THE 2002 ANNUAL REPORT OF THE MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) PROGRAM ON CAPE COD NATIONAL SEASHORE

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EXECUTIVE SUMMARY

Overview

Since 1989, The Institute for Bird Populations has coordinated the MAPS (Monitoring Avian Productivity and Survivorship) Program, a cooperative effort among public and private agencies and individual bird banders in North America, to operate a continent-wide network of constant-effort mist-netting and banding stations. The purpose of MAPS is to provide annual indices of adult population size and post-fledging productivity, as well as estimates of adult survivorship and recruitment into the adult population, for various landbird species. Broad-scale data on productivity and survivorship are not obtained from any other avian monitoring program in North America and are needed to provide crucial information upon which to initiate research and management actions to reverse the well-documented declines in North American landbird populations. The system of national parks provides a group of ideal locations for this large-scale, long-term biomonitoring, because they contain large areas of breeding habitat for year-round resident and both short-distance and Neotropical migratory landbirds that are subject to varying local landscape-related and global climate-related effects.

A second objective of MAPS is to provide standardized population and demographic data for the landbirds found on federally managed public lands, such as national parks and seashores, national forests, and military installations, as part of Long-Term Ecological Monitoring Programs established on many of these federal lands. It is expected that information from MAPS will be capable of aiding research and management efforts within the parks and other federal lands to protect and enhance the parksô and other landsô avifauna and ecological integrity.

A third objective of MAPS is to model vital rates (productivity and survivorship) of landbirds as a function of both station-specific and landscape-level habitat variables, such as total cover of various forest types, mean forest patch size, and total amount of forest edge. The detection of relationships between vital rates and such habitat variables can lead to formulation and implementation of appropriate management actions within a national park or seashore, especially for species where MAPS data suggest that declines are related to local (e.g., productivity) rather than remote (e.g., overwintering survival in Neotropical migrants) factors.

Adult Population Sizes and Productivity in 2002

The Institute for Bird Populations operated six MAPS stations in 2002 on Cape Cod National Seashore, at the same locations at which they were operated in 1999-2001. With few exceptions, the ten net sites per station were operated for six morning hours per day on one day per 10-day period for seven consecutive 10-day periods between May 31 and August 8, 2001. A total of 2324.7 net-hours were accumulated during the summer of 2001, during which 288 captures of 24 species were recorded. Newly banded birds comprised 70.5% of the total captures.

The greatest number of total captures was recorded at the Nauset School station (72), followed in descending order by Marconi Beach (52), Blueberry Hill (47), Higgins House (44), Longnook Beach (40), and Oak Dunes (33). The highest species richness was recorded at Nasuet School (15 species) and the lowest species richness was recorded at Blueberry Hill, Higgins House, and

Marconi Beach (10 species each). Overall, the most abundant breeding species at the six Cape Cod MAPS stations in 2002 (as based on adults captured per 600 net-hours), in decreasing order, were Black-capped Chickadee, Pine Warbler, Chipping Sparrow, Hermit Thrush, American Goldfinch, Common Yellowthroat, Ovenbird, and Tufted Titmouse. The index of productivity, as determined by the percentage of young in the catch, varied from 0.30 at Nauset School, followed by 0.18 at Longnook Beach and Blueberry Hill, 0.16 at Marconi Beach, 0.10 at Higgins House, and 0.04 at Oak Dunes.

Adult population size for all species pooled for all stations combined in Cape Cod National Seashore decreased between 2001 and 2002 by a non-significant -12.8%. The number of young birds captured also showed a non-significant decrease of -27.6% between 2001 and 2002. Productivity (the proportion of young in the catch) in 2002 also decreased non-significantly by an absolute value of -0.029, from 0.209 in 2001 to 0.180 in 2002. These decreases were opposite of changes between 2000 and 2001, when all three parameters increased. Indeed, this continues an alternating pattern noted in last yearǿs report: both adult population size and productivity tended to be high in 1999, low in 2000, higher in 2001, and lower in 2002. No strong patterns emerged as to effects of habitat or housing density on changes between 2001 and 2002, indicating a region-wide influence of some sort on between-year changes in population size and productivity.

We have found that adult populations of all species pooled at many MAPS locations show a two-year alternating pattern population sizes and productivity. In most of these cases, however, the two-year alternating patterns of population size and productivity are out phase with each other, that is, productivity increases in one year and population size increases the next year. We interpret these patterns to be caused by density-dependent productivity coupled with low productivity of first-time breeders. That indices of adult population size and productivity appear to alternate together at the Cape Cod National Seashore in a two-year pattern of increases and decreases, suggests that landbird populations on Cape Cod might not be regulated by density-dependent productivity, and that the populations may not be saturated. Such a situation may be typical of sub-optimal habitats where low productivity may be independent of density. If this is the case at Cape Cod National Seashore, we have no explanation as to why the habitat is poorer every other year.

Mean Indices of Adult Population Size and Productivity and Variation Among Stations and Habitats

Overall, total species richness, mean annual indices of adult population size, and mean annual productivity all appear to be low on Cape Cod National Seashore compared to other MAPS locations. Based simply on four-year means, mean annual numbers of adults of all species pooled captured at the two pitch pine stations were highest, followed by the two oak forest stations and the two mixed pine-oak stations. These univariate analyses also showed higher mean annual numbers of adults in habitats with sparse rather than dense understories, and with higher rather than lower housing density. Multivariate ANOVA analyses on all species pooled showed the same pattern as univariate analyses with respect to understory. Indeed, mutivariate analyses showed that habitats with sparser understories had significantly more adults than habitats with denser understories. Multivariate analyses on all species pooled, however, showed strikingly different patterns than univariate analyses with respect to habitat (canopy type) and housing density, with adult population sizes tending to be highest in oak forest, followed by pine-oak and pitch pine habitats, and with adult populations tending to be slightly higher in low than in high density housing. None of these multivariate differences were significant, however.

The reason for the pronounced differences between the univariate and multivariate results was that both oak forest stations had dense understories, in which population sizes tend to be low, while both pitch pine stations had sparse understories, in which population sizes tend to be high. Similarly, the three high housing density stations had a higher mean annual population size than the three lower housing density stations because two of the three high density stations had sparse understories. These results show the value of multivariate analyses that assess differences for a given variable after adjusting for the confounding effects of other variables.

Multivariate ANOVA analyses of adult population size for the 11 individual target species generally produced patterns that were in agreement with known life history traits and habitat preferences for the species. In particular, significantly or near-significantly higher adult population sizes were found in oak than in pitch pine forest for Tufted Titmouse, Gray Catbird, and Ovenbird, all of which are known to prefer oak forest or, at least, deciduous forest over pine forest. In contrast, significantly or near-significantly higher adult population sizes were found in pitch pine than in oak forest for Pine Warbler and Chipping Sparrow, again in agreement with known habitat preferences for these species. Two species, Tufted Titmouse and Gray Catbird, also showed significantly or near-significantly higher adult population sizes in sparse rather than dense understories, a perhaps expected result for titmouse but unexpected for catbird.

In contrast to the situation for adult population sizes, patterns of mean annual productivity of all species pooled did not differ between univariate and multivariate analyses. This was because productivity for all species pooled did not vary significantly or near-significantly as a function of any environmental variable. The only significant or near-significant relationship found for any individual species was that productivity for Black-capped Chickadee was lower in oak forest habitat than in either pine-oak or pitch pine habitat, primarily because of the very low productivity at the Oak Dunes station. Interestingly, the Oak Dunes station also had the lowest productivity for all species pooled, although the difference in productivity from the reference station (Longnook Beach -- also in oak forest) was not significant or near significant.

The fact that species richness, total population size, and productivity of landbirds all tend to be low on Cape Cod National Seashore compared to other MAPS locations provides additional evidence to suggest that landbird habitat on Cape Cod National Seashore may be sub-optimal. Furthermore, that the annual decreases and increases in population size and productivity appear to be independent of canopy type, understory, and housing density, and that productivity itself appears not be dependent on any of these variables, suggests that none of these variables *per se* is causing the sub-optimal nature of the habitat. Rather, the generally poor habitat may be a geographic result of the narrow peninsular nature of Cape Cod, a geographic characteristic similar to islands that tends generally to lead to low species richness. It is possible that the low species richness, population sizes, and productivity of landbirds on Cape Cod National Seashore relate to a low diversity and abundance of their arthropod food resources. It will be interesting to see whether or not results of terrestrial arthropod monitoring on Cape Cod National Seashore support this hypothesis.

Survival Rates of Landbirds on Cape Cod National Seashore

Using four years of data, we were able to obtain estimates of adult survival and recapture probabilities and proportions of residents for seven of the 11 target species breeding on the Cape Cod National Seashore. The mean annual adult survival-rate estimate of 0.681 was relatively high compared to other MAPS stations, with estimates for all of the seven species except Pine Warbler being greater than 0.65, in itself a high survival rate for landbirds. Several species with notably high (Gray Catbird, Chipping Sparrow) or low (Pine Warbler) survival estimates had low precision (high coefficients of variation) indicating that the high or low survival estimates may be biased high or low. The mean coefficient of variation of the annual adult survival-rate estimate for the seven species was 36.4%, as compared with a mean of 51.0% for the three species for which survival rates could be obtained from three years (1999-2001) of data, thus indicating a substantial improvement in both number of species and in precision as a result of the additional year of data. Up to ten years of MAPS data from other locations and simulations of additional years suggest that maximum precision of survival estimates will not occur until about 12 years of data have been collected. Obviously, additional years of data will be necessary to provide survival-rate estimates with more precision and to investigate time-dependence in survival.

Landbird Population Trends on Cape Cod National Seashore and Their Possible Causes

Population trends for seven (American Robin, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the 11 target species on Cape Cod National Seashore and all species pooled showed substantial decreases over the four years 1999-2002. By contrast just two species (Black-capped Chickadee and Hermit Thrush) showed substantial increases. The annual percentage change for all species pooled was -3.7%. Interestingly, the declining species included both resident and migratory species. Productivity trends for four (Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee) of the 11 target species also showed substantial decreases and only two species (Hermit Thrush and American Robin) showed substantial increases in productivity. The productivity trend for all species pooled was slightly negative (-0.002). Although four years is a minimal time period to estimate population trends, these results suggest that both population sizes and productivity are declining at Cape Cod.

