MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS): A SHARP, RATHER THAN BLUNT, TOOL FOR MONITORING AND ASSESSING LANDBIRD POPULATIONS

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Abstract. Information on avian population trends derived from survey data traditionally has been the major tool used to monitor large-scale, long-term changes in avian populations, and to assess both habitat quality and the responses of birds to both management practices and natural and human-caused environmental changes. Data on population trends alone, however, cannot provide the critical information needed to test competing hypotheses regarding the causes of observed population changes, or even to determine the stage(s) in the life cycle at which the changes are taking place. Moreover, population density may not correlate well with either productivity or survivorship, and thus, may inaccurately assess both habitat quality and the response of avian populations to management practices or environmental changes. Because populations of many landbird species (particularly neotropical migrants) are declining (Robbins et al. 1989), and because Earth's biosphere and its landbird populations are facing a growing number of global environmental threats of ever increasing severity (Brown 1991), an additional tool for accurately assessing changes in avian productivity and survivorship is critically needed. The Monitoring Avian Productivity and Survivorship (MAPS) program has been designed to fill this need. It is a cooperative effort among North American bird banders that utilizes constant-effort mist netting and banding during the breeding season at a continent-wide network of stations. For target landbird species, the MAPS program provides annual, regional indices of post-fledging productivity from the number and proportion of young birds captured, and annual, regional estimates of adult survivorship, recruitment into the adult population and adult population size from capture-recapture data on adult birds. The MAPS program was established in 1989 and 1990 when 17 and 38 stations, respectively, were operated across the continent. Post-fledging productivity in 1990, as determined by the number of young birds captured, decreased significantly ($P < 0.02$) from 1989 by an average of 32.8% at the 10 stations operated in both years. Because this measure of productivity previously has been shown to be highest in years of relatively "average" weather conditions and to decrease markedly in years of extreme weather conditions (DeSante and Geupel 1987), and because 1990 was a year of extreme weather conditions across the continent (and the year of the highest average global

temperature on record), it is suggested that the productivity data from these 10 MAPS stations may be representative of trends across the continent.

INTRODUCTION

It is becoming increasingly apparent that Earth's biosphere, and its landbird populations, are facing a growing number of environmental threats of ever increasing severity. Many of these threats are truly global in scale. They include accelerating habitat loss from the deforestation and fragmentation of tropical and temperate forest ecosystems, the desertification of scrub and savanna ecosystems, and the degradation of riparian ecosystems; global climate change due to the atmospheric accumulation of greenhouse gases; loss of stratospheric ozone due to chlorofluorocarbon pollution of the atmosphere; and toxic pollution of aquatic and terrestrial ecosystems from acid rain, industrial and agricultural wastes, and low-level radiation (Brown 1991). Indeed, the human species seems to have embarked upon a global ecological experiment, the ramifications of which may challenge the greatest rates of avian extinction and the fastest rates of avian range change ever recorded in the fossil record. Unfortunately, the scientific community has barely begun to put into place effective means for recording the data from this experiment. Clearly, a continuing and comprehensive program of avian monitoring is justified.

It is not surprising, therefore, that several large-scale, long-term monitoring programs for landbirds are already in place in North America. They include the North American Breeding Bird Survey, the Breeding Bird Census and Winter Bird Population Studies, and the Christmas Bird Counts. All of these efforts provide annual estimates of population trends for landbirds, and some of the resulting trends are pointing to serious and accelerating declines in many species of landbirds, particularly forest-inhabiting, neotropical migrant species in eastern North America (Robbins et al. 1989, Terborgh 1989).

