THE 2003 ANNUAL AND FINAL REPORT OF THE MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) PROGRAM ON CAPE COD NATIONAL SEASHORE

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Summary

We operated six MAPS stations in a range of habitat types on Cape Cod National Seashore for five years, 1999-2003. The mean annual index of total adult population size was 28% lower than the mean at seven other MAPS locations along the Atlantic slope. Indices of adult population size decreased substantially over the five years, with nine of 11 target species showing declines and all species pooled declining by a near-significant -4.7% per year. These declines may have been responsible for the depressed breeding population sizes on the Seashore.

Strikingly low productivity for most species on the Seashore appeared to drive the population declines of six of seven target species, although low annual adult survival rates, at least in some years, appeared to drive or contribute to the declines in two species. For the most part, however, annual adult survival rates were at least as high as at other locations in the U.S. Productivity trends were negative for all species pooled and for the majority of target species, suggesting that population declines on the Seashore will likely worsen in the near future.

Multivariate ANOVAs of adult population size as a function of habitat characteristics (canopy, understory, housing density) for 11 target species produced results that agreed with known habitat preferences for those species. Analogous multivariate logistic regression analyses of productivity indicated that the various target species tended to have their highest productivity in their preferred habitat. For all species pooled, multivariate ANOVAs showed that population trends associated with oak forest habitat tended to be more negative than those associated with mixed pine-oak or pitch pine woodland, but that understory and housing density did not greatly influence population trends. In addition, the four oak forest specialist target species (as determined from mutivariate ANOVAs of population size) experienced more negative population trends than the two pitch pine specialists, while the five habitat generalists had intermediate population trends that were more similar to the oak specialists than to the pitch pine specialists. These results suggest that ecological problems associated with oak forest habitat may be adversely affecting populations of landbirds on Cape Cod National Seashore.

For all species pooled, the results of the ANOVAs for population trends closely mirrored the results of the ANOVAs for productivity, providing additional evidence that productivity is the primary force driving population trends on the Seashore. Multivariate analyses of productivity provided weak evidence that species having substantial population declines had lower productivity in higher housing density areas, suggesting that factors associated with housing, perhaps cats or other pets, could be contributing to low productivity. This possibility is supported by the fact that two of the three target species that did not have deficient productivity were cavity nesters, which are generally less susceptible to nest and fledgling predation.

We suggest (1) that population trend monitoring of landbirds over the entire Seashore be initiated to determine whether the population declines are continuing and are part of a larger-scale phenomenon; (2) that nest monitoring efforts on the Seashore and modeling of MAPS data from Cape Cod and elsewhere along the Atlantic Seaboard as a function of station-specific and landscape-scale habitat characteristics be initiated to aid in formulating management strategies for reversing the population declines; and (3) that renewed operation of appropriately sited MAPS stations be an integral part of the effectiveness monitoring of any managements actions implemented to reverse the declines.

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 on the landbirds found on federally managed lands, such as national parks and seashores, national forests, and military installations, as part of the 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 parks' and other lands' 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 2003

The Institute for Bird Populations operated six MAPS stations in 2003 on Cape Cod National Seashore, at the same locations at which they were operated in 1999-2002. 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 26 and August 4, 2003. A total of 1932.7 net-hours were accumulated during the summer of 2003, during which 208 captures of 28 species were recorded. Newly banded birds comprised 70.7% of the total captures.

The numbers of adults captured (adult population size), the numbers of young captured, and productivity (proportion of young in the catch) all declined between 2002 and 2003, thus continuing the very similar declines recorded between 2001 and 2002. The decrease in numbers of young captured between 2002 and 2003 was significant, but appeared to result primarily from significant decreases in two common species, Black-capped Chickadee and Tufted Titmouse. Except for an increase in the number of adults at the Higgins House station, decreases in all three parameters occurred at all six stations and thus appeared to be park-wide. The substantial decreases in both population size and productivity during the final two years of the study were mirrored by multivariate ANOVAs of adult population size and multivariate logistic regression analyses of productivity that indicated that both of these measures were greater, and often significantly greater, during the first year of the study, 1999, than during the each of the four subsequent years.

We have found previously that adult population sizes and productivity of all species pooled at many MAPS locations show a two-year alternating pattern, with population size and productivity being out phase with each other, that is, with productivity increasing in one year and population size increasing the next year. We interpret these patterns to be caused by density-dependent factors acting on productivity, coupled with low productivity of first-time breeders. That indices of adult population size and productivity on Cape Cod National Seashore do not alternate in a two-year pattern of increases and decreases, but decrease in-phase with each other, suggests that landbird populations on Cape Cod are not regulated by density-dependent factors acting on productivity, and that populations likely are not saturated. Such a situation may be typical of sub-optimal habitats where low productivity may be caused by density-independent factors.

