AN OVERVIEW OF THE NORTH AMERICAN MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) PROGRAM

David F. DeSante and M. Philip Nott
The Institute for Bird Populations
P.O. Box 1346
Point Reyes Station, CA 94956-1346 USA
415-663-2052
ddesante@birdpop.org

December 2000

I. WHY MONITOR VITAL RATES?

There are three important reasons why monitoring vital rates (primary demographic parameters such as productivity and survivorship) must be a component of any integrated avian population monitoring scheme (Baillie 1990). First, environmental stressors and management actions affect vital rates directly and usually without the time lags that so often occur with population size (Temple and Wiens 1989, DeSante and George 1994). Second, vital rates provide crucial information about the stage of the life cycle at which population change is being effected (DeSante 1992). This information is particularly important for migratory birds that winter in tropical latitudes, because it can determine whether management actions should be directed toward a species' temperate breeding grounds, tropical wintering grounds, or both. Third, monitoring vital rates provides crucial information about the viability of the population being monitored and about the quality of the habitat or landscape in which the population occurs (DeSante and Rosenberg 1998). Because of the vagility of most bird species, local variations in population size may often be masked or accentuated by recruitment or lack thereof from a wider region (DeSante 1990, George et al. 1992). Thus, density of a species in a given area may not be indicative of population viability due to source-sink dynamics (Van Horne 1983, Pulliam 1988, Donovan et al. 1995).

Estimating primary demographic parameters is critical for understanding population dynamics and is directly applicable to population models that can be used to assess land-management practices by examining the effects of the landscapes they produce on vital rates (Noon and Sauer 1992). Although several studies have investigated relationships between regional landscape patterns and population trends (Sauer et al. 1996, Flather and Sauer 1996), a particular need remains to examine relationships between landscape configuration and vital rates, using standardized methods for collecting vital rate data, at various spatial scales (Villard et al. 1999). To be successful, management actions must be designed to influence the key primary demographic parameter responsible for population decline in a specific target species (DeSante 1995). Such an approach will have a much higher likelihood of success than one based on correlations with presence/absence or relative abundance data (DeSante and Rosenberg 1998, Villard et al. 1999). These considerations necessitate the continued collection of demographic monitoring data, indicate the direction in which analyses of such data should proceed, and emphasize the importance of an integrated approach to monitoring and adaptive management.

II. OVERVIEW OF THE MAPS PROGRAM

The Monitoring Avian Productivity and Survivorship (MAPS) program is a cooperative effort among public agencies, private organizations, and individual bird ringers in North America to operate a network of over 500 constant-effort mist netting and ringing stations during the breeding season (DeSante et al. 1995). MAPS was established in 1989 by The Institute for Bird Populations (IBP) and was patterned to a large extent after the British Constant Effort Sites (CES) scheme operated by the British Trust for Ornithology (Baillie et al. 1986, Peach et al. 1996, 1998). MAPS utilizes a standardized constant-effort mist-netting protocol at a network of stations. Each station typically consists of about ten permanent net-sites located opportunistically, but rather uniformly, within the interior eight ha of a 20-ha study area (DeSante et al. 2001a). Typically, one 12-m, 36-mm-mesh mist net is operated at each net site for six morning hours per day, for one day during each of six to ten consecutive 10-day periods. Starting dates vary between May 1 and June 10 (later at more northerly latitudes and higher elevations) and operation continues through the ten-day period ending August 8. All birds captured during the program are identified to species, age, and sex using criteria in Pyle (1997) and, if unmarked, are ringed with a uniquely numbered aluminum ring provided by the U.S. Geological Survey/Biological Resources Division (USGS/BRD) Bird Banding Laboratory or the Canadian Wildlife Service/Bird Banding Office.

Following Peach et al. (1996), productivity indices are calculated as the proportion of young in the catch (number of young individuals captured/total number of aged individuals captured). Annual adult survival rates and adult capture probabilities are estimated from modified Cormack-Jolly-Seber mark-recapture models (Clobert et al. 1987, Pollock et al. 1990, Lebreton et al. 1992) that include a between- and within-year length-of-stay transient model (Pradel et al. 1997, Nott and DeSante in press). These modifications permit estimation of the proportion of residents among newly captured birds and provide survival rate estimates that are unbiased with respect to transient individuals (Pradel et al. 1997).

MAPS protocol (DeSante et al. 2001a) also requires station operators to record the probable breeding status of all avian species seen, heard, or captured at each station on every day of operation using methods similar to those employed in breeding bird atlas projects; and to assign a composite breeding status for every species at the end of the season based on those records. In addition, a station map and standardized quantitative habitat descriptions are prepared each year for each major habitat type contained in the station by means of the MAPS Habitat Structure Assessment protocol (Nott 2000). Finally, MAPS operators are able to enter or import, verify, edit, and submit all their data to IBP by means of MAPSPROG Version 3 (Froehlich et al. 2000, Michel et al. 2000), a specially designed Windows-based computer program distributed free of charge for that purpose by IBP. MAPSPROG has four modules that deal, respectively, with ringing, effort, breeding status, and habitat assessment data. The program includes within- and between-record verification algorithms that substantially improve the quality of the ringing data, particularly age and sex determinations. Importantly, it allows the persons who actually collect the data to also verify and edit them. Moreover, this process can be carried out during the field season, thereby allowing station operators to learn from their errors in a very timely manner.