None of the current avian monitoring programs, however, provides data on the productivity or survivorship of landbirds. Without these critical data, it is difficult, if not impossible, to test competing hypotheses to account for observed population changes, or to determine whether the population changes are being driven by causal agents that affect birth rates or death rates or both (Temple and Wiens 1989). In particular, the current avian monitoring programs generally have been unable to determine to what extent deforestation and forest fragmentation on the temperate breeding grounds, versus that on the tropical wintering grounds, are causes for declining populations of neotropical migrant landbirds (Wilcove 1985, Holmes and Sherry 1988, Hutto 1988, Morton and Greenberg 1989). Indeed, without critical data on productivity and survivorship, it is unlikely that effective conservation actions can be identified to assure that additional species of neotropical migrants do not become endangered. A program that can provide accurate annual estimates of landbird productivity and survivorship is, therefore, an urgent necessity.

In addition, most of the current assessments of habitat quality, such as those used in wildlife habitat guidelines, are based upon population size or density. However, these can provide misleading information, particularly if density does not correlate well with either productivity or survivorship so that density alone may not provide an accurate assessment of habitat quality. Results from the Point Reyes Bird Observatory's Palomarin Field Station (D. F. DeSante and G. R. Geupel *unpublished data*) provide an example. Non-migratory Nuttall's white-crowned sparrows (*Zonotrichia leucophrys nuttalli*) attempt to breed at Palomarin in roughly equal abundance in both the undisturbed mature and disturbed successional stage portions of the 36-ha coastal scrub study area. White-crowned sparrow fledging success, however, differs markedly between the two habitats: 1.83 young per nest in undisturbed mature coastal scrub versus only 1.11 young per nest in disturbed successional stage habitat. It appears that populations in disturbed habitats are maintained primarily by immigration from undisturbed habitats. Thus, density alone does not provide an accurate assessment of habitat quality and leads to false predictions of the effects of habitat manipulation. Additional data on productivity are needed to assess the situation correctly.

In response to these needs, The Institute for Bird Populations initiated the MAPS program, a cooperative effort among federal, state, and private agencies and organizations, and among individual bird banders in North America to operate a continent-wide network of constant-effort mist-netting stations to capture and band landbirds during the breeding season. The design of this program was based on previous studies of constant-effort mist netting at a single site in California (DeSante and Geupel 1987) and at a network of sites in Great Britain (Baillie et al. 1986).

The value of constant-effort mist netting at a single station was confirmed by a now 16-year on-going study at the Point Reyes Bird Observatory's Palomarin Field Station, located on the Point Reyes National Seashore. This study elucidated the relationship between the productivity of landbirds and annual rainfall in central coastal California, and documented a massive and unprecedented reproductive failure of most species of landbirds in 1986 (DeSante and Geupel 1987). This study showed also that the apparent driving force behind much of the annual variation in the number of young birds produced at Palomarin between 1976 and 1985 was the amount of annual (winter) rainfall that occurred in this Mediterranean ecosystem. In particular, the numbers of young birds captured reached a maximum in years of relatively average rainfall, and decreased as the annual rainfall either increased or decreased from average levels. Productivity thus tended to be lowest in both very dry years (the 1976-1977 drought) and in very wet years (the 1983 El Niño Southern Oscillation). It is most important to determine whether the relationship of maximum productivity at average weather conditions holds in other landbird communities, and in other areas of the continent.

Constant-effort mist netting and banding at Palomarin also documented a significant decrease in productivity in 1986 when a relatively normal number of adults (91.7 percent of the previous 10 years' mean) produced a very low number of young (only 37.7 percent of the mean of the previous 10 years). Although the cause of the 1986 reproductive failure is not clear, its timing, geographical extent, and the character of species most affected led DeSante and Geupel (1987) to hypothesize that it may have been caused by radioactive fallout of Iodine-131 from the Chernobyl nuclear power plant accident in the former U.S.S.R.

The concept of a network of constant-effort mist-netting stations to monitor the productivity and survivorship of birds over a large geographical area is not really new.

The British have had such a program, the Constant Effort Sites (CES) program, in operation since 1981. In 1986, the CES program was endorsed by the British Trust for Ornithology and made one of the cornerstones of their avian monitoring strategy (Baillie et al. 1986). By 1990, more than 100 constant-effort sites were in operation in Great Britain (Peach and Baillie 1991). Moreover, other constant-effort banding projects are being established in Finland, France, the Netherlands, and Denmark, and are being considered for New Zealand, Australia, Spain, and Israel.