Five-Year (1999-2003) Trends in Population Size and Productivity

Substantial five-year declines in both population size and productivity were recorded on Cape Cod National Seashore. Indeed, population trends for nine of 11 target species, as well as all species pooled, were negative over the five years, 1999-2003, with only two species showing positive trends. Moreover, the decreasing trends for seven (Tufted Titmouse, Hermit Thrush, American Robin, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the nine species, as well as all species pooled, were substantial ($r \leq -0.5$), with the five-year declines of three species and all species pooled being significant or nearly significant. By contrast, just one species, Black-capped Chickadee, showed a substantial ($r \geq 0.5$), but non-significant, increase. The annual percentage change between 1999 and 2003 in populations of all species pooled was -4.7%, which suggests that total landbird populations on the Cape Cod National Seashore declined by as much as 18% between 1999 and 2003, a very substantial amount over such a short time period.

Likewise, five-year (1999-2003) productivity trends were negative for six of the 11 species and all species pooled. The productivity trends for five (Black-capped Chickadee, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the six species with negative productivity trends, as well as all species pooled, were substantial ($r \leq -0.5$), with those of Gray Catbird and Eastern Towhee being significant. In contrast, the trends for only two (Hermit Thrush and American Robin) of the five species with positive productivity trends were substantial ($r \geq 0.5$), with that of Hermit Thrush being nearly significant. The five-year productivity trend for all species pooled was -0.019 per year, which suggests that productivity of landbirds on Cape Cod National Seashore declined by as much as 37%, from about 0.208 to about 0.132, between 1999 and 2003.

Five-year Mean Indices of Adult Population Size and Productivity

The mean total population size of landbirds (as indexed by the mean number of captures of adults of all species pooled at all stations combined over the five years) on Cape Cod National

Seashore (55.2 birds per 600 net hours [b/600nh]) was low compared to most other MAPS locations across North America, and was even lower than other locations along the Atlantic Seaboard, where populations tend to be lower than at other locations. For example, indices of adult population size at 11 locations in western North America ranged from 87.3 b/600nh on Mt. Baker National Forest (WA) to 229.6 b/600nh in Yosemite National Park (CA) and averaged 122.7 b/600nh (112.1 b/600nh after eliminating the exceptionally high index from Yosemite), more than twice as high as the index for Cape Cod National Seashore. Similarly, indices of adult population size at seven other locations in the Appalachians and along the Atlantic Seaboard ranged from 60.5 b/600nh at Fort Belvoir (VA) to 97.5 b/600nh at Shenandoah National Park (VA) and averaged 76.5 b/600nh.

Mean productivity (as indexed by the mean proportion of young in the catch for all species pooled at all stations combined over the five years) on Cape Cod National Seashore (0.17) also tended to be low compared to most other MAPS locations across North America. Again, for example, productivity at 11 locations in western North America ranged from 0.15 at Siuslaw National Forest (OR) to 0.49 at Denali National Park (AK) and averaged 0.32; and ranged from 0.12 at Fort Bragg (NC) to 0.47 at NSGA Sugar Grove (WV) and averaged 0.26 at seven other locations in the Appalachians and along the Atlantic Seaboard.

As mentioned in last year's report, species richness was also low on Cape Cod National Seashore compared to other MAPS locations. This may be a biogeographic result of the narrow peninsular nature of Cape Cod, a characteristic that tends to lead to low species richness for much the same reasons that islands have low species richness. It is possible that the total population sizes detected on Cape Cod National Seashore are a result, at least in part, of the low species richness. The fact that productivity also tends to be low on Cape Cod National Seashore compared to other MAPS locations, however, suggests that landbird habitat on Cape Cod may be sub-optimal and may relate to a low species richness and/or abundance of 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.

It is also possible that the substantial population declines documented during the five years of this study are part of a longer-term decline. If this is the case, then the low population sizes documented on Cape Cod could be a result of the declines and represent substantially depressed populations. If the five-year population declines totaling -4.7% per year have been on-going for more than the five years documented here, and have been caused by anthropogenic factors, then they should be cause for considerable concern on Cape Cod National Seashore and concerted efforts should be undertaken immediately to begin to reverse them.

Survival Rates of Landbirds on Cape Cod National Seashore

Using five years of mark-recapture data, we obtained estimates of annual adult apparent survival rates, recapture probabilities, and proportions of residents among newly captured adults for nine of the 11 target species breeding on the Cape Cod National Seashore. The mean time-constant survival-rate estimate for the nine species, 0.506, was relatively high compared to other MAPS locations, with estimates for seven of the nine species (all except Tufted Titmouse and Pine Warbler) being greater than 0.525, a relatively high survival rate for a small landbird. Because only five years of mark-recapture data were available (only one more than the minimum number of years needed to be able to obtain an estimate using transient models), however, the precision of the survival-rate estimates was low. Using five years of data, the mean coefficient of variation of the annual adult survival-rate estimate for the seven species for which survival could also be estimated with four years of data was 32.5%, compared to a mean of 36.4% for these seven species from four years (1999-2002) of data, thus indicating an improvement in precision as a result of the additional year of data. Despite the overall low precision, $\Delta QAIC_C$ values averaged 4.4 for the nine species, indicating a moderate amount of time-dependence in survival overall, with Tufted Titmouse showing a high degree of time-dependence.