A look at environmental variables (habitat, housing density, etc.) based on multivariate ANOVAs showed no conclusive patterns among either declining or increasing species. Examination of productivity and survival values, however, indicates that low productivity may be more of a factor than low survival in the declines of Gray Catbird, Ovenbird, and Common Yellowthroat, whereas low survival as well as low productivity may be influencing the decline of Pine Warbler. Survival estimates were not available for the other three declining species, American Robin, Eastern Towhee, and American Goldfinch; however, productivity values were low to moderately low for all three species. Indeed, productivity values in general were extremely low on Cape Cod as compared to other MAPS stations and may indicate that Cape Cod is a ñpopulation sinkò (an area of low productivity wherein populations can only be maintained by recruitment from elsewhere) for these species. Moreover, all four of the declining species with low productivity (Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee) also showed substantially declining productivity trends, suggesting that the problem will worsen. Both of the increasing species (Black-capped Chickadee and Hermit Thrush) showed high survival, and productivity for Black-capped Chickadee was also quite high; neither species showed a declining productivity trend. Thus, it appears that low and declining productivity has been more of an influence in the general declines seen at Cape Cod than low survival, indicating that the problems may be occurring on the Seashore rather than on migration or the wintering grounds.

We must emphasize, however, that the population trends, productivity trends, and survival-rate estimates presented here are based on only four years of data. Thus, the short-term patterns identified may not be representative of the actual long-term, large-scale population dynamics. Moreover, the indices and estimates of primary demographic parameters presented here have relatively low precision and statistical power because of the limited number of years of data. This, of course, will improve dramatically as more years of data accumulate at Cape Cod.

Future Analyses

Using nine or ten years of data from other MAPS stations, we have been able to initiate three broad-scale analyses to help us further understand the population dynamics of landbirds and to allow us to identify potential management actions to reverse population declines and maintain stable or increasing populations. First, we have found significant relationships between global climate cycles (such as the El Niño/Southern Oscillation and the North Atlantic Oscillation) and productivity in a number of areas of North America. In particular, we have found that productivity of Neotropical-wintering migratory landbirds in the Pacific Northwest was strongly related to the mean monthly El Niño/Southern Oscillation Precipitation Index (ESPI) in such a manner that productivity averaged higher during El Niño conditions (such as those in 1998) than during La Niña conditions (such as those in 1999).

Second, by modeling spatial variation in vital rates as a function of spatial variation in population trends, we are beginning to determine the proximate demographic causes of population trends for species at multiple spatial scales. We found, for example, that adult survival-rate estimates for Gray Catbird populations varied appropriately between areas of increasing vs. decreasing population trends while productivity indices were independent of area, suggesting that low survivorship was driving the declining populations in this species. Third, by modeling demographic parameters as a function of landscape-level habitat characteristics, we have found that patterns of landscape structure, as detected within a two- to four-kilometer-radius area of each station, are good predictors not only of the numbers of birds of each species captured but, more importantly, of their productivity levels as well. Such work has revealed the existence of threshold values of critical habitat characteristics, such as mean forest patch size, above which productivity levels could be maximized, thus providing an extremely powerful tool to identify and formulate management actions aimed at increasing landbird populations. These studies have shown that the indices and estimates of primary demographic parameters produced by MAPS are extremely useful for the management and conservation of landbirds at specific locations and, in combination with similar data from other areas, across all of North America.

With additional funding from a variety of sources, we hope to undertake each of the above three analyses with nine or ten year of data from Cape Cod National Seashore as well as data from other MAPS stations operated in northeastern United States and along the Atlantic Coast. We also hope to include estimates of juvenile recruitment and indices of first-year survival in future analyses in order to fully understand what parameters are most affecting population changes in each target species.

Conclusions

Although Cape Cod MAPS stations have been operated for only four years, important data have been gathered on breeding populations and productivity for a number of summer resident landbird species on the seashore. With four years of data, we are now able to provide population and productivity trends, provide estimates of annual adult survival rates, recapture probabilities, and proportions of residents among newly marked adults for seven species with increased precision using the transient model, and begin preliminary analyses into the causal factors leading to declining trends on the Seashore.

Additional years of data will substantially increase the precision and accuracy of survival estimates and population and productivity trends obtained from the Cape Cod MAPS program as well as the power of our multivariate analyses that aim to relate population size and productivity to year and local habitat variables. Moreover, with more years of data, we will be able to analyze the effects of climatological and landscape variables on breeding populations, productivity, and survival on Cape Cod National Seashore. In particular, we will be able to integrate these variables into our constant-effort year-to-year comparisons, long-term trends in population size and productivity, and estimates of adult survival, capture probability, and proportion of residents. In addition, by including data from stations operated outside of the Cape Cod National Seashore, we will be able to make comparison between Cape Cod and other Atlantic coastal parks that may participate in the MAPS program in the future, as well as comparisons between Cape Cod and other unprotected areas along the Atlantic coast. Finally, MAPS data from Cape Cod National Seashore will be pooled with MAPS data from outside the seashore to provide regional and continental indices and estimates of (and longer-term trends in) these key demographic parameters.

The long-term goal for the Cape Cod MAPS program is to continue to monitor the primary demographic parameters of Cape Cod =s landbirds in order to provide critical information that can be used to aid our understanding of the ecological processes leading from environmental stressors to population responses. When we have at least ten years of data from the Cape Cod National Seashore, and appropriate funding for additional analyses has been secured, we will use these data, along with other data from elsewhere along the Atlantic Coast, in an attempt to: (1) determine the proximate demographic factors (i.e., productivity or survivorship or both) causing observed population trends of the various target species by modeling spatial variation in their productivity indices and survival rate estimates as a function of spatial patterns in their population trends; (2) link MAPS data with landscape-level habitat data and spatially explicit weather data in a geographical information system (GIS) in order to identify and describe relationships between landscape-level habitat and/or weather characteristics and the primary demographic responses (productivity and survival rates) of the target species; (3) generate hypotheses regarding the ultimate environmental causes of the population trends; and (4) identify and formulate generalized management guidelines and specific management actions for habitat and use-related issues on the seashore and in other Atlantic coastal parks and lands.

We conclude, therefore, that the MAPS protocol is very well-suited to provide one component of Cape Cod's long-term ecological monitoring program and can provide critical data to aid in resolving problems associated with declining landbird populations along the Eastern Seaboard. Thus, we recommend continuing the MAPS program on the Seashore in perpetuity into the future, as has been recommended at several other national parks, or at least for the five additional years (2004-2008) needed to allow us to initiate the analyses outlined above.

INTRODUCTION

The National Park Service (NPS) has been charged with the responsibility of managing natural resources on lands under its jurisdiction in a manner that conserves them unimpaired for future generations. In order to carry out this charge, the NPS is implementing integrated long-term programs for inventorying and monitoring the natural resources in national parks, national seashores, and other NPS units. Pilot programs to develop and evaluate field and analytical techniques to accomplish these objectives have been implemented in national parks across the United States. The goals of these pilot programs are to develop: (1) quantitative sampling and analytical methods that can provide relatively complete inventories and long-term trends for many components of biological diversity; and (2) effective means of monitoring the ecological processes driving the trends (Van Horn et al. 1992). An additional goal is that the methods evaluated be useful in other NPS units across the United States. These programs are referred to as Long-term Ecological Monitoring (LTEM) Programs, and include the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore (Roman and Barrett 1999).

The development of effective long-term ecological monitoring programs in national parks and seashores can be of even wider importance than aiding the NPS in managing its resources. Because lands managed by the NPS provide large areas of relatively pristine ecosystems that promise to be maintained in a relatively undisturbed manner indefinitely into the future, studies conducted in national parks and seashores can provide invaluable information for monitoring natural ecological processes and for evaluating the effects of large-scale, even global, environmental changes. The national parks, seashores, and other NPS units can also serve as critical control areas for monitoring the effects of relatively local land-use practices. Thus, long-term monitoring data from the national parks and seashores can provide information that is crucial for efforts to preserve natural resources and biodiversity on multiple spatial scales, ranging from the local scale to the continental or even global scale.

Landbirds

Because of their high body temperature, rapid metabolism, and high ecological position on most food webs, landbirds are excellent indicators of the effects of local, regional, and global environmental change in terrestrial ecosystems. Furthermore, their abundance and diversity in virtually all terrestrial habitats, diurnal nature, discrete reproductive seasonality, and intermediate longevity facilitate the monitoring of their population and demographic parameters. It is not surprising, therefore, that landbirds have been selected by the NPS to receive high priority for monitoring. Nor is it surprising that several large-scale monitoring programs that provide annual population estimates and long-term population trends for landbirds are already in place on this continent. They include the North American Breeding Bird Survey (BBS), the Breeding Bird Census, the Winter Bird Population Study, and the Christmas Bird Count.

Analyses of data from the BBS suggest that populations of many landbirds appear to be in serious decline (Peterjohn et al. 1995). Indeed, populations of most landbird species appear to be declining on a global basis. Nearctic-Neotropical migratory landbirds (species that breed in North America and winter in Central and South America and the West Indies; hereafter, Neotropical migratory birds) constitute one group for which pronounced population declines have been documented (Robbins et al. 1989, Terborgh 1989). In response to these declines, the Neotropical Migratory Bird Conservation Program, "Partners in Flight - Aves de las Americas," was initiated in 1991 (Finch and Stangel 1993). The major goal of Partners in Flight (PIF) is to reverse the declines in Neotropical migratory birds through a coordinated program of monitoring, research, management, education, and international cooperation. As one of the major cooperating agencies in PIF, the NPS has defined its role in the program to include the establishment of long-term avian monitoring programs at NPS units using protocols developed by the Monitoring Working Group of PIF. Clearly, long-term ecological monitoring goals of the NPS and the monitoring and research goals of PIF share many common elements.

The goals of these programs differ, however, in at least one important respect. A major goal of PIF is to reverse population declines, especially in rare or uncommon (although not threatened or endangered) Apriority≅ species, while a major objective of the NPS= LTEM program is to understand the ecological processes driving population changes. This latter goal often necessitates concentrating on relatively common or even abundant species that are undergoing population changes, rather than rare or uncommon ones. Thus, appropriate target species might be expected to differ somewhat between PIF and LTEM efforts.

Primary Demographic Parameters

Existing population-trend data on Neotropical migrants, while suggesting severe and sometimes accelerating declines, provide no information on primary demographic parameters (productivity and survivorship) of these birds. Thus, population-trend data alone provide no means for determining at what point(s) in the life cycles problems are occurring, or to what extent the observed population trends are being driven by causal factors that affect birth rates, death rates, or both (DeSante 1995). In particular, large-scale North American avian monitoring programs that provide only population-trend data have been unable to determine to what extent forest fragmentation and deforestation on the temperate breeding grounds, versus that on the tropical wintering grounds, are causes for declining populations of Neotropical migrants. Without critical data on productivity and survivorship, it will be extremely difficult to identify effective management and conservation actions to reverse current population declines (DeSante 1992).