OBJECTIVES AND METHODS

The primary objective of the MAPS program is to provide annual, regional estimates of post-fledging productivity, recruitment into the adult population, adult survivorship, and adult population levels for various common landbirds, including both resident and temperate and neotropical migratory species. A second objective is to provide a means whereby the public can directly participate in conservation efforts for landbirds. Specifically, the MAPS program provides a rigorous framework that encourages bird banders to collect capture-recapture data in a manner that can be used to provide critical information on the survivorship and productivity of landbirds. The third objective of the MAPS program is to utilize protected public lands as critical locations for large-scale, long-term monitoring efforts. The national parks, the Research Natural Areas of the national forests, and other protected natural areas can provide ideal sites for such a network of stations, because they provide large areas of diverse and relatively pristine ecosystems that promise to be protected and maintained indefinitely into the future. The MAPS program thus hopes to forge cooperative partnerships among the federal and state agencies responsible for the stewardship of public lands, those responsible for the conservation and monitoring of living resources, and avian researchers and bird banders of North America, by facilitating the establishment and operation of MAPS stations in protected public areas.

The methodology employed in the MAPS program is a capture-recapture experiment utilizing standardized mist netting and banding during the breeding season. The key species to be considered are those that can be captured in relatively large numbers at several stations in a given region. Key target species are expected to include various flycatchers, chickadees, thrushes, catbirds, vireos, wood warblers, sparrows and finches.

To facilitate analysis of data, the North American continent (north of Mexico) has been divided into eight major regions based on both practical and biogeographic considerations, as well as on the average location and apparent east-west periodicity of the jet stream (Fig. 1). The long-term goal for the MAPS program is the operation of about 260 stations, about 40 in each of the six more southerly regions of the continent and about 20 in Alaska (no stations are expected to be established in the Boreal and Arctic Canada region).

The assumption of the MAPS methodology (and of the British CES effort) is that significant changes in population parameters between a given pair of years or over a longer time period will tend to be similar for a given species at many banding stations

Annual indices of post-fledging productivity are calculated for each species at each station by the number and proportion of young birds in the catch. The statistical significance of regional annual changes in productivity are inferred from confidence intervals calculated from the standard errors of the mean percentage change in productivity indices for each species captured at several stations within the region. This analytical method, although rather ad-hoc, has been successfully applied to constant-effort mist-netting data from the British CES program (Baillie et al. 1986, Peach and Baillie 1991).

RESULTS AND DISCUSSION

A total of 41 MAPS stations were established and operated for at least one year during either 1989 and 1990: 16 stations in the Northeast, 9 in the North-Central, 8 in the Northwest, 4 in the Southeast, and 2 each in the South-Central and Southwest regions (DeSante 1991). Virtually all of the 41 stations were established in forest or woodland habitats, although 28 of the stations (68%) contained at least some riparian, meadow or scrub habitat. Study areas ranged from 2.5 to 19.6 ha and averaged 8.5 ha. The number of nets utilized ranged from 5 to 57 and averaged 12.5 nets per station. The number of nets per ha ranged from 0.6 to 4.3 and averaged 1.6.

Seventeen MAPS stations were operated in 1989 for a mean of 20.3 total days each and with a mean total effort of 1617 net-hours. They recorded a mean of 41.3 captures per 100 net-hours and a mean of 31.1 species. The MAPS program expanded substantially in 1990 when 38 stations were operated for a mean of 21.8 total days and with a mean total effort of 1720 net-hours. They recorded a mean of 38.3 captures per 100 net-hours and a mean of 31.6 species. These totals do not include gamebirds or hummingbirds that many banders do not have permission to band.

