship) Program is a cooperative effort among public agencies, private organizations, and individual bird banders to operate a continent-wide network of over 500 constant-effort mist netting and bird banding stations (DeSante 1992, DeSante and O'Grady 2000). At each station, the program utilizes a standardized netting and habitat-assessment protocol during the breeding season (May-August). The program also utilizes standardized analytical procedures, including modified Cormack-Jolly-Seber mark-recapture models. The specific monitoring objectives of MAPS are to provide, for a suite of target species at multiple spatial scales: (1) annual indices of adult population size and post-fledging productivity (from analyses of data on the numbers of adult and young birds captured), and (2) annual estimates of adult population size, apparent adult survival rate, proportion of residents in the adult population, recruitment into the adult population, and population growth rate (from modified Cormack-Jolly-Seber analyses of mark-recapture data) (DeSante et al. 1995). The justification for monitoring (and basing management on) vital rates (primary demographic parameters) is that: (1) environmental stressors and management actions affect vital rates directly and usually without time lags (Temple and Wiens 1989, DeSante and George 1994); and (2) monitoring vital rates provides crucial information about the stage(s) of the life cycle at which population change is effected, critical information about the health and viability of populations, a clear index of habitat quality, and useful information on source-sink dynamics (Van Horne 1983, Pulliam 1988, DeSante 1995, DeSante and Rosenberg 1998, DeSante et al. this volume).

An often-cited justification for a migration-monitoring network is that population trends of landbird species breeding across boreal Canada and Alaska and wintering south of the United States are not being monitored by either the North American Breeding Bird Survey (because there are too few roads and observers through the vast area of the boreal forests) or the Christmas Bird Count (because there are very few count circles south of the United States) (Blancher et al. 1994, Dunn and Hussell 1995, Francis and Hussell 1998). While this may be sufficient justification for the establishment of a network of migration-monitoring stations across southern Canada, it provides only weak justification for

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stations throughout the United States. I suggest that additional justification is needed for a network of migration-monitoring stations in the United States, and that the appropriate justification should involve efforts to determine habitat characteristics that provide high quality stopover habitat for migratory landbirds, especially declining species. If the major goal of a continent-wide network of migration-monitoring stations becomes assessing the quality of stopover habitat rather than monitoring population trends, the character of the program would change with regard to both station location and station longevity. The most suitable station locations for long-term trend monitoring of migrating birds are locations from which birds are likely to move on as quickly as possible (i.e. locations that are not especially attractive for stopover such as an island or sparse, coastal habitat), because current methods for trend analysis assume that each day's count is an independent sample of the population (Dunn and Hussell 1995). By contrast, if the monitoring questions involve interest in stopover ecology and suitability of habitat for migrants, then stations that have overall large populations of birds would be preferable (Ralph et al. 2004).

Aspects of stopover ecology that could be useful for assessing habitat quality of a stopover site might include total numbers and species diversity of birds using the site, proportion of birds using the site that are adults, mean length of stopover at the site, and rate of mass gain or loss at the site. These could be coupled with site-specific and local landscape-level habitat characteristics in an effort to identify habitat characteristics associated with high quality stopover sites. Certainly each station in a network aimed at assessing the quality of stopover habitat would need to be operated for some minimum number of years, because stopover-habitat quality will likely vary somewhat as a function of weather conditions. However, in such a scenario, each station would not necessarily need to be maintained indefinitely into the future, as they would in a program aimed solely at the long-term monitoring of population trends.

Requirement 2: Provide direct links between the monitoring data and both research and management goals. The specific research objectives of MAPS are to identify and describe, for a suite of target species at multiple spatial scales: (1) temporal and spatial patterns in demographic indices and estimates (DeSante 2000); and (2) relationships between these temporal and spatial patterns and ecological characteristics of the target species (DeSante 2000), population trends of the target species (DeSante et al. 1999), station-specific and landscape-level habitat characteristics (Nott 2000, 2002), and spatially-explicit weather data (Nott 2002, Nott et al. 2002a). The specific management objectives of MAPS are, for the suite of target species at the appropriate spatial scales, to use these temporal and spatial patterns and relationships to: (1) determine the proximate demographic cause(s) of population change (DeSante et al. 2001); (2) formulate station-specific and landscape-level management strategies to reverse population declines and maintain stable or increasing populations (Nott 2000); and (3) evaluate the effectiveness of the management strategies implemented in an adaptive management context.

I suggest that it is critical that the data from a migration-monitoring network be suitable for addressing important research questions and be able to be linked directly to potential avian management efforts. This latter requirement may be especially difficult to achieve for data from a migration-monitoring network, because the origins and destinations of birds captured at such stations are generally unknown, thus creating formidable problems as to exactly where any management efforts should be implemented. Linkages between monitoring and management, however, would be easier to establish if the program were focused more on questions of stopover habitat quality. Indeed, it is possible that destruction or degradation of stopover habitat is a major cause of population decline in some migratory species. In such cases, programs aimed at monitoring population trends on either the breeding grounds (such as the BBS) or wintering grounds (such as the CBC) suffer from the analogous problem of determining where along the migration pathway management efforts should be implemented.