The ability to monitor primary demographic parameters of target species must also be an important component of any successful long-term inventory and monitoring program that aims to monitor the ecological processes leading from environmental stressors to population responses (DeSante and Rosenberg 1998). This is because environmental factors and management actions generally affect primary demographic parameters directly and these effects usually can be observed over a short time period (Temple and Wiens 1989). Because of the buffering effects of floater individuals and density-dependent responses of populations, there may be substantial time lags between changes in primary parameters and resulting changes in population size or density as measured by census or survey methods (DeSante and George 1994). Thus, a population could be in trouble long before this becomes evident from survey data. Moreover, because of the vagility of many animal species, especially birds, local variations in secondary parameters (e.g., population size or density) may be masked by recruitment from a wider region (George et al. 1992) or accentuated by lack of recruitment from a wider area (DeSante 1990). A successful monitoring program should be able to account for these factors.

Finally, a successful monitoring program should be able to detect significant differences in productivity as a function of such local variables as landscape parameters, habitat disturbance, or predator abundance. The detection of such differences can lead to immediate management implementation within a national park or seashore, especially for species where long-term demographic monitoring suggests that declines are related to local (e.g., productivity) rather than remote (e.g., overwintering survival in Neotropical migrants) factors.

MAPS

In 1989, The Institute for Bird Populations (IBP) established the Monitoring Avian Productivity and Survivorship (MAPS) program, a cooperative effort among public agencies, private organizations, and individual bird banders in North America to operate a continent-wide network of constant-effort mist-netting and banding stations to provide long-term demographic data on landbirds (DeSante et al. 1995). The design of the MAPS program was patterned after the very successful British Constant Effort Sites (CES) Scheme that has been operated by the British Trust for Ornithology since 1981 (Peach et al. 1996). The MAPS program was endorsed in 1991 by both the Monitoring Working Group of PIF and the USDI Bird Banding Laboratory, and a four-year pilot project (1992-1995) was approved by the USDI Fish and Wildlife Service and National Biological Service (now the Biological Resources Division [BRD] of the U.S. Geological Survey [USGS]) to evaluate its utility and effectiveness for monitoring demographic parameters of landbirds. A peer review of the program and of the evaluation of the pilot project was completed by a panel assembled by USGD/BRD (Geissler 1996). The review concluded that: (1) MAPS is technically sound and is based on the best available biological and statistical methods; and (2) it complements other landbird monitoring programs such as the BBS by providing useful information on landbird demographics that is not available elsewhere.

Now in its 14th year (11th year of standardized protocol and extensive distribution of stations), the MAPS program has expanded greatly from 178 stations in 1992 to nearly 500 stations in 2002. The substantial growth of the Program since 1992 was caused by its endorsement by PIF and the subsequent involvement of various federal agencies in PIF, including the NPS, USDA Forest Service, US Fish and Wildlife Service, Department of Defense, Department of the Navy, and Texas Army National Guard. Within the past eight years, for example, IBP has been contracted to operate six MAPS stations on Cape Cod National Seashore, and six in Shenandoah, six in Denali, five in Yosemite, and two in Kings Canyon national parks. MAPS stations were established in these NPS units in order to evaluate the usefulness of the MAPS methodology as a major component of the NPS's Long-Term Ecological Monitoring Programs and, subsequently, to implement its use as part of that program.

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

(B) annual estimates of adult population size, adult survival rates, proportions of residents among newly captured adults, recruitment rates into the adult population, and population growth rates from modified Cormack- Jolly-Seber analyses of 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) identify thresholds and trigger points to notify appropriate agencies and organizations of the need for further research and/or management actions;

(b) determine the proximate demographic cause(s) of population change;

(c) suggest management actions and conservation strategies to reverse population declines and maintain stable or increasing populations; and

(d) evaluate the effectiveness of the management actions and conservation strategies actually implemented through an adaptive management framework.

The overall objectives of MAPS are to achieve the above-outlined goals by means of long-term monitoring at two major spatial scales. The first is a very large scale X effectively the entire North American continent divided into eight geographical regions. It is envisioned that the national parks, along with national forests, military installations, and other publicly owned lands, will provide a major subset of sites for this large-scale objective.

The second, smaller-scale but still long-term objective is to fulfill the above-outlined goals for specific geographical areas (perhaps based on BBS physiographic strata, such as the Glaciated Coastal Plain, Southern New England, Upper Coastal Plain, or Coastal Flatwoods, or the newly described Bird Conservation Regions) or specific locations (such as individual national parks, national forests, or military installations). The objective for MAPS at these smaller scales is to aid research and management efforts within the parks, forests, or installations to protect and enhance their avifauna and ecological integrity. The sampling strategy utilized at these smaller scales should be hypothesis-driven and should be integrated with other research and monitoring efforts.

Both long-term objectives are in agreement with objectives laid out for the NPS's Long-Term Ecological Monitoring Program. Accordingly, the MAPS program was established in Cape Cod National Seashore as part of the development of Cape Cod=s LTEM Program. It is expected that information from the MAPS program will be capable of aiding research and management efforts within the Seashore to protect and enhance the park's avifauna and ecological integrity.

SPECIFICS OF THE CAPE COD MAPS PROGRAM

Goals

Cape Cod National Seashore is an important breeding and migration stopover site for both resident and migratory landbirds, including many state listed rare species (Cape Cod 1992). Indeed, landbirds have been included as a critical component of Cape Cod=s LTEM (Roman and Barrett 1999). The specific goals for the initial (first five years) operation of the MAPS Program on Cape Cod National Seashore are to:

(1) evaluate the ability and effectiveness of MAPS to provide a useful component of the long-term inventory and monitoring program in Cape Cod National Seashore;

(2) determine the effectiveness of various MAPS stations in Cape Cod National Seashore to provide reliable demographic information on the landbirds of the Eastern deciduous forest environment; and

(3) evaluate differences in adult population size and productivity among stations located in areas of differing habitat type and housing density.

A five-year period has been selected for this initial operation of stations on Cape Cod National Seashore because a minimum of four consecutive years of data are needed to provide unbiased estimates of survival rates from mark-recapture methods using models that account for the presence of transient individuals moving through the populations. In addition, five years will provide a minimum sample of year-to-year variability in avian productivity and population sizes.

MAPS data collected at Cape Cod National Seashore will be used to address questions at three spatial scales. First, at the smallest scale, MAPS data will provide local indices and estimates of productivity at individual stations or groups of stations that can be compared with indices and estimates derived from MAPS data from other stations within the seashore or from stations near to, but outside, the seashore. The MAPS Program in Cape Cod will specifically address two such questions (variation in housing density and habitat) using MAPS data collected in this manner at these local scales. Second, data from all six MAPS stations on Cape Cod can be pooled to provide park-wide productivity indices and survivorship estimates and longer-term trends in these indices and estimates. Pooling data at this level will also allow comparison between Cape Cod National Seashore and other Atlantic coastal parks that may participate in the MAPS program in the future, as well as comparisons between Cape Cod National Seashore and other unprotected areas along the Atlantic coast. Finally, MAPS data from Cape Cod National Seashore can be pooled with MAPS data from outside the park to provide regional (or even continental) indices and estimates of (and longer-term trends in) these key demographic parameters.

Two specific questions regarding adult population size and productivity will be addressed using MAPS data on Cape Cod. First, MAPS data will be used to provide indices of adult population size and productivity for each of: (1) three habitats types based on canopy characteristics (oak forest, mixed pine/oak woodland, and pitch-pine woodland), and (2) two habitat types based on understory categories (dense blueberry understory [>75% lower-layer cover and/or >90% ground cover] and sparse mixed understory [<50% lower-layer cover and/or <60% ground cover]) to determine the differences, if any, between the habitat types. Each habitat supports a different bird community, and as Cape Cod is a highly successional landscape, the possible succession of one type of habitat to another may negatively or positively affect the adult population sizes of each target species and their ability to produce enough young to prevent population declines.

Second, as Cape Cod is located in the densely populated Eastern Seaboard and is a popular location for summer homes, it is important to understand the effects, if any, of high housing density on the adult population sizes of the of target species and their ability to produce adequate numbers of young to prevent population declines. We will examine data from three stations in landscapes where the housing density is greater than 40 houses/km^2 and compare them to data from three stations in landscapes of less than 15 houses/km^2. The information on adult population sizes and productivity that MAPS data can provide will be extremely important for making and implementing management decisions regarding land-use practices and restoration efforts affecting the succession of habitats necessary for breeding landbirds, including declining species.

The appropriate temporal and spatial scales are different for survivorship than for productivity considerations. In contrast to productivity indices, adult survival-rate estimates require three (for non-transient Cormack-Jolly-Seber [CJS] models) or four (for transient CJS models that rely on between-year recaptures to assess residency) consecutive years of data to provide initial estimates of survival rates. In addition, because the adults whose survival rates are estimated by MAPS are the adults that are residents on the study area (at least during summer), MAPS survival-rate estimates are site- or habitat-specific, at least in terms of breeding season survival. However, because survival of migratory individuals may depend primarily upon considerations on their wintering grounds or migratory routes thousands of kilometers away, site-, habitat-, or landscape-specific considerations on the breeding grounds for survivorship may well be moot. Because only a single survival-rate estimate will be produced by pooling data from all six stations on the Seashore, temporal, rather than spatial, considerations become the focus for survivorship analyses.

Examining the variation over time in survival-rate estimates and productivity (as well as indices of adult population size) will allow park biologists to determine the effect that their management actions, or lack thereof, have on the primary demographic parameters of the birds species breeding on Cape Cod. It could also be important to determine characteristics of (and temporal variation in) the weather associated with the landscapes in which stations or clusters of stations are sited. Appropriate local information could include summary data on the mean temperatures and precipitation during the previous winter and spring and current summer, and records of unusual weather events (large storms, high winds, major hot or cold spells, etc.). Important global climate information could include various indices (such as the El Niño/Southern Oscillation Precipitation Index, North Atlantic Oscillation Index, and Pacific Decadal Oscillation Index) that measure long-term (several years or more) global weather cycles. Information on both local and global weather could be included as factors for landscape level analyses, as weather may mask or accentuate the affects of management actions on survival-rate estimates or productivity indices.

These data can be obtained from standardized local weather-data-collection centers operated as part of the Cape Cod long-term ecological monitoring program and from national climate institutes (e.g., NOAA) that monitor global climate phenomena.

The long-term goal for the Cape Cod MAPS program is to continue to monitor the primary demographic parameters of Cape Cod=s landbirds in order to provide critical information that can be used to aid our understanding of the ecological processes leading from environmental stressors to population responses. To achieve this goal, we will first need to analyze spatial patterns in productivity indices and survival rate estimates as a function of spatial patterns in population trends for target species, in order to determine the proximate demographic factor (i.e., productivity or survivorship) causing the observed population trends (DeSante et al. 2001). We will then need to link MAPS data with landscape-level habitat data and spatially explicit weather data in a geographical information system (GIS) to identify relationships between landscape-level habitat and/or weather characteristics and the primary demographic responses (productivity and survival rates) of the target species. This will allow hypotheses to be generated regarding the ultimate environmental causes of the population trends. Successful implementation of this approach will necessitate analyses of MAPS stations from areas larger than just Cape Cod National Seashore. For example, Cape Cod data can be compared to data from relatively pristine ecosystems (e.g., other national parks and seashores) at other locations, and from data in more heavily managed or disturbed ecosystems in eastern North America. Successful implementation of this approach will also require generating the necessary funding to undertake these analyses.