Determining the Cause of the Population Declines on Cape Cod National Seashore

A primary goal of MAPS is to determine the proximate demographic cause(s) of population declines in target 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, for each of the declining species at Cape Cod, five-year mean productivity indices and productivity trends, time-constant annual adult apparent survival rates and a measure of their interannual variability, and, especially, productivity and survival values at Cape Cod relative to continent-wide relationships for productivity and survival as a function of body mass. Examination of these data indicates that low and often declining breeding productivity at Cape Cod appeared to be more of a factor than low survival at or away from Cape Cod in causing the declines of six of seven declining species: Hermit Thrush, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, and Eastern Towhee, although very low annual adult survival also appeared to be driving the decline in Pine Warbler. Tufted Titmouse was the only declining species having productivity that was as expected or higher than expected relative to its body mass. Very low annual adult survival rates, especially during the latter two winters (2001-02 and 2002-03) of this study, appeared to be driving the population decline in Tufted Titmouse, a species that is near to the northeastern limit of its range on Cape Cod. Because Tufted Titmouse is a permanent resident species, the ultimate environmental cause for its poor survival may be attributable to problems on the Seashore, as is also the case for the other six species showing declines due to low productivity. The one substantially increasing species, Black-capped Chickadee, showed as-expected productivity and higher-than-expected survival. Productivity in this species, however, declined substantially, so we might expect its population to begin to decline in future years. Thus, overall, it appears that poor productivity and, in one case, poor survival at Cape Cod National Seashore, has resulted in declines in landbird populations there.

We must emphasize that the population trends, productivity trends, and adult apparent survival-rate estimates presented here are based on only five years of data from six stations. Thus, the short-term patterns identified may not be representative of the actual long-term, large-scale population dynamics. However, these preliminary results indicate that there may well be serious problems with the productivity of landbirds on Cape Cod National Seashore and with their resulting population trends that should require careful and continued monitoring and, possibly, the implementation of management actions in the near future.

Landbird Habitat Use Patterns on Cape Cod and Their Relationship to Declining Trends

Examination of the effects of habitat characteristics, based on multivariate ANOVA analyses of population size and logistic regression analyses of productivity, suggest that, overall (i.e., for all species pooled and for many individual species), after controlling for all other variables, higher breeding populations of landbirds tended to occur in habitats having an oak canopy rather than a mixed oak/pine or pitch pine canopy, and having a sparse mixed understory rather than a dense blueberry understory, while housing density had little effect. In contrast, higher productivity tended to occur in mixed pine/oak woodland than in oak forest or pitch pine woodland, while both understory and housing density had little effect. These results differed from those of obtained from univariate analyses, thus underscoring the importance of multivariate adjustments.

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. Analogous multivariate logistic regression analyses of productivity indicated that the various target species tended to have their highest productivity in their preferred habitat.

To investigate the relationship between habitat (canopy types) and population trends, we calculated population trends for all species pooled at each of the six Cape Cod MAPS stations, and ran multivariate ANOVA analyses on the resulting Annual Percentage Changes (*APC*s) and *r*-values as a function of the three habitat variables (canopy type, understory type, and housing density class). Each of the two stations in oak forest habitat had substantially more negative population trends than those at any of the other stations. Multivariate ANOVA analyses also showed that more negative population trends tended to be associated with oak forest habitat than with either pine-oak or pitch pine woodland. These results suggest that, for all species pooled, ecological problems associated with oak forest habitat may be adversely affecting the population dynamics of landbirds on Cape Cod National Seashore. Interestingly, for all species pooled, the results of the ANOVAs for population trends more closely mirrored the ANOVAs for productivity than the ANOVAs for population size, providing more evidence that productivity is the primary driving force for the population trends on Cape Cod National Seashore.

To investigate the effect of habitat (canopy type) on the population dynamics of individual species of landbirds on Cape Cod, we classified the 11 target species into three groups based on multivariate ANOVA analyses of indices of adult population size in each of the three canopy types, and calculated population trends for the pooled species in each group. Clearly, the four oak forest specialists (Tufted Titmouse, Gray Catbird, Ovenbird, and Common Yellowthroat) experienced much more negative population trends (mean $APC = -9.7$, mean $r = -0.660$) than the two pitch pine specialists (Pine Warbler and Chipping Sparrow; mean $APC = -0.4$, mean $r = -0.071$), while the habitat generalists (Black-capped Chickadee, Hermit Thrush, American Robin, Eastern Towhee, and American Goldfinch) had intermediate population trends (mean $APC = -7.1$, mean $r = -0.502$) that were, however, much more similar to the oak specialists than to the pitch pine specialists. This provides further evidence that declining populations tend to be associated more with oak forest than with pitch pine habitat, and that ecological problems that are negatively affecting landbird populations may exist in oak forest habitat on the Cape Cod National Seashore. Oak habitat itself appears to be declining on Cape Cod and elsewhere along the Atlantic Seaboard. Indeed, oak habitat appears generally to be declining throughout North America.