During its first three years (1989-1991), MAPS was comprised of an IBP-sponsored feasibility study, during which time the program grew from 16 to 66 stations and the protocol became standardized. The Program was endorsed in 1991 by the Monitoring Working Group of the Neotropical Migratory Bird Conservation Initiative, “Partners in Flight” (PIF), and the Bird Banding Laboratory, and a four-year pilot project (1992-1995) was approved and funded by the U.S. Department of the Interior (USDI) to evaluate the utility and effectiveness of the Program for monitoring demographic parameters of landbirds. During the ensuing four-year pilot study, the program grew from 178 to 391 stations. A general evaluation of the pilot project (DeSante 1996, 2000, DeSante et al. 1999) and an evaluation of the statistical properties of the data (Rosenberg 1996, Rosenberg et al. 1999, 2000) were completed in 1996. A review of the Program and of the evaluations of the pilot project was completed by a panel assembled by USGS/BRD (Geissler 1996). The review concluded that: (1) MAPS is technically sound and is based on the best available biological and statistical methods; (2) it complements other landbird monitoring programs such as the North American Breeding Bird Survey (BBS) by providing useful information on landbird demographics that is not available elsewhere; and (3) it is the most important project in the nongame bird monitoring arena since the creation of the BBS.

MAPS thus became an "established" monitoring program in 1996 and continued to grow from 424 stations in 1996 to about 507 stations in 2000, the ninth year of standardized operation. The substantial growth of the Program was caused in part by its endorsement by PIF and the involvement of various federal agencies in PIF, including the USDA Forest Service; the USDI National Park Service, Fish and Wildlife Service, and Bureau of Land Management; and the USDoD Department of the Navy, Department of the Army, and Texas Army National Guard. During 2000, for example, 151 “agency” stations were operated by IBP personnel under federal contracts. Support for the operation of the remaining 356 “independent” stations (those not operated by IBP personnel) has come from a wide variety of federal, state, and private sources.

III. GOALS AND OBJECTIVES OF MAPS

MAPS is organized to fulfill three tiers of goals and objectives: monitoring, research, and management.

- The specific monitoring goals of MAPS are to provide, for over 100 target species, including Neotropical-wintering migrants, temperate-wintering migrants, and permanent residents:

  (A) indices of adult population size and post-fledging productivity from data on the numbers and proportions of young and adult birds captured; and

  (B) estimates of adult population size, adult survival rates, proportions of residents, and recruitment into the adult population from mark-recapture data on adult birds.

- The specific research goals of MAPS are to identify and describe:

  (1) temporal and spatial patterns in these demographic indices and estimates at a variety of spatial scales ranging from the local landscape to the entire continent; and
  (2) relationships between these patterns and ecological characteristics of the target species, population trends of the target species, station-specific and landscape-level habitat characteristics, and spatially-explicit weather variables.

- The specific management goals of MAPS are to use these patterns and relationships, at the appropriate spatial scales, to:

  (a) determine the proximate demographic cause(s) of population change;
  (b) suggest management actions and conservation strategies to reverse population declines and maintain stable or increasing populations; and
  (c) evaluate the effectiveness of the management actions and conservation strategies actually implemented through an adaptive management framework.

IV. RECENT IMPORTANT RESULTS FROM THE MAPS PROGRAM

For the past nine years, IBP has been publishing monitoring results from MAPS (DeSante 1992, DeSante and Burton 1994, DeSante et al. 1993, 1996, 1998, 2000). These papers have documented pronounced annual variation in regional productivity indices as well as the pattern that increases or decreases in productivity in a given year are typically followed by respective increases or decreases in population size the following year (DeSante et al. 1996, 1998). More recently, MAPS data have yielded interesting research and management related results. Several of the more important of these are described below.

A. Patterns of productivity as a function of nest location and migration strategy

DeSante (2000) described patterns of productivity indices at two spatial scales: all of eastern North America and the Sierra Nevada physiographic stratum. Productivity indices for species groups at both spatial scales varied as a function of nest location (in descending order: cavity, ground, open-cup tree, and open-cup shrub nesters) and migration strategy (again in descending order: permanent residents, temperate-wintering migrants, and Neotropical-wintering migrants). These patterns agree with those found by direct nest monitoring and those predicted from theoretical considerations, are robust with respect to time and space, and thus apparently reflect real population processes at multiple spatial scales.

B. The development and utilization of transient models in MAPS mark-recapture analyses

Not all individual adult birds captured as part of MAPS protocol are resident in the study area during the breeding season. Some, such as floaters, failed breeders, and post-breeding dispersing individuals, may be merely passing through the study area and have essentially zero probability of being recaptured there at a later date. The inclusion of such transient individuals in standard mark-recapture analyses violates the basic assumption that all individuals have an equal probability of recapture and causes substantial underestimation of survival-rates. This problem can be overcome by use of a transient model (Pradel et al. 1997, Nott and DeSante in press) that utilizes both between- and within-year information to estimate the proportion of residents among newly captured adults and the survival rate of those resident adults.

Figure 1 shows that survival rate estimates in the range of 0.4 to 0.5 obtained for target species from the standard CJS non-transient model were increased by 12% to 20% through the use of the transient model. Moreover, the precision of the survival rate estimates from the transient model averaged 7.5% higher than the precision of the estimates obtained from the standard CJS non-transient model (Nott and DeSante in press). These transient models are now being employed in all mark-recapture analyses of MAPS data. Nevertheless, survival rate estimates from MAPS and virtually all mark-recapture experiments on landbirds, including estimates obtained from use of the transient model, are confounded by emigration of breeding individuals and, therefore, are actually estimates of apparent survival.