Establishment of Stations

Six MAPS stations were established on Cape Cod National Seashore in 1999. The six stations were arranged into three pairs of stations X each pair was situated in a different canopy habitat type and each pair contained one station in an area of high housing density and one in an area of low housing density. In addition, three of the stations contained dense blueberry understory, whereas the other three stations contained sparse, mixed understory. The six stations were located (according to habitat and housing density) as follows: (1) the Longnook Beach station in oak forest with dense blueberry understory habitat and high housing density at 46 m elevation to the north of Longnook Road near Longnook Beach; (2) the Oak Dunes station in oak forest with dense blueberry understory habitat and low housing density at 30 m elevation east of Collins Road to the south of Ballston Beach; (3) the Nauset School station in mixed pine/oak woodland with sparse mixed understory and with high housing density at 15 m elevation south of Cable Road near Nauset Light Beach; (4) the Blueberry Hill station in mixed pine/oak woodland with dense blueberry understory and low housing density at 15 m elevation south of Calhoon Hollow Road near Calhoon Hollow Beach; (5) the Higgins House station in pitch-pine woodland with sparse mixed understory and with high housing density at 15 m elevation north of Wellfleet; and (6) the Marconi Beach station in pitch-pine woodland with sparse mixed understory and with low housing density at 12 m elevation near the National Seashore Headquarters northwest of Marconi Beach.

The 2002 Cape Cod MAPS Program

The 2002 Cape Cod field biologist interns, Wadih Kanaan and Mathew Waltner-Toews, received two weeks of intensive training in a comprehensive course in mist netting and bird-banding techniques given by IBP biologists Blair Hayman, Amy McAndrews, Amy Finfera, and Danielle Kaschube, during the first two weeks of May, 2002, at the Jug Bay Wetland Sanctuary on the shores of the Chesapeake Bay, Maryland. IBP biologist Blair Hayman supervised the 2002 interns for the duration of the fieldwork at Cape Cod. Blair and the two interns arrived on May 30 to re-establish and begin operation of the stations. The six MAPS stations were re-established on Cape Cod National Seashore in 2002 in exactly the same locations where they were established and operated from 1999 through 2001. Data collection at the six stations began during the period June 1-8 (Table 1).

All ten net sites at each station were re-established in the exact same locations as in 1999-2001. One 12m, 30mm-mesh, 4-tier, nylon mist net was erected at each of the net sites on each day of operation. Each station was operated for six morning hours per day (beginning at local sunrise), on one day in each of seven consecutive 10-day periods between Period 4 (May 31-Jun 9) and Period 10 (Jul 30-Aug 8). With very few exceptions, the operation of all stations occurred on schedule in each of the seven 10-day periods. A summary of the operation of the 2002 Cape Cod MAPS Program and the major habitats at each of the six stations is presented in Table 1.

METHODS

The operation of each of the six stations during 2002 followed MAPS protocol, as established for use by the MAPS Program throughout North America and spelled out in the MAPS Manual (DeSante et al. 2002). Detailed protocols specific to Cape Cod are also provided in *The Monitoring Avian Productivity and Survivorship (MAPS) Program at Cape Cod National Seashore* (DeSante 2001) produced for the USGS Patuxent Wildlife Research Center, Cooperative Park Studies Unit at the University of Rhode Island. An overview of both the field and analytical techniques is presented here.

Data Collection

With few exceptions, all birds captured during the course of the study were identified to species, age, and sex and, if unbanded, were banded with USGS/BRD numbered aluminum bands. Birds were released immediately upon capture (before being banded) if situations arose where bird safety would be comprised. Such situations involved exceptionally large numbers of birds being captured at once, or the sudden onset of adverse weather conditions such as high winds or sudden rainfall. The following data were taken on all birds captured and processed, including recaptures, according to MAPS guidelines using standardized codes and forms. :

(1) capture code (newly banded, recaptured, band changed, unbanded);
(2) band number;
(3) species;
(4) age and how aged;
(5) sex (if possible) and how sexed (if applicable);
(6) extent of skull pneumaticization;
(7) breeding condition of adults (i.e., presence or absence of a cloacal protuberance or brood patch);
(8) extent of juvenal plumage in young birds;
(9) extent of body and flight-feather molt;
(10) extent of primary-feather wear;
(11) fat class;
(12) wing chord and body mass;
(13) date and time of capture (net-run time); and
(14) station and net site where captured.

Effort data, i.e., the number and timing of net-hours on each day (period) of operation, were also collected in a standardized manner. In order to allow constant-effort comparisons of data to be made, the times of opening and closing the array of mist nets and of beginning each net check were recorded to the nearest ten minutes. The breeding status (confirmed breeder, likely breeder, non-breeder) of each species seen, heard, or captured at each MAPS station on each day of operation was recorded using techniques similar to those employed for breeding bird atlas projects.

For each of the six stations operated, simple habitat maps were prepared on which up to four major habitat types, as well as the locations of all mist nets, structures, roads, trails, and streams, were identified and delineated. The pattern and extent of cover of each major habitat type identified at each station, as well as the pattern and extent of cover of each of four major vertical layers of vegetation (upperstory, midstory, understory, and ground cover) in each major habitat type were classified into one of twelve pattern types and eight cover categories according to guidelines spelled out in the MAPS Habitat Structure Assessment Protocol, developed by IBP Landscape Ecologist, Philip Nott (Nott et al. 2002a).

Computer Data Entry and Verification

The computer entry of all banding data was completed by John W. Shipman of Zoological Data Processing, Socorro, NM. The critical data for each banding record (capture code, band number, species, age, sex, date, capture time, station, and net number) were proofed by hand against the raw data and any computer-entry errors were corrected. Computer entry of effort and vegetation data was completed by IBP biologists using specially designed data entry programs. All banding data were then run through a series of verification programs as follows:

(1) Clean-up programs to check the validity of all codes entered and the ranges of all numerical data;
(2) Cross-check programs to compare station, date, and net fields from the banding data with those from the summary of mist netting effort data;
(3) Cross-check programs to compare species, age, and sex determinations against degree of skull pneumaticization, breeding condition (extent of cloacal protuberance and brood patch), and extent of body and flight-feather molt, primary-feather wear, and juvenal plumage;
(4) Screening programs which allow identification of unusual or duplicate band numbers or unusual band sizes for each species; and
(5) Verification programs to screen banding and recapture data from all years of operation for inconsistent species, age, or sex determinations for each band number.

Any discrepancies or suspicious data identified by any of these programs were examined manually and corrected if necessary. Wing chord, weight, station of capture, date, and any pertinent notes were used as supplementary information for the correct determination of species, age, and sex in all of these verification processes.

Data Analysis

To facilitate analyses, we first classified the landbird species found at each station into five groups based upon their breeding or summer residency status. Each species was classified as one of the following: a regular breeder (B) if we had positive or probable evidence of breeding or summer residency within the boundaries of the MAPS station *during all years* that the station was operated; a usual breeder (U) if we had positive or probable evidence of breeding or summer residency within the boundaries of the MAPS station *during more than half but not all of the years* that the station was operated; an occasional breeder (O) if we had positive or probable evidence of breeding or summer residency within the boundaries of the MAPS station *during half* *or fewer of the years* that the station was operated; a transient (T) if the species was *never* a breeder or summer resident at the station, but the station was located within the overall breeding range of the species; and a migrant (M) if the station was not located within the overall breeding range of the species. Data for a given species from a given station were included in productivity analyses if the station was within the breeding range of the species; that is, data were included from stations where the species was a breeder (B, U, or O) or transient (T), but not where the species was a migrant (M). Data for a given species from a given station were included in survivorship analyses only if the species was classified as a regular (B) or usual (U) breeder at the station.

A. Population-size and productivity analyses -- The proofed, verified, and corrected banding data from 2002 were run through a series of analysis programs that calculated for each species and for all species combined at each station and for all stations pooled:

(1) the numbers of newly banded birds, recaptured birds, and birds released unbanded;
(2) the numbers and capture rates (per 600 net-hours) of first captures (in 2002) of individual adult and young birds; and
(3) the proportion of young in the catch.

Following the procedures pioneered by the British Trust for Ornithology (BTO) in their CES Scheme (Peach et al. 1996), the number of adult birds captured was used as an index of adult population size, and the proportion of young in the catch was used as an index of post-fledging productivity.

For all six stations we calculated changes between 2001 and 2002 in the indices of adult and young population sizes and post-fledging productivity and determined the statistical significance of any changes that occurred according to methods developed by the BTO in their CES scheme (Peach et al. 1996). These year-to-year comparisons were made in a Aconstant-effort≅ manner by means of a specially designed analysis program that used actual net-run (capture) times and net-opening and -closing times on a net-by-net and period-by-period basis to exclude captures that occurred in a given net in a given period in one year during the time when that net was not operated in that period in the other year. For species captured at several stations in Cape Cod National Seashore, the significance of park-wide annual changes in the indices of adult and young population sizes and post-fledging productivity was inferred statistically using confidence intervals derived from the standard errors of the mean percentage changes. The statistical significance of the overall change at a given station was inferred from a one-sided binomial test on the proportion of species at that station that increased (or decreased). Throughout this report, we use an alpha level of 0.05 for statistical significance, but we also use the terms Anear-significant≅ or Anearly significant≅ for differences for which $0.05 \leq P < 0.10$.

B. Multivariate analyses of adult population size and productivity X We conducted multivariate ANOVAs of indices of adult population size (mean number of adult birds captured), and logistic regression analysis on productivity values, as a function or year, habitat type, housing density, and station. These analyses provide an analytical framework for examining the number of adults captured and productivity in a multivariate manner as a function of year (in multi-year data sets), station, and various environmental variables, including habitat (canopy type), understory type, and housing density class.

We used the ñrelative number of adults,ò the index of adult population size relative to a reference station, as the dependent variable in the ANOVAs, and the "odds ratio" as the dependent variable in the logistic regression analyses. Odds ratio is the term used for the probability of a captured individual being an adult or a young bird, respectively, after the variables incorporated into the model (e.g., year, habitat type, housing density) have been accounted for. If, for example, the odds ratio calculated for a given species from a model incorporating year and two habitat types was 1.2, then the probability, in one habitat type, of a captured individual being a juvenile instead of an adult was 1.2 times as great as in the other habitat type.