Requirement 3: Provide critical information useful at both small (local) and large (regional) spatial scales. MAPS provides useful information at each of the following five major spatial scales: (1) the range-wide scale, which can vary from the entire continent for widely distributed species (i.e., all of continental United States and Canada), through major portions of the continent (e.g., United States and southern Canada east of the Great Plains for many eastern species), to a small portion of the continent for species with restricted ranges (e.g., Wrentit, Golden-cheeked Warbler, etc.); (2) the regional scale, which also can vary from the size of a MAPS Region (e.g., the Northwestern or Southeastern regions), through large NABCI Bird Conservation Regions (e.g., the Great Basin), to small physiographic strata (e.g., the Sierra Nevada); (3) the local management unit scale, which can encompass an individual national forest, national park, or military installation, and which can also vary substantially in size; (4) the local landscape scale, which can, for example, be a 2- to 10-km-radius area surrounding an individual MAPS stations; and (5) the scale of the individual MAPS station, which is typically the 20-ha area within which nets are operated. MAPS provides information at each of these spatial scales by pooling data from stations over successively larger areas.

For monitoring population trends of migrating populations, it is generally agreed that sampling should be conducted daily, or near daily (at least 75 percent of the days during the period when the middle 95 percent of the individuals normally occur), in order to allow modeling of the effects of weather and date on numbers of migrants present (Hussell et al. 1992, Ralph et al. 2004). Daily or near-daily coverage will also improve the precision of trends, decrease the number of years to establish weather and date effects, and decrease the number of years before a trend can be detected (Dunn et al. 1997, Thomas et al. 2004). Because the effort necessary to obtain meaningful results from a migration-monitoring station will, therefore, be much greater than the effort needed to run a MAPS station (which is operated only once in each of 6-10 consecutive 10-day periods), a migration-monitoring network will likely contain many fewer stations than the existing MAPS network. Nevertheless, it will be important that a migration-monitoring program be organized in a manner that data from stations can be pooled to provide information at several spatial scales, and that sufficient data be available from each area of interest at each scale.

Requirement 4: Utilize standardized protocols for all aspects of data collection. A summary of the standardized MAPS protocol is as follows. About ten 4-tier, 12-m-long mist nets are erected at fixed locations within the central eight ha of the 20-ha study area (MAPS station). These nets are operated for six morning hours per day beginning at local sunrise, for one day per 10-day period, and for six to ten consecutive 10-day periods (depending on latitude) beginning between May 1-10 (at low latitudes) and June 10-19 (at high latitudes) and continuing through July 30-August 8 (at all stations). All birds captured are identified to species, age, and (if possible) sex, and all unmarked birds are marked with a uniquely numbered U.S. Geological Survey/Biological Resources Division (USGS/BRD) leg band. The net-opening and -closing times and net-run times are recorded to the nearest ten minutes. The breeding status for all species present at the station (including those that were never captured) is determined each year from data collected during each day of station operation (these data are similar to those collected by breeding bird atlas projects). A detailed habitat map of the station is prepared, and the structure and pattern of each habitat present is assessed during the first year or two of station operation and then once every five years (or sooner if major habitat changes occur). All of these data are recorded on standardized MAPS data forms which are available from the Institute of Bird Populations (IBP) website, using standardized codes. Detailed instructions for the establishment and operation of MAPS stations are provided by the *MAPS Manual* (DeSante et al. 2003) while detailed instructions for assessing the habitat are provided by the *MAPS Habitat Structure Assessment (HSA) Protocol* (Nott et al. 2002b), both of which are also available on the IBP website.

It should be noted that the present MAPS protocol and the exact layout of the data sheets and wording in the MAPS Manual is the result of improvements that were made during and after the first three years (1989-1991) of the program, which amounted to an IBP-sponsored feasibility study, and the four-year (1992-1995) pilot project and evaluation of the program which was concluded in 1996. For example, the MAPS season initially extended for 12 10-day periods through August 28. However, we found that substantial numbers of birds captured during the last two periods (August 9-28) carried moderate fat deposits indicating that they likely did not breed or were not produced within the landscape surrounding the station. Thus, we revised the program in 1997 to exclude operation after Period 10 (July 30-August 8).

Some analogous modifications to a developing migration-monitoring program should be expected, although it is likely that they will be fewer than what was experienced by MAPS, because the current state-of-the-art regarding migration monitoring is relatively much better developed than was the state-of-the-art regarding breeding season monitoring of productivity and survival when MAPS was first developed in 1989. While a number of different techniques, ranging from mist netting and diurnal visual counts to nocturnal call counts, will likely be employed in migration monitoring, and different stations might employ different suites of these techniques, it will still be important that each technique be standardized and fully described in standardized and readily accessible written manuals.