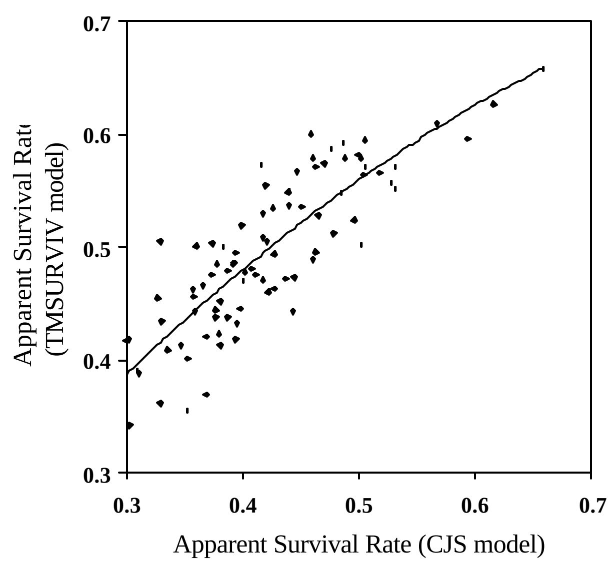

Figure 1. Relationship between 1992-1998 MAPS continent-wide, time-constant annual adult survival rates from use of the within- and between-year transient model (TMSURVIV) versus use of the standard Cormack-Jolly-Seber (CJS) non-transient model for 89 species. Adapted from Nott and DeSante in press.

C. Relationships between adult survival rate estimates from MAPS and body mass and migration strategy

Although previous researchers have made broad inferences about variation in avian survivorship, they generally have done so by comparing survival rates of two or more populations of a single species (e.g., Greenberg 1980) or by aggregating multi-species data from many disparate sources (e.g., Martin 1995). The latter studies have been hampered by the fact that the survivorship values from different studies were derived from many different field methods and analytical models, each of which has its own unique biases. In contrast, survival rate estimates from MAPS are derived from modified Cormack-Jolly-Seber mark-recapture analyses that include a between- and within-year transient model and are applied to continent-wide data generated by a standardized mark-recapture methodology. As a result, ecological and geographical correlates of adult survival rates can be examined with much greater rigor than ever before.

Figure 2 shows time-constant 1992-1998 annual adult survival rates plotted against the natural logarithm of mean body mass (Dunning 1992, Sibley 2000) for 89 target species and for

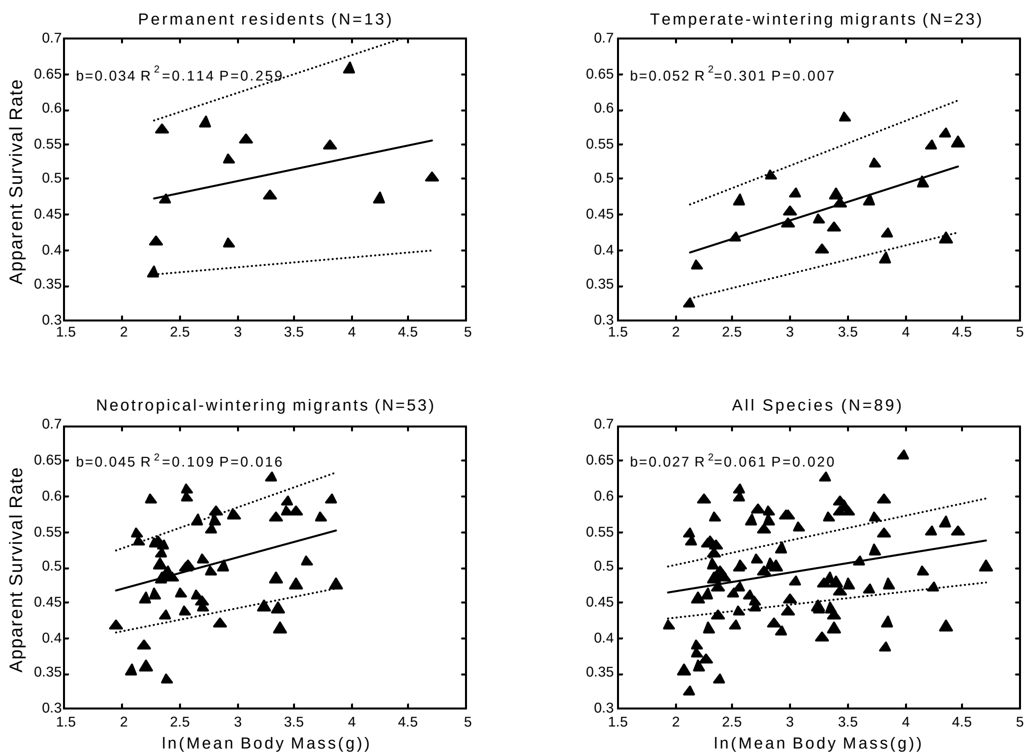

Figure 2. Relationships between time-constant annual adult survival rates from 1992-98 continent-wide MAPS data and the logarithm of the mean body mass for each of three migratory-strategy species groups (permanent residents, temperate-wintering migrants, and Neotropical-wintering migrants) and for all species. IBP unpublished data.