Because station, habitat (canopy type), understory type, and housing density class are included in the multivariate ANOVA and logistic regression models as non-continuous variables, the analysis format requires the designation of a reference station or reference group against which the index of adult population size or odds ratios can be compared. For each multivariate analysis, we chose Longnook Beach as the reference station (or, if there were no birds captured there, Marconi Beach), because it produced an intermediate value of productivity when all species were pooled and because data were available from that station for the largest number of individual species. We chose oak as the reference habitat (canopy type), dense blueberry as the reference understory type, and low as the reference housing density class, because we felt these classes represented the most mature and/or natural habitat types of those available. In all cases, we used the current year (2002) as the reference year. For the ANOVAs we set the relative number of adults to be zero for the reference year, environmental variables, and station, while for the logistic regression analyses we set the relative productivity value at 1.0 for each of theses reference states.

Data preparation for the ANOVA and logistic regression analyses were completed using data-management programs in dBASE4. The multivariate analyses themselves were completed using the statistical-analysis package STATA (Stata Corporation 1995). We conducted these multivariate analyses for all species pooled and for each of the 11 target species. Because each station has a unique combination of habitat (canopy type), understory type, and housing density class, we could not also include the variable station in these latter multivariate analyses. Thus, the analyses incorporating station controls only for year as an additional term. Statistical significance in the ANOVAs was determined by mean of the F-statistic. Statistical significance in the logistic regression analyses was determined by means of the z-statistic (or Wald Statistic) that equates to the maximum-likelihood estimate based on the odds ratio divided by the standard error (Stata Corporation 1995).

C. Analyses of trends in adult population size and productivity X We examined four-year (1999-2002) trends in indices of adult population size and productivity for 11 target species for which we recorded an average of seven or more individual adult captures per year from pooled data from all of the six Cape Cod stations at which the species was a regular (B) or usual (U) breeder.

For trends in adult population size, we first calculated adult population indices for each species for each of the four years based on an arbitrary starting index of 1.0 in 1999. Constant-effort changes (as defined above) were used to calculate these Achain≅ indices in each subsequent year by multiplying the proportional change (percent change divided by 100) between the two years times the index of the previous year and adding that figure to the index of the previous year, or simply:

$$PSI_{i+1} = PSI_i + PSI_i * (d_i/100)$$

where PSI_i is the population size index for year i and d_i is the percentage change in constant-effort numbers from year i to year i+1. A regression analysis was then run to determine the slope of these indices over the four-years (*PT*). Because the indices for adult population size were based on percentage changes, we further calculated the annual percent change (*APC*), defined as the average change per year over the four-year period, to provide an estimate of the population trend for the species; *APC* was calculated as:

(actual 1999 value of *PSI* / predicted 1999 value of *PSI* based on the regression) * *PT*.

We present *APC*, the standard error of the slope (*SE),* the correlation coefficient *(r),* and the significance of the correlation (*P*) to describe each trend. Again, we use an alpha level of 0.05 for statistical significance. For purposes of discussion, however, we use the terms Anearly significant≅ or Anear-significant≅ for trends for which $0.05 \leq P < 0.10$. Species for which $r \geq 0.5$ are considered to have a substantially increasing trend; those for which $r \leq -0.5$ are considered to have a substantially decreasing trend; those for which $-0.5 < r < 0.5$ and $SE \leq 0.219$ (for four-year trends) are considered to have a stable trend; and those for which $-0.5 < r < 0.5$ and $SE > 0.219$ (for four-year trends) are considered to have widely fluctuating values but no substantial trend.

Trends in Productivity, *PrT*, were calculated in an analogous manner by starting with actual productivity values in 1999 and calculating each successive year=s value based on the actual constant-effort changes in productivity between each pair of consecutive years. For trends in productivity, the slope (*PrT*) and its standard error (*SE*) are presented, along with the correlation coefficient *(r),* and the significance of the correlation (*P*). Productivity trends are characterized in a manner analogous to that for population trends, except that productivity trends are considered to be highly fluctuating if the SE of the slope > 0.125 (for four-year productivity trends).

D. Survivorship analyses -- Modified Cormack-Jolly-Seber (CJS) mark-recapture analyses (Pollock et al.1990, Lebreton et al.1992) were conducted on the 11 target species using four years (1999-2002) of capture histories of adult birds. As in the analyses of population and productivity trends and in the ANOVAs and logistic regression analyses, target species were those for which, on average, at least seven individual adults per year were recorded from pooled data from all of the six Cape Cod stations at which the species was a regular (B) or usual (U) breeder. Using the computer program SURVIV (White 1983), we calculated, for each target species, maximum- likelihood estimates and standard errors (*SE*s) for adult survival probability (φ), adult recapture probability (p), and the proportion of residents among newly captured adults (τ) using both a between-year and within-year transient model (Pradel et al. 1997, Nott and DeSante 2002). The use of the transient model ($\varphi p \tau$) accounts for the existence of transient adults (dispersing and floater individuals which are only captured once) in the sample of newly captured birds, and provides survival estimates that are unbiased with respect to these transient individuals (Pradel et al. 1997). Recapture probability is defined as the conditional probability of recapturing a bird in a subsequent year that was banded in a previous year, given that it survived and returned to the place it was originally banded.

Because we had only four years of data, we used a time-constant transient model for estimating survival and recapture probabilities and the proportion of residents among newly captured adults. We did not consider models that included time-dependence, as four years of data are generally insufficient to provide time-dependent estimates with any reasonable precision. We limited our consideration to models that produced estimates for both survival and recapture probability that were neither 0 nor 1, and to models that fit the data. The goodness of fit of the models was tested by using a Pearson's goodness-of-fit test. We calculated the Akaike Information Criterion ($QAIC_C$, which corrects for over-dispersion of data and is used with smaller sample sizes relative to the number of parameters examined) for each species. The $QAIC_C$ was calculated by multiplying the log-likelihood for the given model by -2, adding two times the number of estimable parameters in the model, and providing corrections for overdispersed data and small sample sizes.

RESULTS

A total of 2324.7 net-hours was accumulated at the six MAPS stations operated in Cape Cod National Seashore in 2002 (Table 1). Data from 2194.5 of these net-hours could be compared directly to 2001 data in a constant-effort manner.

Indices of Adult Population Size and Post-fledging Productivity

A. 2002 values -- The 2002 capture summary of the numbers of newly-banded, unbanded, and recaptured birds in Cape Cod National Seashore is presented for each species at each of the six stations individually in Table 2 and for all stations combined in Table 4. A total of 288 captures of 24 species was recorded during 2002. Newly banded birds comprised 70.5% of the total captures. The greatest number of total captures was recorded at the Nauset School station (72), followed in descending order by Marconi Beach (52), Blueberry Hill (47), Higgins House (44), Longnook Beach (40), and Oak Dunes (33). The highest species richness was recorded at Nasuet School (15 species) and the lowest species richness was recorded at Blueberry Hill, Higgins House, and Marconi Beach (10 species each). Among individual species, Black-capped Chickadee was the most frequently captured, followed by Chipping Sparrow, Hermit Thrush, Pine Warbler, Tufted Titmouse, and Common Yellowthroat and American Goldfinch (Table 4).

The capture rates (per 600 net-hours) of individual adult and young birds and the percentage of young in the catch are presented for each species and for all species pooled at each station (Table 3) and for all stations combined (Table 4). We present capture rates (captures per 600 net-hours) of adults and young so that the data can be compared among stations that, because of the vagaries of weather and accidental net damage, can differ from one another in effort expended (see Table 1). The following is a list of the common breeding species (captured at a rate of at least 3.0 adults per 600 net-hours), in decreasing order, at each station in 2002 (see Table 3):

Longnook Beach	**Oak Dunes**	**Blueberry Hill**
Common Yellowthroat	Black-capped Chickadee	Black-capped Chickadee
Black-capped Chickadee	Pine Warbler	Pine Warbler
Hermit Thrush	Hermit Thrush	Ovenbird
Eastern Wood-Pewee	Hairy Woodpecker	Tufted Titmouse
American Robin	Common Yellowthroat	Hermit Thrush
Scarlet Tanager	Eastern Towhee	Eastern Towhee
Eastern Towhee		American Goldfinch
	Nauset School	
Higgins House	Black-capped Chickadee	**Marconi Beach**
Hermit Thrush	Tufted Titmouse	Chipping Sparrow
Pine Warbler	Gray Catbird	American Goldfinch
Chipping Sparrow	Ovenbird	Pine Warbler
Black-capped Chickadee	Eastern Wood-Pewee	Black-capped Chickadee
	Blue Jay	Hermit Thrush

Overall, the most abundant breeding species at the six Cape Cod MAPS stations in 2002 (captured at a rate of at least 2.0 adults per 600 net-hours), in decreasing order, were Black-capped Chickadee, Pine Warbler, Chipping Sparrow, Hermit Thrush, American Goldfinch, Common Yellowthroat, Ovenbird, and Tufted Titmouse (Table 4).

The indices of adult captures presented in Table 3 indicate that the total adult population size in 2002 was greatest at Nauset School, followed in descending order by Marconi Beach, Blueberry Hill, Longnook Beach, Higgins House, and Oak Dunes. In contrast to previous years, mean adults captured at the two mixed-woodland stations (55.5; Nauset School and Blueberry Hill) was higher than that at the two pitch-pine stations (51.7; Higgins House and Marconi Beach), which in turn was higher than that at the two oak-forest stations (43.1; Longnook Beach and Oak Dunes). Each of the past three years has had a different canopy-type group with the highest adult capture rate. As with last year, mean adults captured at the three sparse-understory stations (55.5; Nauset School, Higgins House, and Marconi Beach) was higher than at the three dense-understory stations (44.6; Longnook Beach, Oak Dunes, and Blueberry Hill), while mean adults captured at the three high-density-housing stations (50.3; Longnook Beach, Nauset School, and Higgins House) was nearly identical to the mean at the three low-density-housing stations (49.9; Oak Dunes, Blueberry Hill, and Marconi Beach). Thus, in 2002, it appeared that mixed woodlands supported the highest breeding bird populations, followed by pitch pine and oak forest, there were more breeding adults in habitats with sparse than with dense understory, but there were nearly equal numbers of breeding adults at stations with high and low housing density.

Captures of young (Table 3) of all species pooled at each station in 2002 followed an identical sequence to that of adults, being highest at Nauset School, followed by Marconi Beach, Blueberry Hill, Longnook Beach, Higgins House, and Oak Dunes. As with adults, mean young captured at the mixed-woodland stations (19.1) was the highest, followed by the two pitch-pine stations (8.0) and the two oak-forest stations (6.0). Again as for adults, mean young captured at the three dense-understory stations (7.6) was substantially less than at the three sparse-understory stations (14.4). However, in contrast to adults, mean young captured at the three high-density-housing stations (14.0) was greater than at the three low-density-housing stations (7.9). Thus, in 2002, more young birds occurred in mixed woodlands than in pitch pine or oak forests, more young were found in areas with sparse rather than dense understory, and more young were found in high-density than in low-density-housing areas.