Requirement 5: Provide electronic data verification programs to be used by contributors. In order to assure the highest quality information, all MAPS data are subjected to rigorous within- and between-record computerized data verification procedures. Within-record procedures check the codes and ranges of all data entered, including banding, effort, breeding status, and HSA data; and compare species, age, and sex determinations to supplementary data on skull pneumatization, breeding condition, extent of molt and molt limits, feather wear, and wing chord. Between-record procedures compare date, time, station, and net of capture on banding data sheets with analogous information on summary of effort sheets; and compare all records for a given band number for discrepancies in species, age, and sex determinations. All discrepancies or suspect data are examined and, if necessary, corrected. These verification procedures are codified into MAPSPROG, an electronic data input/import, verification/editing computer program that allows MAPS cooperators to verify and submit their MAPS banding, effort, breeding status, and habitat data. The MAPSPROG Program (currently Version 3.7.2; Ruhlen and Michel 2003) and the MAPSPROG User's Guide and Manual (Froehlich et al. 2003) are also available on the IBP website.

To be successful, I suggest that a migration-monitoring network will also need to provide electronic programs that will allow cooperators to enter, verify, and edit their own data before they submit those data to the coordinator. For trend monitoring, this might not be quite so important, but if age ratios are desired then internal consistency of each record must be checked to ascertain that the birds are appropriately aged. The appropriate state-of-the-art models for length of stay and stopover ecology now involve mark-recapture analysis (Kaiser 1995, 1999), for which between record verification is essential.

Requirement 6: Utilize state-of-the-art analytical models for making inferences. The MAPS Program employs a number of standardized analytical models and techniques for analyzing MAPS data. For example, MAPS utilizes logistic regression models to make inferences regarding spatial and temporal differences in productivity indices for a given species. In addition, we recently developed and tested a technique that corrects capture rates of both adult and young birds to account for missed effort (Nott and DeSante 2002a). This technique, which is a modification of work by Peach et al. (1998), obviates both the need for eliminating data to perform constant-effort between-year comparisons of indices of adult population size and productivity, and the need to use chain indices to make inferences regarding trends in adult population size and productivity. MAPS uses modified Cormack-Jolly-Seber mark-recapture models (Pollock et al. 1990, Lebreton et al. 1992) to estimate annual adult survival rates. These models are implemented through the computer programs SURVIV (White 1983) and MARK (White and Burnham 1999). We employ both a within- and between-year transient model to provide survival-rate estimates that are unbiased by the presence of transient individuals in the data and to estimate the proportion of residents among newly captured adults (Pradel et al. 1997, Nott and DeSante 2002b). Akaike's Information Criterion ($QAIC_C$, adjusted for small sample sizes and overdispersion of data) is used for model selection for both logistic regression models of productivity and mark-recapture models of survival (Burnham and Anderson 1998). The relative likelihood of each model in an *a priori* set of candidate models is estimated with $QAIC_C$ weights (w_i; Burnham and Anderson 1998). A model averaging procedure, that is based on the w_i values for each model and that includes model selection uncertainty, is used to provide the best estimates for parameters of interest (Burnham and Anderson 1998). This method of multi-model inference permits use of the entire set of candidate models to make inferences regarding the importance of a variable to a parameter estimate, rather than basing conclusions solely on the single best-fit model.

It will be important that analyses of data from a migration-monitoring network also be performed using standardized state-of-the-art analytical models and model selection methods. As mentioned above, state-of-the-art analyses of stopover ecology necessitate the use of modified Cormack-Jolly-Seber mark-recapture models (Kaiser 1995, 1999).

Requirement 7: Establish a central repository for all data and an organization responsible for timely analysis of data and publication of results. The Institute for Bird Populations serves as the coordinator and central data repository for MAPS data. At the beginning of each season, IBP provides copies of the standardized MAPS protocol and data forms to all new cooperators, and requests that established cooperators download copies of the current forms from IBP's website. MAPS cooperators are asked to provide computer entry, verification, and editing of their MAPS data prior to submitting them to IBP. IBP then provides management and archiving of all MAPS data and fills requests for these data from valid users. IBP also provides computer entry, verification, and editing of MAPS data from cooperators who are unable to submit data through MAPSPROG. Finally, IBP provides analyses of data and reports, appropriate collaboration with other researchers, and dissemination of results from the Program. Backup copies of all MAPS data, along with all appropriate metadata, have also been provided to the Biological Resources Division (BRD) of the U.S. Geological Survey.