Multivariate analyses indicated that population trends for all species pooled were not greatly affected by understory type and housing density class. Moreover, in general, productivity did not differ between declining and non-declining species either as a function of understory type or housing density. However, three of the four species with substantial population declines tended to have lower productivity in high rather than low housing density habitat, while the one species with a substantial population increase (Black-capped Chickadee) tended to have higher productivity in high housing density habitat, suggesting that higher housing density may be weakly associated with lower productivity in species with strongly declining populations.

Thus, overall, the multivariate analyses demonstrate a pattern where declining species tend to be rather strongly associated with (have higher population sizes and more negative population trends) in oak forest habitats, and show a weak tendency, at least for substantially declining species, to have lower productivity in high housing-density areas. This suggests (1) that overall ecological problems may be occurring in the oak forests on Cape Cod National Seashore, and (2) that declining species breeding in higher housing-density areas may be suffering from lower productivity in those areas. We have no explanation at this time concerning what problems may be limiting productivity and survival of the birds inhabiting oak-habitats of Cape Cod National Seashore, but suggest that additional study and management actions are warranted to address these problems. Regarding lower productivity in high housing density areas, one possible explanation may be that pets, such as cats, associated with the housing may be preying upon nestling and fledgling birds in these areas. Interestingly, two of the three species that had did not have deficient (lower-than-expected) productivity on Cape Cod National Seashore were cavity-nesting species (Black-capped Chickadee, Tufted Titmouse) that tend to suffer less nest and fledgling predation than species with open cup nests. That there is only a weak association between high housing density and lowered productivity and declining populations may indicate that even the low density housing is sufficient to produce substantially lowered productivity. Moreover, housing density alone may not provide a reliable indicator of pet density or of the intensity of disturbance associated with the presence of houses. We suggest that the Seashore attempt to raise awareness about potential impact that predation by cats and other pets in the housing areas may have on landbird populations.

Suggestions for Future Work

The initial goal of the first five years of the MAPS Program on Cape Cod National Seashore, to monitor the population sizes and primary demographic parameters of Cape Cod's landbirds in order to provide critical information to aid the understanding of the ecological processes leading from environmental stressors to population responses, has been achieved. With only five years of data, we have been able to provide population trends showing substantial declines in most of the landbird species, productivity indices showing that deficient reproductive success is the likely driving force for many of the population declines, initial estimates of annual adult survival rates that, overall, do not seem to be deficient, and analyses of habitat characteristics that may be influencing the declining trends on the Seashore. Thus, we have shown that the indices and estimates of demographic parameters produced by MAPS are extremely useful for the management and conservation of landbirds at this specific location. In combination with similar data from other areas, we suggest that the demographic information produced by MAPS can be equally useful across all of North America.

These results lead us to suggest that landbird populations on Cape Cod National Seashore are experiencing significant problems that likely have their origin on the Seashore itself and that, if uncorrected, may become more severe in the near future. We suggest that the Seashore take the following steps to address this problem:

(1) Initiate or continue population trend monitoring of landbirds, including the 11 target species analyzed here, over the entire Seashore to determine whether the five-year population declines documented here are continuing and are part of a larger-scale, longer-term phenomenon. The Institute for Bird Populations (IBP) has considerable experiencing designing and implementing large-scale, long-term population trend monitoring protocols for use in national parks, and will be pleased to help achieve this step.

(2) If the declines are found to be continuing or are part of a larger-scale trend, initiate research to identify the ultimate environmental cause(s) of the declines and formulate management actions to reverse the declines. We suggest two approaches here. First, because MAPS data indicate that low productivity is the proximate demographic cause of most of the declines, we suggest a hypothesis-driven effort to monitor nests of individually color-banded birds of several target species in several key habitats. Second, we suggest that modeling MAPS data from the six stations on Cape Cod National Seashore and all other stations along the Atlantic Seaboard of northeastern United States and southeastern Canada as a function of station-specific and landscape-scale habitat characteristics would aid in formulating management actions to reverse the declines. Again, IBP has considerable experience with both of these approaches and will be available to help achieve this step.

(3) Lastly, because management ultimately aims to reverse declines by enhancing one or more specific vital rates (i.e., productivity, recruitment, or survival), truly appropriate effectiveness monitoring requires detailed monitoring of the targeted vital rate(s). Thus, we suggest that renewed operation of appropriately sited MAPS stations be an integral part of the effectiveness monitoring of any managements actions implemented to reverse the declines.

We conclude, therefore, that the MAPS protocol has been well-suited to provide one component of Cape Cod's long-term ecological monitoring program. We hope that the results of the MAPS program will be used to prompt management actions to reverse declining landbird populations on the Seashore, help restore oak habitats, and raise awareness about potential impacts that predation by cats and other pets in the housing-areas may have on landbird populations. We also hope that the MAPS protocol will eventually be used as one component of the effectiveness monitoring of future management actions on the Cape Cod National Seashore.