Given the general similarity in adults and young captured by station, the index of productivity (Table 3), as determined by the proportion of young in the catch, was similar among four of the stations, varying from a high of 0.30 at Nauset School, followed by 0.18 at both Longnook Beach and Blueberry Hill, 0.16 at Marconi Beach, 0.10 at Higgins House, and only 0.04 at Oak Dunes. As with numbers of young captured, mean productivity at the two mixed-woodland stations (0.24) was highest, followed by productivity at the two pitch-pine stations (0.13) and productivity at the two oak-forest stations (0.11); mean productivity at the three sparse-understory stations (0.19) was higher than at the three dense-understory stations (0.13); and mean productivity at the three high-density-housing stations (0.19) was greater than at the three low-density-housing stations (0.13). Thus, productivity in 2002 tended to be higher in mixed-woodland than in pitch pine or oak forest, it tended to be higher in areas with sparse understory, and it tended to be higher in high-density than in low-density-housing areas.

B. Comparisons between 2001 and 2002 -- Constant-effort comparisons between 2001 and 2002 were undertaken at all six Cape Cod National Seashore MAPS stations for numbers of adult birds captured (adult population size; Table 5), numbers of young birds captured (Table 6), and proportion of young in the catch (productivity; Table 7).

Adult population size for all species pooled for all stations combined decreased between 2001 and 2002 by a non-significant -12.8% (Table 5). Eighteen of 30 species at all stations combined showed decreases; this proportion was not significantly greater than 0.50 (P=0.181). The change in overall adult population size for all species pooled showed decreases at three stations, by amounts ranging from -26.9% at Marconi Beach to -35.9% at Longnook Beach, and showed increases at three stations by amounts ranging from +4.0% at Oak Dunes to +29.2% at Blueberry Hill. This is generally the opposite pattern to changes recorded between 2000 and 2001. These increases and decreases did not seem to be related to habitat type or housing density in any way. The proportion of increasing or decreasing species was not significantly greater than 0.50 at any station. The number of adult Tufted Titmice captured at all stations combined showed a significant decrease while no species showed a significant or near-significant increase.

The number of young birds captured of all species pooled for all stations combined in Cape Cod National Seashore showed a non-significant decrease of -27.6% between 2001 and 2002 (Table 6). Nine of 15 species at all stations combined showed decreases, a proportion not significantly greater than 0.50 (P=0.304). The number of young birds captured, of all species pooled, showed decreases at three of the six stations, ranging from -53.3% at Marconi Beach to -83.3% at Oak Dunes, and increased at three stations by amounts ranging from +5.6% at Nauset School to +250.0% at Blueberry Hill. The proportion of increasing or decreasing species was not significantly greater than 0.50 at any station. The number of young Chipping Sparrows showed a near-significant decrease between 2001 and 2002 for all stations were combined; no species showed significant or near-significant increases.

With non-significant decreases in numbers of adults captured, and larger non-significant decreases in numbers of young captured, it is not surprising that productivity (the proportion of young in the catch) in 2002 also decreased non-significantly by an absolute value of -0.029, from 0.209 in 2001 to 0.180 in 2002 (Table 7). Nine of 20 species decreased overall, a non-significant proportion (P=0.478). Productivity decreased at four of the six stations, by amounts ranging from -0.009 at Nauset School to -0.150 at Higgins House, whereas it increased by +0.074 at Longnook Beach and by +0.107 at Blueberry Hill. No station showed significant or near-significant proportions of increasing or decreasing species. As with the numbers of young captured, Chipping Sparrow showed a near-significant decline in productivity across stations and no species showed significant or near-significant increases. As with changes in numbers of adults captured, changes in numbers of young captured and productivity were generally opposite to those recorded between 2000 and 2001. In addition, there seemed to be no relationship between these changes in either numbers of young or productivity and habitat type or housing density.

Thus, the numbers of adults and young captured and productivity all generally decreased between 2001 and 2002, the opposite of changes between 2000 and 2001, when all three parameters increased. No strong patterns emerged as to effects of station, habitat, or housing density on any changes between 2001 and 2002.

C. Mean values for the four years, 1999-2002 -- Table 8 presents mean annual numbers of individual adults captured, numbers of young captured, and proportions of young in the catch on Cape Cod National Seashore during the four-year period 1999-2002 for each of the six stations and for all stations pooled. Examination of all-species-pooled values at the bottom of the table indicates that the highest breeding populations at Cape Cod during the four-year period occurred at Marconi Beach, followed by Nauset School, Higgins House, Longnook Beach, Oak Dunes, and, finally, Blueberry Hill. Four-year productivity values showed a different pattern, being highest at Nauset School, followed by Blueberry Hill, Longnook Beach, Marconi Beach, Higgins House, and, finally, Oak Dunes. Among habitats (forest canopy types), breeding populations tended to be highest in pitch pine (mean 65.2 adults captured per 600 net-hours), followed by oak forest (53.5) and mixed woodland (51.8), whereas productivity showed a different pattern, being highest in the mixed woodland (mean 0.230 proportion of young), followed by pitch pine (0.155) and oak forest (0.135). Among understory types, both breeding populations and productivity were higher in sparser understory (means 64.8 and 0.183, respectively) than in denser understory (48.7 and 0.163). Among housing densities, both breeding populations and productivity were higher in high-density housing areas (means 60.9 and 0.186, respectively) than in low-density housing (52.6 and 0.160).

D. Multivariate analyses of adult population size and productivity ï Figures 1-12 present the results for multivariate ANOVA and logistic regression analyses of adult population size and productivity, respectively, for all species pooled and for 11 target species, using the design variables year, habitat (canopy type), understory type, housing density class, and station.

Controlling for the habitat (canopy type), understory, and housing density, adult population sizes of all species pooled were significantly higher in 1999 than in 2002, with populations in 2000 and 2001 being intermediate (Fig. 1A). There were no significant differences in adult population size for all species pooled by habitat (canopy type) or housing density (when controlling for the other variables; Fig. 1B and 1D); however, significantly more adults were captured at stations with sparse understories than with dense understories (Fig. 1C). Controlling for year, no station had significantly or near-significantly lower or higher population sizes than found at Longnook Beach (Fig. 1E); however, those at Blueberry Hill appeared to be substantially smaller and those at Marconi Beach appeared to be substantially higher, and it is possible that there was a significant difference between these two stations (or between Blueberry Hill and Nauset Beach, which also showed higher populations).

For all species pooled, there were no significant differences in productivity by station, habitat (canopy type), understory type, or housing density (Figs. 1F, 1H-J); in fact, there was very little difference at all in productivity for all species pooled between any of the habitat, understory, or housing densities types. However, productivity for all species pooled in 2000 was significantly lower than in 2002, while productivity in both 1999 and 2001 tended to be higher than in other years (Fig. 1G).

Results of these multivariate analyses for 11 target species are shown in Figs. 2-12. Sufficient data for logistic regression analyses on productivity (the species was captured in adequate numbers at two or more stations) were only available for six (Black-capped Chickadee, Tufted Titmouse, Hermit Thrush, American Robin, Pine Warbler, and Chipping Sparrows) of the 11 species (Figs. 2-5, 7, and 11), so we only show results of ANOVAs on population size for the other five species (Figs. 6, 8-10, and 12). The only significant effect on productivity found with logistic regression analysis for any individual target species was for Black-capped Chickadee, where productivity at the Oaks Dune station was near-significantly lower than at the reference Longnook Beach station (Fig. 2F), and productivity in both pine-oak and pitch pine habitats was near-significantly higher than in oak forest habitat (Fig. 2H). However, productivity for Hermit Thrush was zero at the Nauset School and Higgins House stations (Fig. 4F), in pine-oak habitat (Fig. 4H), and in 2000 (Fig. 4G); productivity for American Robin was also zero at the Nauset School station (Fig. 5F), in pine-oak habitat (Fig. 5H), and in 2000 (Fig. 5G); and productivity for Pine warbler was zero at the Higgins House station (Fig. 7F), at high housing density stations (Fig. 7J), and in 2000 and 2002 (Fig. 7G).

For adult population sizes, two species (Gray Catbird and Ovenbird; Figs. 8A & 10A) showed near-significant year effects; in both species, population size was higher in 1999 than in 2002 (as was the case for all species pooled). Interestingly, controlling for other variables, population sizes tended to be higher in 1999 than in 2000 for ten of 11 species (all but Hermit Thrush for which productivity in 1999 was almost identical to that in 2000). Five species showed significant or near significant differences by habitat (canopy type): for Tufted Titmouse (Fig. 3B), Gray Catbird (Fig. 6B), and Ovenbird (Fig. 8B), populations were lower in pitch pine than in oak forest; for Pine Warbler (Fig. 7B) and Chipping Sparrow (Fig. 11B), populations were higher in pitch pine than in oak forest; and for Common Yellowthroat (Fig. 9B), populations were lower in mixed pine-oak than in oak forest. Two species (Tufted Titmouse and Gray Catbird; Figs. 3C & 6C) showed significant or near-significant understory effects, and in both species population size was higher in sparse than in dense understory (again as was the case for all species pooled). Overall, population sizes tended to higher in habitats with a sparse than a dense understory for eight of the 11 species, and very similar in two other species; only Common Yellowthroat tended to have higher population sizes in habitats with a dense understory. Two species showed significant or near-significant housing density effects: for Common Yellowthroat (Fig. 9D) populations were higher among high-density than low-density housing, whereas for American Goldfinch (Fig. 12D) the opposite was the case. Station effects were found among eight species: for Gray Catbird (Fig. 6E), Pine Warbler (Fig. 7E), Chipping Sparrow (Fig. 11E), and American Goldfinch (Fig. 12E), population sizes at Longnook Beach were lower than at one or more other stations, whereas for Ovenbird (Fig. 8E), Common Yellowthroat (Fig. 9E), and Eastern Towhee (Fig. 10E), population sizes were higher at Longnook Beach than at one or more other stations. For Tufted Titmouse (Fig. 3E) populations were higher than Longnook Beach at one station (Nauset Beach) and lower than Longnook Beach at two stations (Higgins House and Marconi Beach).

E. Four-year trends in adult population size and productivity -- "Chain" indices of adult population size are presented in Figure 13 for the 11 target species (with an average of at least seven individual adults captured per year) and for all species pooled at the six Cape Cod stations combined. See Methods for an explanation of the calculations used to obtain these indices. We used the slope of the regression line for each species to calculate the Annual Percentage Change (*APC*) for the population. *APC* along with the standard error of the slope (SE), the correlation coefficient (*r*), and the significance of the correlation (*P*) for each target species and for all species pooled are included in Figure 13.