three groupings of these species classified according to migration strategy (permanent residents; temperate-wintering migrants; Neotropical-wintering migrants). Positive linear relationships were found between adult survival rates and ln (body mass) for each species group and were significant (P<0.05) for all groups except permanent residents. An analysis of co-variance (ANCOVA), which took body mass into consideration, showed significant (P=0.01) variation in annual adult survival rates among the three migration-strategy species groups, with both permanent residents and Neotropical-wintering migrants having higher survivorship than temperate-wintering migrants. Interestingly, the species group with the lowest average survival rate, temperate-wintering migrants, also had the steepest slope for its survival rate versus body mass relationship, suggesting that the low survival rates for species in this group were especially pronounced among species with small body mass. This may suggest that species with small body mass are better off either by migrating to tropical latitudes where overwintering climates are predictably benign, or by adapting to predictably harsh climatic conditions and foregoing migration. The poorest strategy (at least as regards adult survivorship) may to be that of migrating to areas where overwintering climate may sometimes be unpredictably harsh, such that costs of migration are always incurred without always reaping the benefits.

D. Measures of productivity and survival from MAPS are consistent with observed population trends

DeSante (1995) showed that reproductive indices based on the ratio of young to adult captures can provide unbiased estimators of actual productivity if the capture probabilities of young and adult birds are equal. This is unlikely to be the case, however, because the young captured by the MAPS protocol are primarily juveniles dispersing from the surrounding landscape, while the numbers of dispersing adults are inflated by captures of the breeding adults that are resident at the station during much of the MAPS season (DeSante 1995). Thus we might expect MAPS reproductive indices to underestimate actual productivity.

Considerable evidence is accumulating, however, to indicate that measures of productivity and survival from MAPS are generally capable of producing modeled population growth rates for multiple species that correlate with observed population trends for those species (DeSante et al. 1999). Moreover, such relationships have been demonstrated at multiple spatial scales, ranging from the smaller scale of a single national forest, national park or military installation, through the larger scale of groups of national forests or military installations within different geographic areas, and finally to the largest scale of the entire continent. These demonstrations indicate that although MAPS productivity indices may indeed be biased low, the biases remain relatively consistent over time and space and among various species, including those with widely different nest locations and migration strategies.

An example of such a relationship for multiple species on a single national forest is shown in Figure 3. Here we see that trends in adult captures for eight target species were significantly positively related to modeled population changes obtained from data pooled from six MAPS stations operated from 1992 through 1995 on Wenatchee National Forest (DeSante et al. 1999). Similar relationships have been obtained for a number of other national forests and parks including Flathead, Umatilla, Willamette, and Siuslaw National Forests and Denali, Yosemite, and Shenandoah National Parks (DeSante et al. 1999).

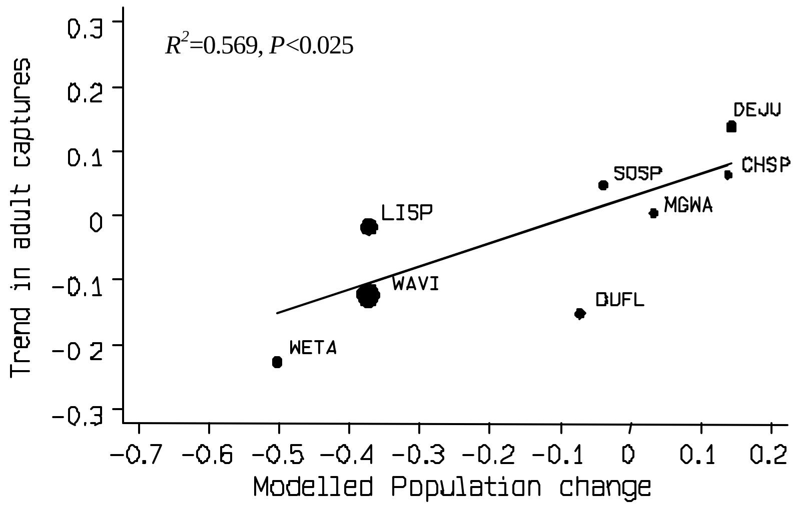

Figure 3. Relationship between trends in adult captures and modeled population changes calculated from reproductive indices and survival estimates from 1992-1995 MAPS data for eight species on Wenatchee National Forest. Trends in adult captures were weighted by the reciprocal of their standard errors and the size of each point reflects the relative weight of each species. From DeSante et al. 1999.

E. MAPS productivity indices and survival rate estimates can be used to identify the proximate demographic cause(s) of population decline

DeSante et al. (2001b) recently described and evaluated a technique for identifying the proximate demographic cause(s) of population change. The approach involves modeling spatial variation in vital rates (productivity and survivorship) both as a function and not as a function of spatial variation in population trends, and using Akaike's Information Criteria (AIC) to select the appropriate (area-dependent or area-independent) model (Burnham and Anderson 1992).

We conducted these analyses at two spatial scales. At the larger scale, we examined 1992-1998 BBS and MAPS data for Gray Catbird. We modeled productivity and survival rates from MAPS stations located in BBS physiographic strata where catbirds were significantly (P<0.01) increasing, as well as strata where they were significantly decreasing. We found that catbird productivity was best modeled as independent of area, while adult survival rates for catbirds were best modeled as area dependent. Moreover, differences in adult survival rates were of the magnitude needed to cause the observed differences in population trends. We concluded that low adult survival rate, rather than low productivity, was the proximate demographic cause of population decline for Gray Catbirds in the physiographic strata where they were declining.