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) "priority" species, while a major objective of the NPS's 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 five-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 15th year (12th 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 2003. 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: monitoring, research, and management.

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

(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 – 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.

Recent Important Results from MAPS

Recent important results from MAPS reported in the peer-reviewed literature include the following. (1) Age ratios obtained during late summer, population-wide mist netting provided a good index to actual productivity in the Kirtland's Warbler (Bart et al. 1999). (2) Measures of productivity and survival derived from MAPS data were consistent with observed population changes at multiple spatial scales (DeSante et al. 1999). (3) Patterns of productivity from MAPS at two large spatial scales (eastern North America and the Sierra Nevada) not only agreed with those found by direct nest monitoring and those predicted from theoretical considerations, but were in general agreement with current life-history theory and were robust with respect to both time and space (DeSante 2000). (4) Modeling spatial variation in MAPS productivity indices and survival-rate estimates as a function of spatial variation in population trends provides a successful means for identifying the proximate demographic cause(s) of population change at multiple spatial scales (DeSante et al. 2001). (5) Productivity of landbirds breeding in Pacific Northwest national forests is affected by global climate cycles including the El Niño Southern Oscillation and the North Atlantic Oscillation in such a manner that productivity of Neotropical migratory species is determined more by late winter and early spring weather conditions on their wintering grounds than by late spring and summer weather conditions on their breeding grounds (Nott et al. 2002). These results indicate that MAPS is capable of achieving, and in some cases is already achieving, its objectives and goals.

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 five-year operation of the MAPS Program on Cape Cod National Seashore were 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) use 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 was selected for the operation of stations on Cape Cod National Seashore because a minimum of five 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 provides a minimum sample of year-to-year variability in avian productivity and population sizes. With completion of the five years of operation in 2003 we have fulfilled these goals, as detailed in this report.

MAPS data collected at Cape Cod National Seashore has addressed questions at three spatial scales. First, at the smallest scale, MAPS data has provided 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 of, the seashore. The MAPS Program in Cape Cod specifically addressed 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 has been pooled to provide park-wide productivity indices and survivorship estimates and five-year trends in these indices and estimates. Pooling data at this level will also allow comparison between Cape Cod National Seashore and other parks or protected areas along the Atlantic coast that have participated in the MAPS program during this period, 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 have been addressed using MAPS data on Cape Cod. First, MAPS data have been used to provide indices of adult population size and productivity for each of: (a) three habitats types based on canopy characteristics (oak forest, mixed pine/oak woodland, and pitch-pine woodland), and (b) 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 differences in these demographic parameters 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 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 having less than 15 houses/km^2. The information on adult population sizes and productivity that MAPS data has provided will assist with management decisions regarding land-use practices and restoration efforts affecting the succession of habitats necessary for breeding landbirds, including declining species.

Five years of data also allow us to examine the variation over time in survival-rate estimates and, when combined with productivity (as well as indices of adult population size) allows park biologists to determine what effect that their management actions, or lack thereof, have on the primary demographic parameters of the birds species breeding on Cape Cod.

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 – 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 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 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 understory and with low housing density at 12 m elevation near the National Seashore Headquarters northwest of Marconi Beach.

The 2003 Cape Cod MAPS Program
The 2003 Cape Cod field biologist interns, Jasmine McConnell and Mona Lemp, received two weeks of intensive training in a comprehensive course in mist netting and bird-banding techniques given by IBP biologist Amy McAndrews during the first two weeks of May, 2003, at

the Jug Bay Wetland Sanctuary on the shores of the Chesapeake Bay, Maryland. Amy McAndrews continued to supervise the 2003 interns for the duration of the fieldwork at Cape Cod. Amy and the two interns arrived on May 22 to re-establish and begin operation of the stations. The six MAPS stations were re-established on Cape Cod National Seashore in 2003 in exactly the same locations where they were established and operated from 1999 through 2002. Data collection at the six stations began during the period May 28-June 7 (Table 1).

All ten net sites at each station were re-established in the exact same locations as in 1999-2002. One 12-m, 30-mm-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 2003 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 2003 followed MAPS protocol, as established for use by the MAPS Program throughout North America and spelled out in the MAPS Manual (DeSante et al. 2003). 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. 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; when suitable maps from previous years were available, they were updated. 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. 2003a).

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 2003 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 2003) 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 2002 and 2003 in the indices of adult and young population sizes and post-fledging productivity. We 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 "constant-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 "near-significant" or "nearly significant" for differences for which $0.05 \leq P < 0.10$.

B. Multivariate analyses of adult population size and productivity. We conducted multivariate ANOVAs of indices of adult population size (mean number of adult birds captured) and population trend, and logistic regression analyses of 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, productivity, and population trends in a multivariate manner as a function of year, station, and various environmental variables, including habitat (canopy type), understory type, and housing density class.