Population trends for seven species (American Robin, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) and all species pooled showed substantial decreases ($r \leq -0.5$) over the four years, 1999-2002. The decline of American Robin was nearly significant. By contrast, just two species, Black-capped Chickadee and Hermit Thrush, showed substantial (non-significant) increases, with that for Hermit Thrush being very slight (+1.3% per year). The remaining two species (Tufted Titmouse and Chipping Sparrow) showed no substantial trend (absolute $r < 0.5$) and little population fluctuation (*SE* of the slope ≤ 0.219). Overall, as indicated by *APC* values, population trends for eight species and all species pooled were negative, whereas only three species showed positive trends. The annual percentage change (*APC*) in populations between 1999 and 2002 varied from -18.2% for American Robin to +6.8% for Black-capped Chickadee, and was -3.7% for all species pooled. Many species (and all species pooled) showed generally lower population sizes in 2000 and 2002 and generally higher population sizes in 1999 and 2001.

Productivity trends (Fig. 14) for four species (Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee) showed substantial decreases ($r \leq -0.5$), with those of Gray Catbird and Eastern Towhee being nearly significant. Two species (Hermit Thrush and American Robin) showed substantial but non-significant increases in productivity ($r \geq 0.5$). The remaining five species and all species pooled showed no substantial trend (absolute $r < 0.5$) and little fluctuation in productivity (*SE* of the slope ≤ 0.125). Overall, as indicated by PrT values, the productivity trend was negative for five species and all species pooled, was positive for five other species, and was flat for American Goldfinch, for which no young birds were caught because they typically fledge in August after the MAPS season terminates. The productivity trend (PrT) between 1999 and 2002 varied from -0.085 for Eastern Towhee to +0.047 for Chipping Sparrow, and was -0.002 for all species pooled. As with population size, many species and all species pooled showed generally lower productivity in 2000 and 2002 and generally higher productivity in 1999 and 2001.

Estimates of Adult Survivorship

Using four years of data from all six stations combined, estimates of apparent adult survival probability, recapture probability, and proportion of residents could be obtained for seven of the 11 target species breeding at Cape Cod. Estimates could not be generated for the remaining four species (Tufted Titmouse, American Robin, Eastern Towhee, and American Goldfinch) due to insufficient between-year capture data. Maximum-likelihood estimates of annual adult survival probability, recapture probability, and proportion of residents among newly captured adults from the time-constant transient model are presented in Table 9 for each of the seven species.

Annual adult survival-rate estimates ranged from a low of 0.264 for Pine Warbler to a high of 0.917 for Gray Catbird, with a mean of 0.681 for the seven species. This is a relatively high mean survival rate from MAPS data, with the estimates for all but Pine Warbler being greater than 0.65, itself a high estimate. Estimates of recapture probability for the seven species varied from 0.140 for Chipping Sparrow to 0.682 for Hermit Thrush, with a mean of 0.436. Estimates of the proportion of residents among newly captured adults ranged from 0.138 for Ovenbird to 0.999 for Chipping Sparrow, with a mean of 0.501. These are not particularly high or low estimates of mean recapture probability or proportion of residents. The mean coefficient of variation of the annual adult survival-rate estimate, CV(φ), for the seven species was 36.4%. Such relatively poor precision is not unexpected considering that only four years of data were available, the minimum needed to estimate survival using the transient model. Obviously, additional years of data will be necessary to provide survival-rate estimates with more precision and to investigate time-dependence in survival.

DISCUSSION OF RESULTS AND CONCLUSIONS

Indices of Population Size and Productivity

Both breeding population sizes and productivity on Cape Cod National Seashore during 2002 tended to decrease slightly from values recorded in 2001. This continues the alternating pattern noted in last year's report: both of these parameters were high in 1999, low in 2000, higher in 2001, and lower in 2002. No strong patterns emerged as to effects of habitat or housing density on changes between 2001 and 2002, indicating that whatever drove the between-year changes in population size and productivity was at least seashore-wide.

It is of interest that adult populations of all species pooled at many MAPS locations show a two-year alternating pattern population sizes and productivity. In most of these cases, however, the two-year alternating patterns of population size and productivity are out phase with each other, that is, productivity increases in one year and population size increases the next year. We interpret these patterns to be caused by density-dependent productivity coupled with low productivity of first-time breeders. Thus, high productivity in a given year causes high recruitment of young the following year and an increase in population size, which, because of increased inter-and intra-specific competition and a high proportion of first-time breeders causes a decrease in productivity. This low productivity then leads to low recruitment and a decrease in population size the following year that, in turn, leads to higher productivity and the out-of-phase alternating two-year pattern in population size and productivity.

That the population dynamic of landbirds at Cape Cod National Seashore was characterized by population size and productivity alternating in phase, suggests that landbird populations on Cape Cod might not be regulated by density-dependent productivity and that the populations may not be saturated. Such a situation may be typical of sub-optimal habitats where low productivity is independent of density. The decreased population sizes may occur because of low intrinsic recruitment in years in which the habitat is especially poor. Such years would be expected to have poor productivity as well. If such were the case, we have no explanation as to why the habitat is poorer every other year. Additional years of data may, in fact, show the two-year pattern to be spurious.

That species richness, total population size, and productivity of landbirds all tend to be low at Cape Cod National Seashore compared to other MAPS locations provides further evidence to suggest that landbird habitat on Cape Cod National Seashore is sub-optimal. Furthermore, that the decreases and increases in population size and productivity appear to be independent of canopy type, understory, and housing density, and that productivity itself appears not be very dependent on any of these variables (see below), suggests that none of these variables *per se* is causing the sub-optimal nature of the habitat. Rather, the generally poor habitat may be a geographic result of the narrow peninsular nature of Cape Cod, a geographic characteristic that tends generally to lead to low species richness for much the same reasons that islands have low species richness. It is possible that the low species richness, population sizes, and productivity of landbirds on Cape Cod National Seashore relate to a low species richness and abundance of their arthropod food resources. It will be interesting to see whether or not results of terrestrial arthropod monitoring on Cape Cod National Seashore support this hypothesis.

Examination of the mean number of adults captured and mean productivity at each station over all four years combined, can provide some insight regarding the habitat types and housing density classes that seem to support larger breeding populations and better productivity. Similar to previously observed patterns, mean annual number of adults captured of all species pooled was highest at the two pitch-pine stations, followed by the two oak-forest stations and the two mixed-pine/oak stations. These univariate analyses also showed higher mean annual numbers of adults in habitats with sparse rather than dense understories, and with higher rather than lower housing density.

Multivariate ANOVA analyses on all species pooled showed the same pattern as univariate analyses with respect to understory. Indeed, mutivariate analyses showed that habitats with sparser understories had significantly more adults than habitats with denser understories. Multivariate analyses on all species pooled, however, showed strikingly different patterns than univariate analyses with respect to habitat (canopy type) and housing density, with adult population sizes tending to be highest in oak forest, followed by pine-oak and pitch pine habitats, and with adult populations tending to be slightly higher in low than in high density housing. None of these multivariate differences were significant, however.

The reason for the pronounced differences between the univariate and multivariate results was that both oak forest stations had dense understories while both pitch pine stations had sparse understories. Thus, the two pitch pine stations had a higher mean adult population size than the two oak forest stations because sparse understories were associated with the pitch pine stations and dense understories were associated with the oak forest stations. Similarly, the reason why the three high housing density stations had a higher mean annual population size than the three lower housing density stations was that two of the three high density stations had sparse understories. These results show the value of multivariate analyses that assess differences for a given variable after adjusting for the confounding effects of other variables.

Multivariate ANOVA analyses of adult population size for the 11 individual target species produced patterns that were in agreement with known life history traits and habitat preferences for these species. In particular, significantly or near-significantly higher adult population sizes were found in oak than in pitch pine forest for Tufted Titmouse, Gray Catbird, and Ovenbird, all of which are known to prefer oak forest or, at least, deciduous forest over pine forest. In contrast, significantly or near-significantly higher adult population sizes were found in pitch pine than in oak forest for Pine Warbler and Chipping Sparrow, again in agreement with known habitat preferences for these species. Two species, Tufted Titmouse and Gray Catbird, also showed significantly or near-significantly higher adult population sizes in sparse rather than dense understories, a perhaps expected result for titmouse but unexpected for catbird. We have no explanation for the significant or near-significant preference of Common Yellowthroat for high and American Goldfinch for low housing density, respectively. These may be spurious results tied to some other variable in the local landscape that we have not yet measured.

In contrast to the situation for adult population sizes, patterns of mean annual productivity of all species pooled did not differ between univariate and multivariate analyses. This was because productivity for all species pooled did not vary significantly or near-significantly as a function of any environmental variable. For all species pooled, productivity tended to be slightly higher in pine-oak habitat than in either oak or pitch pine habitats, very slightly higher in high than in low housing density habitat, and virtually identical in habitats with sparse and dense understories. The only significant or near-significant relationship found for productivity for any individual species was that productivity for Black-capped Chickadee was lower in oak forest habitat than in either pine-oak or pitch pine habitat, primarily because of the very low productivity at the Oak Dunes station. Interestingly, the Oak Dunes station had the overall lowest productivity for all species pooled, although the difference in productivity from the reference station (Longnook Beach -- also in oak forest) was not significant or near significant.

Controlling for habitat (canopy type), understory, and housing density, adult population sizes of all species pooled were significantly higher in 1999 than in 2002, with populations in 2000 and 2001 being intermediate. Productivity for all species pooled showed a similar temporal pattern when controlling for habitat, understory, and housing density. The year 2000, however, was the year in which productivity was most different; indeed, productivity was significantly lower in 2000 than in 2002, while productivity in both 1999 and 2001 tended to be higher than in other years

Four-Year Trends in Population Size and Productivity

Population trends for seven species (American Robin, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) and all species pooled showed substantial decreases at Cape Cod over the four years 1999-2002, whereas just two species (Black-capped Chickadee and Hermit Thrush) showed substantial increases. The annual percent change for all species pooled over the four years was -3.7%. Interestingly, the declining and increasing species each include both residents and migrants. Similarly, productivity trends were substantially negative for four species (Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee -- all of which had substantially negative population trends) and were substantially positive for only two species (Hermit Thrush and American Robin -- one of which also had a substantially positive population trend). The productivity trend for all species pooled was slightly negative (-0.002). Although four years is a minimal time period to effectively estimate population trends, these preliminary results indicate that both population sizes and productivity may be declining at Cape Cod, and suggest that the declining productivity might be driving the declining population trends.