At the smaller scale, we examined six years (1994-1999) of MAPS data from stations on military installations in both the western and eastern Midwest. We conducted analyses on five target species that showed significant negative or positive trends in adult captures on installations in either the western or eastern Midwest, and trends with the opposite sign on installations in the other area. For all five species, we found that low productivity on the installations where the species was declining was a cause of population decline. Low adult survival was an additional cause of decline for Gray Catbird and Yellow-breasted Chat. These are important results because they confirm that MAPS data can be used to identify the vital rate(s) responsible for population declines and, thus, the vital rate(s) toward which management actions should be directed.

F. MAPS productivity indices, coupled with landscape-level habitat data, can be used to identify management strategies for reversing population declines

A critical management goal of MAPS is to identify management actions and conservation strategies to reverse population declines by quantifying relationships between reproductive indices and landscape-level habitat characteristics (Askins and Philbrick 1987). Ideally, habitat variables should be measured in the landscape surrounding the station that includes the area from within which the dispersing juveniles captured by MAPS protocol have originated. The size of this area undoubtedly varies from species to species, and possibly varies geographically and among habitats for a given species. Although the size of this area is unknown for virtually all species, radio telemetry data demonstrate that dispersing juvenile and post-breeding adult Wood Thrushes generally disperse less than four km from their nests and often to edge locations that have dense shrub cover and an abundance of fruit (Anders 1996, Anders et al. 1997).

Using funding supplied by the DoD Legacy Resources Management Program, we have begun to investigate relationships between bird captures and landscape characteristics within four-km-radius areas surrounding MAPS stations on military installations. For example, for each of the nine most common target species on Jefferson Proving Ground, Indiana, we established logarithmic relationships between bird captures and various landscape metrics based upon 30-m resolution Multi-Resolution Land Characterization (MRLC) Consortium remote-sensed data (Bara 1994). Then, from these fitted logarithmic curves, we calculated the relationships between reproductive indices (young/adult) and landscape metrics (Fig. 4).

Figure 4a shows these results for four target species (Ovenbird, Acadian Flycatcher, Wood Thrush, Kentucky Warbler) as a function of mean forest patch size, the single landscape metric that showed the strongest correlation with number of adults captured for each of the four species. These four species are generally considered to be forest interior species and, for each of them, numbers of both adults and young were significantly ($P<0.05$) positively correlated with mean forest patch size at the six stations. Even more interesting were the relationships between reproductive index and mean forest patch size (Fig. 4b). For each species, a threshold patch size (the patch size associated with the 45 degree inflection point of the relationship) was found, below which reproductive indices increased rapidly with increasing forest patch size and above which increases in forest patch size produced relatively small increases in reproductive indices.

Both the threshold patch size and the sharpness of the threshold varied among species. Of the four, the reproductive index for Ovenbird was the most sensitive to mean forest patch size; that is, its threshold patch size was highest (about 30 ha) and its threshold was least sharp of the four species. This is in accordance with recent literature on Ovenbirds (Porneluzi et al. 1993, Burke and Nol 1998). Acadian Flycatcher showed the least sensitive response of reproductive index to mean forest patch size; its threshold patch size was lowest and its threshold was sharpest with very little increase above 20 ha. Reproductive indices for Wood Thrush and Kentucky Warbler showed intermediate sensitivity to mean forest patch size. These tolerances to forest fragmentation are also similar to those previously reported (Gibbs and Faaborg 1990, Robinson

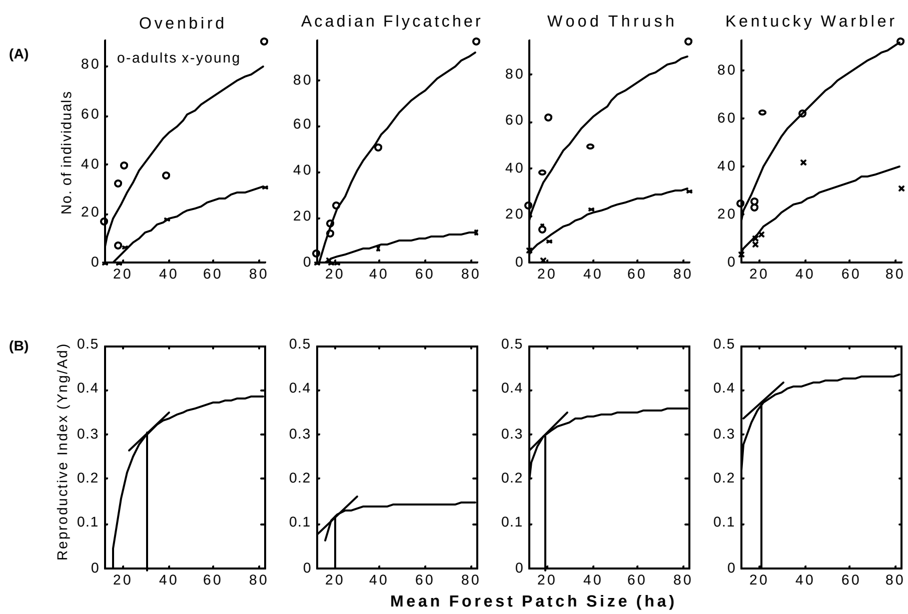

Figure 4. (A) Numbers of individual adult (o) and young (x) birds of four forest interior species captured per 3600 net-hours at six MAPS stations operated during 1994-1999 on Jefferson Proving Ground, Indiana, as a function of mean forest patch size in the 4-km-radius area surrounding each station. (B) Relationship between reproductive index (young/adult) and mean forest patch size at Jefferson Proving Ground for these four species (obtained from the fitted curves in A). IBP unpublished data.

et al. 1995), but here, for the first time, we are able to relate the vital rate actually causing the area sensitivity to habitat conditions in the local landscape.