We used the "relative number of adults," the index of adult population size relative to a reference station, and the "relative population trend," the annual percentage change (*APC*, see below) in population size, as the dependent variables 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, population trend, or odds ratios can be compared. For each multivariate analysis, we chose Longnook Beach as the reference station (or Marconi Beach, if there were no birds captured at Longnook 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 (2003) as the reference year. For the ANOVAs we set the relative number of adults or the population trend 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 dBASE. 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. We examined five-year (1999-2003) 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 five years based on an arbitrary starting index of 1.0 in 1999. Constant-effort changes (as defined above) were used to calculate these "chain" 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 five-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 five-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 "nearly significant" or "near-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 $SE \leq 0.140$ (for five-year population trends) are considered to have a stable trend; and those for which $-0.5 < r < 0.5$ and $SE > 0.140$ 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 > 0.080 (for five-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 five years (1999-2003) 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 ($\phi p \tau$) 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.

The five years of data, 1999-2003, available for using the transient model allowed us to consider all possible combinations of both time-constant and time-dependent models for each of the three parameters estimated, for a total of eight models. We limited our consideration to models that produced estimates for both survival and recapture probability that were neither 0 nor 1. The goodness of fit of the models was tested by using a Pearson's goodness-of-fit test. Of those models that fit the data, the one that produced the lowest Akaike Information Criterion, correcting for dispersion of data and for use with smaller sample sizes relative to the number of parameters examined ($QAIC_C$), was chosen as the optimal model (Burnham et al. 1995). Models showing $QAIC_C$'s within 2.0 $QAIC_C$ units of each other were considered effectively equivalent (Anderson and Burnham 1999). 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.

To assess the degree of annual variation in survival for each species, we calculated $\Delta QAIC_C$ as the difference between the completely time-constant model ($\phi p \tau$) and the model with time-dependent survival but time-constant capture probability and proportion of residents ($\phi_t p \tau$); thus, $\Delta QAIC_C$ was calculated as $QAIC_C(\phi_t p \tau)$-$QAIC_C(\phi p \tau)$, with lower (or more negative) $\Delta QAIC_C$ values indicating stronger interannual variation in survival.

E. Analyses of productivity and survival as a function of mean body mass. In birds, both productivity and survival vary with body mass: on average, the larger the bird the lower the annual productivity and the higher the annual survival. Thus, in order to assess whether or not annual productivity or survival in a given species is higher or lower than expected, body mass needs to be accounted for. We regressed both mean productivity indices and time-constant survival-rate estimates against body mass (log transformed to normalize the values) for the nine target species for which survival-rate estimates were obtained, and compared productivity indices and survival-rate estimates for individual species to the regression lines produced by these fits. We used the log of mean body mass values given by Dunning (1993). In this way we attempted to assess whether or not productivity and survival of a given species on the Cape Cod National Seashore was as expected, lower than expected, or higher than expected based on its body mass.

RESULTS

A total of 1932.7 net-hours was accumulated at the six MAPS stations operated in Cape Cod National Seashore in 2003 (Table 1). Data from 1806.5 of these net-hours could be compared directly to 2002 data in a constant-effort manner.

Indices of Adult Population Size and Post-fledging Productivity

A. 2003 values. The 2003 capture summary of the numbers of newly-banded, unbanded, and recaptured birds on the 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 208 captures of 28 species was recorded during 2003. Newly banded birds comprised 70.7% of the total captures. The greatest number of total captures was recorded at the Marconi Beach station (55), followed in descending order by Nauset School (43), Longnook Beach (37), Higgins House (30), Blueberry Hill (23), and Oak Dunes (20). The highest species richness was recorded at Nasuet School (17 species) and the lowest species richness was recorded at Higgins House (7 species). Among individual species, Black-capped Chickadee was the most frequently captured, followed by Chipping Sparrow, Ovenbird, Pine Warbler, Common Yellowthroat, American Goldfinch, and Hermit Thrush (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 highest adult population sizes were recorded at Marconi Beach (72.8 adults/600net-hours), followed in descending order by Nauset School (60.1), Longnook Beach (49.3), Higgins House (47.1), Blueberry Hill (35.3), and Oak Dunes (27.5). The capture rate of young in 2003 followed a different order, being highest by far at Nauset School (16.9 young/600 net-hours), followed in descending order by Marconi Beach (5.3), Blueberry Hill (4.2), Higgins House (1.9), Loognook Beach (1.8), and Oak Dunes (0.0). Productivity (proportion of young in the catch) followed a rather similar sequence to numbers of young, with the highest productivity by far at Nauset School (0.22), followed in descending order by Blueberry Hill (0.11), Marconi Beach (0.07), Higgins House (0.04), Longnook Beach (0.03), and Oak Dunes (0.00).