Because three years of data are required to calculate initial values for capture probability, adult survivorship, and adult population size, and four years of data are required for an initial value for recruitment into the adult population (Pollock et al. 1990), no results regarding these parameters are yet available from the MAPS program. Preliminary estimates of capture probability and adult survivorship, however, were obtained from an analysis of data from a single "minimum-effort" MAPS station operated by Dennis Vromen in 1989 and 1990 (and in a roughly similar manner in 1987) at Horse Creek Meadow in the Siskiyou National Forest in southern Oregon. From data on the capture history of each bird banded at the station, maximum likelihood estimates of the capture probability and the annual adult survival rate for all individuals of all species combined were calculated according to the methods described by Pollock et al. (1990). These values, 0.33 ± 0.11(SE) for capture probability and 0.57 ± 0.17(SE) for adult survival rate, were quite comparable to values calculated from longer term capture-recapture studies of passerine birds (Loery et al. 1987, Pollock et al. 1990). The computer program CAPQUOTA, based on the models of Jolly (1965) and Pollock (1981), was then used to output the expected coefficients of variation (C.V.) of adult survival rate for various specified population sizes for a 10-year study having a capture probability of 0.33 and an adult survival rate of 0.57. These results, coupled with data from the other 1989 MAPS stations, suggest that the establishment of about 40 stations in a region will generate sufficient data for some 12 to 18 target landbird species, including both resident and neotropical migratory species. Further, the resulting estimates of population parameters will have adequate precision (a C.V. for mean annual survival rate of about 0.05 and a C.V. for the mid-year annual survival rate of about 0.20) to provide critically useful information. Moreover, because the average MAPS station is expected to involve more effort, the actual capture probabilities may be substantially greater than the value of 0.33 determined from this single "minimum-effort" station.

Despite the fact that capture-recapture analyses cannot be undertaken without three years of data, the total number of adult birds captured each year can provide an annual index of the adult population size, and the number and proportion of young birds captured each year can provide annual indices of productivity, provided that the data are standardized by effort. It is important to understand that data on the number and proportion of young in the catch do not provide absolute values for the productivity of any species, because adults and young are not necessarily sampled by mist nets in proportion to their actual abundances. The data do, however, provide accurate indications of year-to-year (or longer) *changes* in productivity for a given species, and do provide accurate comparisons of year-to-year changes in productivity among species or among stations, provided that each station is operated in a relatively constant-effort manner from year to year.

Constant-effort data on the numbers of adult and young birds captured per 100 net-hours and on the proportion of young in the catch were obtained for 1989 and 1990 from ten MAPS stations (Table 1). It should be noted that the widely different values between stations in the number of birds captured per 100 net-hours and in the proportion of young in the catch are due to widely different netting regimes rather than to actual differences in the densities or productivities of birds. The annual changes in these parameters are what are meaningful and important. Following the procedures developed for the British CES program (Baillie et al. 1986), the statistical significance of the annual changes in the numbers of adults and young and in the proportion of young in the catch were inferred from confidence intervals calculated from the standard errors of the mean percentage change in each population parameter for the ten stations.

In general, the number of adults captured per 100 net-hours decreased between 1989 and 1990 at the more westerly stations and increased at the more easterly ones. Most of these changes, however, were relatively small, usually less than about 25%. The overall combined change in the number of adults was a decrease of only 3.0% between 1989 and 1990. This decrease was not statistically significant.

In contrast, however, the number of young birds captured per 100 net-hours decreased substantially between 1989 and 1990 across most of the continent. Decreases ranging from 21.6% to 74.5% were recorded at seven of the ten stations, while increases of less than 6.0% were recorded at the other three stations. The overall combined decrease of 32.8% in the number of young birds captured was statistically significant ($P < 0.02$).

A similar change was also evident in the percentage of young, which decreased at seven stations by amounts ranging from 3.2% to 17.9%, and increased at the remaining three stations by 3.1% or less. The overall combined change in the percentage of young was a decrease of 9.0% from 42.6% young in 1989 to 33.6% in 1990. The decreased

TABLE 1. Changes from 1989 to 1990 in the number of birds captured, and in the percentage of young in the catch at ten MAPS stations across North America.