It will be vitally important that a central repository be established for migration-monitoring data and that some agency or organization be responsible for 1) filling requests for the use of the data, 2) providing timely analyses of the data, and 3) publishing and disseminating the results.

Requirement 8: Provide frequent and substantive feedback and results to its cooperators. Peer-reviewed annual reports from the MAPS Program are published biennially in *Bird Populations*, a journal of global avian demography and biogeography. IBP has also recently become a partner with USGS/BRD in the National Biological Information Infrastructure (NBII) and has made the annual reports of the MAPS Program available on-line through the NBII/MAPS web-based query interface for MAPS data (IBP 2003). This avian demographics query interface provides regional, between-year changes in adult population size and productivity indices and regional annual estimates of adult apparent survival rates from mark-recapture analyses of MAPS data. For each of the 718 MAPS stations operated for at least one year through 2000, the query interface provides the geographic location, history of operation, a brief habitat description, USGS-NPS National Vegetation Classification Standard (NVCS; http://biology.usgs.gov/npsveg/nvcs.html) classifications of the dominant and subdominant habitat types to formation level, and the composite breeding status of all species captured, seen, or heard at the station. IBP also provides an annual newsletter, *MAPS Chat*, to all MAPS cooperators and other interested parties. Finally, during the 12 years between 1991 and 2002, IBP produced 27 peer-reviewed papers; 22 manuals, handbooks, and non-peer-reviewed position papers; and 109 technical (mostly annual) reports to federal and state agencies and non-governmental organizations dealing with results of the MAPS Program.

A successful migration-monitoring program must also strive to produce frequent and substantive feedback to its cooperators and timely publications of its results.

Requirement 9: Undergo peer review after an appropriate pilot period. The MAPS Program underwent a peer-reviewed evaluation after completing a four-year (1992-1995) pilot project. The evaluation was undertaken in three parts. First, a general evaluation of the MAPS Program was conducted by DeSante (1997), who (1) examined growth and continuity of the program, distribution of stations, and verification and accuracy of age determinations; (2) compared MAPS and BBS data for between-year changes in indices of adult population size; (3) compared patterns of reproductive success from MAPS productivity indices for various nest-location and migration-strategy classes with analogous patterns from nest-monitoring data and life history theory (DeSante 2000); and (4) compared predicted population changes modeled from MAPS productivity indices and adult survival-rate estimates against observed population changes from BBS and MAPS data at two spatial scales (DeSante et al. 1999, 2001). Second, an evaluation of the statistical properties of the MAPS Program was conducted by Rosenberg (1997), who (1) evaluated the ability to detect spatial differences in productivity at various spatial scales; (2) evaluated the statistical power to detect spatially heterogeneous survival rates and exponentially declining survival rates among various spatial scales (Rosenberg et al. 1999, 2000); and (3) examined the relative bias in survival rate estimates caused by pooling simulated populations with heterogeneous survival rates (Rosenberg et al. 2000). Finally, a peer-review of the MAPS Program and its evaluations (DeSante 1997, Rosenberg 1997) was completed by a panel convened by USGS/BRD at the Patuxent Wildlife Research Center (Geissler 1997).

I suggest that a similar four-year pilot program be established for a migration-monitoring network and that a similar evaluation and peer review be conducted at the end of the pilot period. Such a length of time will allow mark-recapture models to be employed to estimate stopover times and make inferences regarding the stopover ecology of various stations.

Requirement 10: Adequately budget for data management and analysis, publication of results, program development, and outreach. Perhaps the most difficult aspect of creating a migration-monitoring network will be securing funding to keep the network operating over the long term. I suggest that the key to success lies in achieving the ability to provide timely results and frequent and substantive feedback to its cooperators. I further suggest that this ability can only be achieved by budgeting and securing sufficient funding, beginning with the very first year of operation or even earlier, to provide for adequate program development, for data management and analysis, and for the production, publication, and dissemination of results. A rule of thumb might be that 1/3 of the total cost of a monitoring program should be dedicated to these critical data analysis and publication efforts. Moreover, all of the actual field costs of all of the cooperating stations must be included in the total cost of the program. Thus, for example, if the annual cost of operating a single station in the migration-monitoring network would average $5,000 (this assumes that much of the field work is provided by volunteers) and the network would consist of 80 stations (total field cost of $400,000), efforts should be made to secure $200,000 per year for program maintenance and development, data verification, management, and analysis, publication of results, and outreach. Some of these latter funds would be secured and expended by the individual stations (for data entry and verification, for example), but much of these funds would need to be secured and expended by the organization responsible for coordinating the program.

It may be tempting to try to establish and operate a long-term, large-scale monitoring program with less funding, but experience with MAPS suggests that long-term success will be greatly aided if these more aggressive funding goals are articulated up-front and are rigorously pursued. Let me also add that the continued long-term generation of such levels of funding is a very difficult task that cannot be taken lightly.

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