Overall, the most abundant breeding species at the six Cape Cod MAPS stations in 2003 (captured at a rate of at least 2.0 adults per 600 net-hours), in decreasing order, were Black-capped Chickadee, Pine Warbler, Ovenbird, Chipping Sparrow, American Goldfinch, Common Yellowthroat, and Hermit Thrush (Table 4). 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 2003 (see Table 3):

Longnook Beach	**Oak Dunes**	**Higgins House**
Black-capped Chickadee	Ovenbird	Black-capped Chickadee
Common Yellowthroat	Pine Warbler	Pine Warbler
Ovenbird	Black-and-white Warbler	Chipping Sparrow
Tufted Titmouse		Hermit Thrush
Eastern Towhee	**Nauset School**	American Robin
	Black-capped Chickadee	
Blueberry Hill	Gray Catbird	**Marconi Beach**
Ovenbird	Pine Warbler	Chipping Sparrow
Downy Woodpecker	Tufted Titmouse	Black-capped Chickadee
Pine Warbler	Northern Cardinal	Pine Warbler
Black-capped Chickadee	Eastern Wood-Pewee	Cedar Waxwing
		Eastern Towhee

B. Comparisons between 2002 and 2003. Constant-effort comparisons between 2002 and 2003 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 2002 and 2003 by a non-significant -10.1% (Table 5). This decrease is similar to that recorded between 2001 and 2002, thus making a second consecutive year of population decline at Cape Cod. Sixteen of 28 species at all stations combined showed decreases, a proportion that was not significantly greater than 0.50. The change in adult population size for all species pooled showed decreases at five of the six stations by amounts ranging from -3.0% at Marconi Beach to -32.0% at Blueberry Hill; however, an increase of 25.0% was recorded at Higgins House. The proportion of increasing or decreasing species was not significantly greater than 0.50 at any station. Among individual species, only Hermit Thrush -- with a highly significant decrease -- showed a significant or near-significant change in the number of adult birds captured at all stations combined.

The number of young birds captured of all species pooled for all stations combined in Cape Cod National Seashore showed a highly significant decrease of -56.8% between 2002 and 2003 (Table 6). However, only six of 13 species at all stations combined showed decreases, a proportion not significantly greater than 0.50. Number of young birds captured showed decreases at all six stations, by amounts ranging from -40.0% at Marconi Beach to -100.0% at Oak Dunes where no young birds were captured during the entire season. The proportion of increasing or decreasing species was not significantly greater than 0.50 at any station. The number of young Black-capped Chickadees and Tufted Titmice, two of the commoner species on Cape Code, showed highly significant and significant decreases, respectively, between 2002 and 2003 for all stations combined; no species showed significant or near-significant increases.

Productivity (the proportion of young in the catch) in 2003 also decreased, by a non-significant absolute value of -0.089, from 0.190 in 2002 to 0.101 in 2003 (Table 7). Six of 20 species decreased overall, a non-significant proportion. Productivity decreased at all six stations, by amounts ranging from -0.033 at Blueberry Hill to -0.161 at Longnook Beach. No station showed significant or near-significant proportions of increasing or decreasing species and no species showed significant or near-significant decreases or increases for all stations combined.

Thus, the numbers of adults and young captured and productivity all decreased between 2002 and 2003, similar to changes from 2001 to 2002 but opposite to changes between 2000 and 2001, when all three parameters increased. The decrease in young captured was significant, but appeared to result primarily from significant decreases in only two common species, Black-capped Chickadee and Tufted Titmouse. Except for an increase in the number of adults at Higgins House, the decreases in all three parameters occurred at all six stations and thus appeared to be park-wide.

C. Mean values for the five years, 1999-2003. 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 five-year period 1999-2003 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 five-year period occurred at Marconi Beach (71.0 adults/600 net-hours), followed by Nauset School (63.4), Higgins House (57.3), Longnook Beach (56.9), Oak Dunes (44.0), and, finally, Blueberry Hill (38.5). The mean index of adult population size for the five year for all species pooled at all stations combined was 55.2 adults/600 net hours. Five-year productivity (proportion of young in the catch) values showed a different pattern, being highest at Nauset School (0.24), followed by Blueberry Hill (0.20), Longnook and Marconi Beachs (0.14 each), Higgins House (0.13), and, finally, Oak Dunes (0.08). The mean productivity index for the five year for all species pooled at all stations combined was 0.17.

Mean adults captured at the two pitch-pine stations (64.2; Higgins House and Marconi Beach) tended to be higher than that at the two mixed pine/oak woodland stations (51.0; Nauset School and Blueberry Hill) which, in turn, tended to be slightly higher than that at the two oak-forest stations (50.4; Longnook Beach and Oak Dunes). However, this order has varied interannually; for example, in 2002, the two mixed pine/oak woodland stations showed the highest adult population sizes. Mean adults captured at the three sparse-understory stations (63.9; Nauset School, Higgins House, and Marconi Beach) were much higher than at the three dense-understory stations (46.5; Longnook Beach, Oak Dunes, and Blueberry Hill), while mean adults captured at the three high-density-housing stations (59.2; Longnook Beach, Nauset School, and Higgins House) tended to be higher than at the three low-density-housing stations (51.2; Oak Dunes, Blueberry Hill, and Marconi Beach).