These results have profound management implications. When these types of analyses become fully developed, it should be possible to calculate, from MAPS survivorship and population trend data, the critical values of productivity needed to reverse population declines and produce positive population trends. It should then be possible to predict the values of various landscape metrics that would be needed to produce such reproductive indices. The development of such landscape-level management strategies is one of the ultimate goals of the MAPS Program.

V. MAPS FIVE-YEAR PLAN AND OBJECTIVES FOR THE NEXT THREE YEARS

With the completion of ten years (1992-2001) of standardized data collection, MAPS will have matured to the point where it can begin to achieve its major research and management goals, as well as provide meaningful summaries of monitoring results. Here I present our overall five-year plan and a plan for achieving a specific set of monitoring, research, and management objectives over the next three years (2001-2003).

The major monitoring objective for these three years is the production of a ten-year summary of regional patterns and trends in productivity indices and estimates of adult population size, adult survival rate, recruitment rate into the adult population, and population growth rate for about 100 target species, and a comparison of these data to population trend data from the BBS and other sources. This will represent the first ever comprehensive summary and regional analysis of the vital rates of 100 or so of the more common landbird species over an entire continent.

These monitoring results will provide the basis for achieving the two major research objectives that are to be addressed during the next three years: (1) to identify *spatial* patterns in the relationship between a major climate variable (standardized El Nino Southern Oscillation [ENSO] Index) and productivity indices from the MAPS Program; and (2) to identify *spatial* patterns in the relationships between vital rates (productivity, recruitment, and survival) and species-specific demographic and ecological correlates and life history traits, including population growth rate, body mass, migration strategy, nest location, foraging strategy, and habitat preference. Achieving these two research objectives also paves the way for reaching the major research goal for the final two years of this five-year plan: to describe *temporal* patterns in the vital rates of target landbird species and to relate them to demographic and ecological correlates. All of these research objectives address critical areas of current scientific investigation that have profoundly important practical applications. Understanding the manner in which global climate variables affect bird demographics, and the manner in which bird demographics affect and are constrained by life history strategies, are fundamental for projecting the effects of human-induced climate change upon avian diversity across north America.

Fulfilling these research objectives will, in turn, provide the basis for achieving the major management objective of these three years: identification of the proximate demographic cause(s) of population change for some 40 or more target species. We will accomplish this objective by modeling spatial variation in vital rates as a function of spatial variation in population trends and ecological characteristics. Identification of the demographic cause(s) of population decline is crucial for assuring that the most appropriate species-specific management actions are being implemented to reverse the declines, and that management efforts are not being directed towards inappropriate stages in the life cycles of the species.

The application to MAPS data of two recently developed analytical techniques is necessary for achieving the research and management results proposed above. These are: (1) extension of a method for adjusting indices of adult population size and productivity to account for missed effort during operation of MAPS stations (Peach et al. 1998); and (2) the use of temporal symmetry models that permit direct estimation of recruitment and population growth rates from mark-recapture data (Pradel 1996, Nichols and Hines in press). Application of these new methods to MAPS data provides the final two objectives to be addressed during the first three years of this five-year plan.

Completing the three-year objectives discussed above will set the stage for fulfilling the major management goal for the final two years of this plan: formulation of landscape-level management actions and conservation strategies for 40 or more target species to reverse population declines and maintain stable or increasing populations. We will achieve this goal by establishing relationships between productivity indices and recruitment estimates obtained from 12 years (1992-2003) of MAPS data and station-specific and landscape-level habitat characteristics.

The objectives proposed here have been achieved for very few species anywhere, and for virtually no landbird species in North America, save a few that are critically endangered because of outright habitat destruction. Still, we believe that we can meet these objectives, given the increasingly powerful mark-recapture models that have recently been developed and more than ten years of data from the network of over 500 MAPS stations all utilizing a standardized protocol. We are confident that we can fulfill these objectives, because we have already completed successful pilot studies on all of them at one or more spatial scales.

Completion of the objectives outlined in this five-year plan will allow the information derived from 12 years of MAPS data to be applied to the development and implementation of landscape-level management plans in a scientifically rigorous manner. The management goal for MAPS subsequent to these five years will be to evaluate, through an adaptive management framework, the effectiveness of the management actions and conservation strategies that are actually implemented. Under this approach, we will utilize hypothesis-driven sampling strategies for siting new stations, such that existing stations will serve as controls and will be paired with new experimental stations in areas where management strategies designed specifically to increase productivity are being implemented. If the goal is to manage for increased productivity, then the adaptive management process demands that productivity, and not simply population size, be monitored. Before reaching that stage of the program, however, we need first to identify those species whose population declines can be reversed by increasing their productivity, and then to formulate appropriate management strategies for them. That is the goal of our five-year plan.

VI. LITERATURE CITED

Anders, A.D. 1996. *Post-fledging survival, dispersal, and habitat selection of juvenile wood thrushes*. MA Thesis. Univ. of Missouri, Columbia.

Anders, A.D., Dearborn, D.C., Faaborg, J. and Thompson III, F.R. 1997. Juvenile survival in a population of neotropical migrant birds. *Conservation Biology* 11:698-707.

Askins, R.A. and Philbrick, M.J. 1987. Effects of changes in regional forest abundance on the decline and recovery of a forest bird community. *Wilson Bulletin* 99:7-21.