Estimates of Apparent Adult Survival Rates

Using four years of data, we were able to obtain estimates of adult survival and recapture probabilities and proportions of residents for seven of the 11 target species breeding on the Cape Cod National Seashore. The mean annual adult survival-rate estimate of 0.681 was relatively high compared to other MAPS stations, with estimates for all of the seven species except Pine Warbler being greater than 0.65, in itself a high survival rate for landbirds. The mean coefficient of variation of the annual adult survival-rate estimate, CV(φ), for the seven species was 36.4%. Survival rate estimates were obtained after the 2001 season from three years of data for only three species, Black-capped Chickadee, Hermit Thrush, and Common Yellowthroat. The mean CV(φ) for those three species from three years of data (51.0%) was notably higher than the mean CV(φ) for the same three species from four years of data (30.0%), indicating a substantial improvement in both number of species and in precision as a result of the additional year of data. Nevertheless, several species with notably high (Gray Catbird, Chipping Sparrow) or low (Pine Warbler) survival estimates had notably high CV(φ)s (> 47%) indicating that the high or low survival estimates may not be accurate. Obviously, additional years of data will be necessary to provide survival-rate estimates with more precision and to investigate time-dependence in survival.

At other MAPS locations, we have noted substantial improvements in the number of species for which survival estimates could be obtained and in the precision of those estimates with each additional year of data (so far, up to ten years). These predictions are in agreement with simulations of MAPS data completed by Dan Rosenberg as part of his evaluation of the statistical properties of the MAPS Program, which suggested that maximum precision of survival estimates would not be reached until about 12 years of data have been collected (Rosenberg et al. 1996, 1999). Thus, we expect to be able to estimate adult survival rates for as many as 11 target species at Cape Cod once more years of data are available. Time-dependence in estimates of survivorship, recapture probability, and/or proportion of residents will also become available when about eight years of data have accumulated from the six stations.

Primary Demographic Causes of Population Declines

A primary goal of MAPS is to determine causal factors of declining species and whether or not the declines are caused by problems on the breeding grounds, wintering grounds, or both. These causal factors can be inferred by examining four-year mean productivity values, productivity trends, survival estimates, and environmental characteristics for each of the declining species as well as the two species showing substantial increases at Cape Cod. A look at environmental characteristics as based on multivariate ANOVAs shows no conclusive patterns among declining vs. increasing species. For example, both increasing species (Black-capped Chickadee and Hermit Thrush) favor (have higher populations in) oak forest and sparse understory, but five out of seven declining species also favor oak forests and four out of seven declining species favor sparse understory. Housing density class preferences are more or less evenly split between the declining and increasing species. Thus, as we surmised above regarding between-year changes, it appears that other, perhaps region-wide, factors are influencing these trends more than local physical environmental variables.

Examination of productivity and survival values, however, indicates that low productivity may be more of a factor than low survival in the declines of Gray Catbird (productivity 0.07, survival 0.917), Ovenbird (0.02 and 0.850), and Common Yellowthroat (0.05 and 0.655), whereas low survival as well as low productivity may be influencing the decline of Pine Warbler (0.04 and 0.264). We could not calculate survival values for the other three species; however, productivity values were low to moderately low for all three species: American Robin (0.10), Eastern Towhee (0.07) and American Goldfinch (0.02, although this value is likely biased low by late breeding in this species). Indeed, these productivity values are extremely low as compared to other MAPS stations and may indicate that Cape Cod is a ñpopulation sinkò (area of low productivity wherein populations can only be maintained by recruitment from elsewhere) for these species. All four of the declining species with low productivity (Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee) also showed substantially declining productivity trends. Both of the increasing species showed high survival (0.724 for Black-capped Chickadee and 0.657 for Hermit Thrush); productivity for Black-capped Chickadee was also relatively high (0.27), whereas it was quite low (0.07; but increasing -- see above) for Hermit Thrush. Neither species, however, showed a declining productivity trend. Thus, it appears that low and declining productivity has been more of an influence than low survival in driving the general population declines seen at Cape Cod, indicating that the problems might likely be occurring on the Seashore rather than on migration or on the wintering grounds.

We must emphasize, however, that the population trends, productivity trends, and survival-rate estimates presented here are based on only four years of data from the six stations. Thus, the short-term patterns identified may not be representative of the true long-term, large-scale population dynamics. Moreover, the indices and estimates of primary demographic parameters presented here have relatively low precision and statistical power because of the limited number of years of data. This, of course, will improve dramatically as more years of data accumulate at Cape Cod.

Future Analyses

Using nine or ten years of data from other MAPS stations, (Nott et al. 2002b), we have been able to examine relationships between global climate cycles (such as the El Niño/Southern Oscillation and the North Atlantic Oscillation) and productivity, and have found significant correlations. In particular, we have found that productivity in the Pacific Northwest and most other locations in western and southern United States, particular for Neotropical-wintering migratory landbirds, is strongly related to the mean monthly El Niño/Southern Oscillation Precipitation Index (ESPI; a measure of the effects of El Niños and La Niñas) in such a manner that productivity averages higher during El Niño conditions (such as those in 1998) than during La Niña conditions (such as those in 1999). Once more years of data have accumulated at Cape Cod, we will be able to better understand avian population dynamics at the Seashore and along the Eastern Seaboard generally and their relationships to global climate cycles. This will allow us to better understand some of these overall population dynamics.

Moreover, in addition to the analyses involving climate cycles, we have initiated two broad-scale analyses on longer-term data from other locations to help us further understand the population dynamics of landbirds and to allow us to identify potential management actions to reverse population declines and maintain stable or increasing populations. First, by modeling spatial variation in vital rates as a function of spatial variation in population trends, we are beginning to determine the proximate demographic causes of population trends for species at multiple spatial scales (DeSante et al. 2001). Among Gray Catbird populations, for example, we found that adult survival-rate estimates varied appropriately between areas of increasing vs. decreasing population trends while productivity indices were independent of area, suggesting that low survivorship was driving the declining populations in this species. Second, by modeling vital rates as a function of landscape-level habitat characteristics, we have found that patterns of landscape structure detected within a two- to four-kilometer-radius area of each station are good predictors not only of the numbers of birds of each species captured but, more importantly, of their productivity levels as well (Nott 2000). This study revealed the existence of threshold values of critical habitat characteristics, such as mean forest patch size, above which productivity levels could be maximized, thus providing an extremely powerful tool to identify and formulate management actions aimed at increasing landbird populations. With additional funding from a variety of sources, we hope to undertake such analyses with data from Cape Cod as well as with data from all 500 MAPS stations that are now being operated across North America. We also hope to include estimates of juvenile recruitment and indices of first-year survival in future analyses in order to fully understand what parameters are most affecting population changes in each target species. We are excited by the prospect of conducting these analyses on data from Cape Cod in upcoming years.

Conclusions

Previous extensive analyses conducted on MAPS data have indicated that the indices and estimates of primary demographic parameters (productivity and survivorship) of common landbird species produced by the MAPS Programs could adequately predict the relative short-term population trends of those species (DeSante et al. 1999). In addition, late-summer mist netting has been shown to provide accurate indices of region-wide productivity in targeted endangered species suggesting that Amist-netting programs like MAPS and the Constant Effort Sites used in Britain can provide useful measures of temporal patterns, large-scale spatial patterns, and year-specific patterns in avian productivity≅ (Bart et al. 1999). As a result, the indices and estimates of primary demographic parameters produced by MAPS are proving to be extremely useful for the management and conservation of landbirds at specific locations and, in combination with similar data from other areas, across all of North America.

Although Cape Cod MAPS stations have been operated for only four years, important data have been gathered on breeding populations and productivity for a number of summer resident landbird species on the seashore. In 1999 we were able to pool data from six MAPS stations on Cape Cod National seashore to provide the first station-specific and park-wide indices of breeding population size and productivity for a number of target species and for all species pooled. With the addition of a second year of data in 2000, we were able to compare these indices between two years using constant-effort data. With three years of data, we were able to assess interannual variation in breeding populations and productivity more fully, provide more robust analyses on the effects of habitat type and housing density on the population dynamics of landbirds on the seashore, and provide initial estimates of annual adult survival rates and capture probabilities for three species using a non-transient model. Now, with four years of data, we are able to provide population and productivity trends, provide initial estimates of annual adult survival rates, recapture probabilities, and proportions of residents among newly marked adults for seven species with increased precision using the transient model, and begin preliminary analyses into the causal factors leading to declining trends on the Seashore.

Additional years of data will substantially increase the precision and accuracy of survival estimates and population and productivity trends obtained from the Cape Cod MAPS program as well as the power of our multivariate analyses that aim to relate population size and productivity to year and local habitat variables. Moreover, with more years of data, we will be able to analyze the effects of climatological and landscape variables on breeding populations and productivity at Cape Cod. In particular, we will be able to integrate these variables into our constant-effort year-to-year comparisons, long-term trends in population size and productivity, and estimates of adult survival, capture probability, and proportion of residents. In addition, by including data from stations operated outside of the Cape Cod National Seashore, we will be able to make comparison between Cape Cod and other Atlantic coastal parks that may participate in the MAPS program in the future, as well as comparisons between Cape Cod and other unprotected areas along the Atlantic coast. Finally, MAPS data from Cape Cod National Seashore will be pooled with MAPS data from outside the seashore to provide regional and continental indices and estimates of (and longer-term trends in) these key demographic parameters.

The long-term goal for the Cape Cod MAPS program is to continue to monitor the primary demographic parameters of Cape Cod =s landbirds in order to provide critical information that can be used to aid our understanding of the ecological processes leading from environmental stressors to population responses. When we have at least ten years of data from the Cape Cod National Seashore and appropriate funding for additional analyses has been secured, we will use these data, along with other data from elsewhere along the Atlantic Coast, in an attempt to: (1) determine the proximate demographic factors (i.e., productivity or survivorship or both) causing observed population trends of the various target species by modeling spatial variation in their productivity indices and survival rate estimates as a function of spatial patterns in their population trends; (2) link MAPS data with landscape-level habitat data and spatially explicit weather data in a geographical information system (GIS) in order to identify and describe relationships between landscape-level habitat and/or weather characteristics and the primary demographic responses (productivity and survival rates) of the target species; (3) generate hypotheses regarding the ultimate environmental causes of the population trends; and (4) identify and formulate generalized management guidelines and specific management actions for habitat and use-related issues on the seashore and in other Atlantic coastal parks and lands.

We conclude, therefore, that the MAPS protocol is very well-suited to provide one component of Cape Cod's long-term ecological monitoring program (Roman and Barrett 1999), and can provide critical data to aid in resolving problems associated with declining landbird populations along the Eastern Seaboard. Thus, we recommend continuing the MAPS program on the Seashore in perpetuity into the future, as has been recommended in an extensive review of monitoring protocols for the Channel Islands National Park (McEachern 2001), or at least for the six additional years needed to allow us to initiate the analyses outlined above.

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