	Number of birds captured per 100 net-hours								
	Adults			Young			Percentage of young		Change in percentage
St[1]	1989	1990	% change	1989	1990	% change	1989	1990	of young
Northwest									
A	16.9	12.7	-25.3	8.6	5.6	-35.4	33.7	30.5	-3.2
B	52.2	49.2	-5.8	60.6	31.7	-47.7	53.7	39.2	-14.5
C	3.5	3.1	-11.6	6.0	6.1	+ 1.0	63.2	66.3	+ 3.1
North-central									
D	26.4	25.3	- 4.2	19.0	20.1	+ 6.0	41.8	44.3	+ 2.5
E	13.9	15.3	+10.0	5.1	3.3	-34.6	26.6	17.7	- 8.9
F	9.1	11.3	+24.6	3.3	1.1	-67.6	26.5	8.6	-17.9
G	20.5	15.4	-24.7	12.4	9.7	-21.6	37.7	38.7	+ 1.0
Northeast									
H	7.4	8.0	+ 7.8	1.1	0.6	-42.2	12.9	7.3	- 5.6
I	10.6	12.8	+20.8	3.3	0.8	-74.5	23.5	6.1	-17.4
South-central									
J	7.2	9.7	+34.1	3.1	3.2	+3.6	29.9	24.7	- 5.2
T[2]	167.8	162.8	- 3.0	122.3	82.2	-32.8	42.6	33.6	- 9.0
SE[3]			4.9			10.4*			6.7

[1] Stations: A. Seventeen Mile creek, MT, mixed coniferous forest, montane meadow; B. Siskiyou National Forest, OR, mixed conifer-hardwood forest, montane meadow; C.Point Reyes Bird Observatory, CA, mixed evergreen forest, coastal shrub; D. Beaverhill Bird Observatory, AB, aspen parkland; E. Crow Wing, MN, northern hardwood forest, riparian; F. Schlitz Audubon Center, WI, mixed wooded "islands" in grassland; G. Rogers City, MI, aspen-cedar woodland, brush; H. Hubbard Brook Experimental Forest, NH, northern hardwood forest; I. Mount Moosilauke, NH, northern hardwood forest; J. Driftwood Wildlife Association, TX, oak-juniper and riparian woodlands.

[2] Totals

[3] Standard error of the total change; * Statistically significant: $P < 0.02$

trend in proportion of young in the catch, however, was not statistically significant, presumably because of the small sample size of ten stations.

I suggest, however, that the significant decrease in the number of young birds captured and the decreasing trend in the proportion of young in the catch indicates a real and widespread decrease in productivity in 1990 as compared to 1989 across the continent. This decrease in productivity may have been related to extremes in weather conditions that characterized the spring and early summer of 1990 across North America, when severe droughts were recorded over much of the West and locally excessive rainfall occurred over much of the East.

I also suggest that the weather extremes of 1990 may themselves have resulted from the high global temperature that characterized 1990 (now established as the hottest year ever recorded), and further suggest that an important result of global warming may well be a redistribution of moisture regimes in such a way that markedly higher or lower precipitation than usual will be characteristic of most temperate zone localities. If this is in fact the case, and if the lowering of productivity by unusual weather is a general phenomenon, then we should expect that years of high global temperature would also be years of notably low landbird productivity over much of the temperate zone. In this respect it is noteworthy that six of the seven warmest years on record occurred during the decade between 1981 and 1990. Perhaps the documented decreases in landbirds during the past decade may be attributed at least partially to reduced productivity associated with abnormal weather. Given the few data, these relationships remain speculative.

The paucity of data itself, however, underscores the importance of continuing and expanding programs that estimate demographic parameters in landbirds. The data presented here suggest that the MAPS program can provide critically needed information on the productivity and survivorship of target species that will aid in the identification of the stage(s) in the life cycle at which population changes are taking place, and that will thus assist in identifying the causes of recently observed population decreases in landbirds. The MAPS program should play a major role in conserving avian diversity in North America.

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