Baillie, S.R. 1990. Integrated population monitoring of breeding birds in Britain and Ireland. *Ibis* 132:151-166.

Baillie, S.R., Green, R.E., Boddy, M., and Buckland, S.T. 1986. *An Evaluation of the Constant Effort Sites Scheme.* BTO, Thetford, U.K.

Bara, T.J., comp., ed. 1994. Multi-resolution land characteristics consortium -- documentation notebook, *[Environmental Monitoring and Assessment Program-Landscape Characterization, Contract 68-DO-0106]*: Research Triangle Park, N.C., ManTech Environmental Technology, Inc. [variously paged].

Burke, D.M., and Nol, E. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. *Auk* 115:96-104.

Burnham, K.P. and Anderson, D.R. 1992. Data-based selection of an appropriate biological model: the key to modern data analysis. Pp. 16-30 *in* McCullough, D.C. and R.H. Barrett, Eds., *Wildlife 2001: Populations,* Elsevier Applied Science, London, U.K.

Clobert, J., Lebreton, J.-D. and Allaine, D. 1987. A general approach to survival rate estimation by recaptures or resightings of marked birds. *Ardea* 75:133-142.

DeSante, D.F. 1990. The role of recruitment in the dynamics of a Sierran subalpine bird community. *American Naturalist* 136, pp. 429-455.

DeSante, D.F. 1992. Monitoring Avian Productivity and Survivorship (MAPS): a sharp, rather than blunt, tool for monitoring and assessing landbird populations. In: D. R. McCullough and R. H. Barrett (Eds.), *Wildlife 2001: Populations,* pp. 511-521. (London, U.K.: Elsevier Applied Science).

DeSante, D.F. 1995. Suggestions for future directions for studies of marked migratory landbirds from the perspective of a practitioner in population management and conservation. *Journal Applied Statistics* 22, pp. 949-965.

DeSante, D.F. 1997. *General Evaluation of the Monitoring Avian Productivity and Survivorship (MAPS) Program*. The Institute for Bird Populations, Point Reyes Station, California.

DeSante, D.F. 2000. Patterns of productivity and survivorship from the MAPS Program. Pp.166-177 In: Bonney, R. D.N. Pashley, R.J. Cooper, and L. Niles (eds.) *Strategies for Bird Conservation: the Partners in Flight Planning Process.* Proceedings of the Third Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: USDA, Forest Service, Rocky Mountain Research Station.

DeSante, D.F., and Burton, K.M. 1994. The Monitoring Avian Productivity and Survivorship (MAPS) program third annual report (1992). *Bird Populations* 2:62-89.

DeSante, D.F., Burton, K.M., and O'Grady, D.R. 1996. The Monitoring Avian Productivity and Survivorship (MAPS) Program fourth and fifth annual report (1993 and 1994). *Bird Populations* 3:67-120.

DeSante, D.F., Burton, K.M., Saracco, J.F., and Walker, B.L. 1995. Productivity indices and survival rate estimates from MAPS, a continent-wide programme of constant-effort mist netting in North America. *Journal Applied Statistics* 22:935-947.

DeSante, D.F., Burton, K.M., Velez, P., and Froehlich, D. 2001a. *MAPS Manual: 2001 Protocol*. The Institute for Bird Populations, Point Reyes Station, CA. 67 p.

DeSante, D.F., Burton, K.M., and Williams, O.E. 1993. The Monitoring Avian Productivity and Survivorship (MAPS) Program second annual report (1991). *Bird Populations* 1:68-97.

DeSante, D.F. and George, T.L. 1994. Population trends in the landbirds of western North America. In J.R. Jehl, Jr. and N.K. Johnson (eds.), A Century of Avifaunal Change in Western North America. *Studies in Avian Biology* 15:173-190.

DeSante, D.F., Nott, M.P., and O'Grady, D.R. 2001b. Identifying the proximate demographic cause(s) of population change by modelling spatial variation in productivity, survivorship, and population trends. *Ardea* 89(special issue): 185-207.

DeSante, D.F., O'Grady, D., Burton, K.M., Velez, P., Froehlich, D., Feuss, E.E., Smith, H., and Ruhlen, E.D. 1998. The Monitoring Avian Productivity and Survivorship (MAPS) program sixth and seventh annual report (1995 and 1996). *Bird Populations* 4:69-122.

DeSante, D.F., O'Grady, D.R., and Nott, M.P. 2000. The Monitoring Avian Productivity and Survivorship (MAPS) program 1997 and 1998 annual report. *Bird Populations* 5.

DeSante, D.F., O'Grady, D.R., and Pyle, P. 1999. Measures of productivity and survival derived from standardized mist-netting are consistent with observed population changes. *Bird Study* 46:S178-188.

DeSante, D.F., and Rosenberg, D.K. 1998. What do we need to monitor in order to manage landbirds? In: J. Marzluff and R. Sallabanks (Eds.), *Avian Conservation: Research and Management*, pp. 93-106. Island Press, Washington, DC.

Donovan, T.M., Thompson III, F.R., Faaborg, J. and Probst, J.R. 1995. Reproductive success of migratory birds in habitat sources and sinks. *Conservation Biology*. 9: 1380-1395.

Dunning, J.B. 1992. CRC handbook of avian body masses. 371 pages. CRC Press.

Flather, C.H., and Sauer, J.R. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory songbirds. *Ecology* 77:28-35.

Froehlich, D., DeSante, D.F. and Velez, P. 2000. *MAPSPROG Version 3.0. User's Guide and Manual*. The Institute for Bird Populations, Point Reyes Station, CA. 93 p.

Geissler, P. 1996. *Review of the Monitoring Productivity and Survivorship (MAPS) Program*. The Institute for Bird Populations, Pt. Reyes, Calif.

George, T.L., Fowler, A.C., Knight, R.L., and McEwen, L.D. 1992. Impacts of a severe drought on grassland birds in western North America. *Ecological Applications* 2:275-284.

Gibbs, J. P., and Faaborg, J. 1990. Estimating the viability of ovenbird and Kentucky warbler populations in forest fragments. Conservation Biology 4:193-196.

Greenberg, R. 1980. Demographic aspects of long-distance migration. In: A. Keast and Eugene S. Morton (Eds.), *Neotropics: Ecology, behavior, distribution and conservation*, pp. 493-504. Smithsonian Institution Press, Washington, DC.

Lebreton, J.-D., Burnham, K.P., Clobert, J. and Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecol. Monogr*.62:67-118.

Martin, T.E. 1995. Avian life histories evolution in relation to nest sites, nest predation, and food. *Ecological Monographs* 65: 101-127.

Michel, N., Froehlich, D. Velez, P., Nott, M.P. and DeSante, D.F. 2000. *MAPSPROG Version 3.5, User's Guide and Manual: Breeding Status and Habitat Modules*. The Institute for Bird Populations, Point Reyes Station, CA. 34 p.

Nichols, J.D. and Hines, J.E. In press. Approaches for the direct estimation of lambda, and demographic contributions to lambda, using capture-recapture data. *J. Applied Statistics*.

Noon, B.R., and Sauer, J.R. 1992. Population models for passerine birds: structure, parameterization, and analysis. In *Wildlife 2001: Populations*. D.C. McCullough and R.H. Barrett (eds), pp. 441-464. Elsevier Applied Science, London.

Nott, M.P. 2000. *Monitoring Avian Productivity and Survivorship (MAPS) Habitat Structure Assessment (HSA) Protocol*. The Institute for Bird Populations, Point Reyes Station, CA 42 p.

Nott, M.P. and DeSante, D.F. In press. Demographic monitoring and the identification of transients in mark-recapture models. *In* J.M. Scott and P. Heglund (eds.), *Predicting Species Occurrences: Issues of Scale and Accuracy*. Island Press, New York.

Peach, W.J., Baillie, S.R. and Balmer, D.E. 1998. Long-term changes in the abundance of small passerines in Britain and Ireland as measured by constant effort mist-netting. *Bird Study* 45: 257-275.

Peach, W.J., Buckland, S.T. and Baillie, S.R. 1996. The use of constant mist-netting to measure between-year changes in the abundance and productivity of common passerines. *Bird Study* 43:142-156.

Pollock, K.H., Nichols, J.D., Brownie, C. and Hines, J.E. 1990. Statistical inference for capture-recapture experiments. *Wildlife Monographs*, No. 107.

Porneluzi P., Bednarz, J.C., Goodrich, L.J., Zawada, N., Hoover, J. 1993. Reproductive performance of territorial ovenbirds occupying forest fragments and a contiguous forest in Pennsylvania. *Conservation Biology* 7:618-622.

Pradel, R. 1996. Utilization of capture-mark-recapture for the study of recruitment and population growth rate. *Biometrics* 52:703-709.

Pradel, R., Hines, J.E., Lebreton, J.-D., and Nichols, J.D. 1997. Capture-recapture survival models taking account of transients. *Biometrics*, 53, 60-72.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652-661.

Pyle, P. 1997. *Identification Guide to North American Birds, Part I*. Slate Creek Press, Bolinas, Calif.

Robinson, S.K., Thompson III, F.R., Donovan, T.M., Whitehead, D.R. and Faaborg, J. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267:1987-1990.

Rosenberg, D.K. 1997. *Evaluation of the statistical properties of the Monitoring Avian Productivity and Survivorship (MAPS) Program*. The Institute for Bird Populations, Point Reyes Station, California.

Rosenberg, D.K., DeSante, D.F., and Hines, J.E. 2000. Monitoring survival rates of landbirds at varying spatial scales: an application of the MAPS program. Pp 178-184 In: Bonney, R. D.N. Pashley, R.J. Cooper, and L. Niles (eds.) *Strategies for Bird Conservation: the Partners in Flight Planning Process*. Proceedings of the Third Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: USDA, Forest Service, Rocky Mountain Research Station.

Rosenberg, D.K., DeSante, D.F., McKelvey, K.S., and Hines, J.E. 1999. Monitoring survival rates of Swainson's Thrush Catharus ustulatus at multiple spatial scales. *Bird Study* 46:S198-208.

Sauer, J. R., Pendleton, G.W. and Peterjohn, B.G. 1996. Evaluating causes of population changes in North American insectivorous songbirds. *Conservation Biology* 10:465-478.

Sibley, D.A. 2000. *National Audubon Society The Sibley Guide to Birds.*Chanticleer Press, New York.

Temple, S. A., and Wiens, J. A. 1989. Bird populations and environmental changes: can birds be bio-indicators?. *American Birds*, 43, pp. 260-270.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47:893-901.

Villard, M-A, Trzcinski, M.K., and Merriam, G. 1999. Fragmentation effects on forest birds: relative influence of woodland cover and configuration on landscape occupancy. *Conservation Biology* 13: 774-783.

This is Contribution No. 150 of The Institute for Bird Populations.