Captures of young of all species pooled tended to be highest at the two mixed pine/oak woodland stations (16.2), followed by those at the two pitch pine stations (10.9) and the two oak forest stations (8.1). Mean young captured at the three sparse understory stations (13.9) tended to be higher than that at the three dense understory stations (9.5), and mean young captured at the three high housing density stations (13.4) tended to be greater than at the three low housing density stations (10.0). Mean productivity, as determined by the proportion of young in the catch, was highest at the two mixed pine/oak stations (0.22), followed by productivity at the two pitch-pine stations (0.14) and productivity at the two oak-forest stations (0.11); mean productivity at the three sparse-understory stations (0.17) tended to be higher than at the three dense understory stations (0.14); and mean productivity at the three high housing density stations (0.17) tended to be greater than at the three low housing density stations (0.14).

Thus, during the five-year period, the highest breeding populations of landbirds, according to univariate analyses, occurred in pitch-pine canopy with sparse understory and in high-density housing areas, while the highest productivity occurred in the mixed pine/oak woodland stations with sparse understory and in high-density housing areas. However, multivariate analyses on all species pooled, adjusting for all other variables, revealed quite different results (see below).

D. Multivariate analyses of adult population size and productivity. Figures 1-12 present the results for multivariate ANOVA analyses of adult population size and multivariate logistic regression analyses of productivity for all species pooled and for 11 target species, using the four design variables, year, habitat (canopy type), understory type, and housing density class and, in a separate analysis, comparing stations while adjusting for year.

Controlling for the three non-temporal variables, habitat (canopy type), understory, and housing density, adult population size of all species pooled was higher in 1999 (the reference year) than during all subsequent years and was significantly or near-significantly higher in 1999 than in 2000, 2002, and 2003 (Fig. 1A). Controlling for the other three variables, higher breeding populations were recorded in oak forest habitat than in mixed pine/oak or pitch pine woodland, with that of mixed pine/oak woodland being near-significantly lower (Fig. 1B). Controlling for the other variables, breeding populations in sparse understory were significantly higher than those of dense understory (Fig. 1C). Controlling for the other variables, breeding populations showed little variation between low and high housing-density areas (Fig. 1D). Finally, controlling for year, breeding populations were significantly higher and lower at Marconi Beach and Blueberry Hill, respectively, than at the reference station, Longnook Beach (Fig. 1E).

Controlling for the three non-temporal variables, habitat (canopy) type, understory, and housing density, productivity showed the same pattern as breeding population size, being higher in 1999 (the reference year) than during all subsequent years and being significantly higher in 1999 than in 2000, 2002, and 2003 (Fig. 1G). Controlling for the other three design variables, significantly lower productivity was recorded in oak forest than in mixed pine/oak or pitch pine woodland, with that of mixed pine/oak woodland being highly significantly greater than that of oak forest, the reference habitat (Fig. 1H). Controlling for the other design variables, productivity showed little variation as a function of understory or housing density(Fig. 1I-J). Finally, controlling for year, productivity of all species pooled was significantly higher at Nauset School and Blueberry Hill than it was at the reference station, Longnook Beach (Fig. 1F).

Thus, for all species pooled, according to multivariate analyses, the highest breeding populations of landbirds occurred in oak forest habitat and sparse understories, with housing density having little effect. The highest productivity, however, occurred in mixed pine/oak woodland, with both understory and housing density having little effect. These results differ from those of univariate analysis (Table 8; see above) which indicated that the highest breeding populations occurred in mixed pine/oak habitat and in high-density housing areas and that productivity was markedly better in sparse understory and high-density housing areas. These differences underscore the importance of multivariate analyses.

Results of these multivariate analyses for 11 target species are shown in Figs. 2-12. Sufficient data for logistic regression analyses on productivity were not available for American Goldfinch (for any analysis) or for American Robin, Pine Warbler, and Common Yellowthroat (habitat and housing-density analyses). The interannual patterns noted above, with 1999 showing higher (and at times significantly higher) breeding populations and productivity than subsequent years, were generally shown for breeding populations of American Robin, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch, and for productivity of Black-capped Chickadee, Tufted Titmouse, Gray Catbird, Ovenbird, Common Yellowthroat, and Eastern Towhee. Significantly higher productivity in 2001 than in 1999 for Chipping Sparrow (Fig. 11G) was the only case in which another year was significantly or near-significantly higher than 1999 for either population size or productivity. More detail on trends in population sizes and productivity in these species is presented in the next section, below.

Relative to the reference canopy habitat type (oak forest), significant or near-significant differences were noted for breeding populations of Tufted Titmouse (lower in pines; Fig. 3B), Gray Catbird (lower in pines; Fig. 6B), Pine Warbler (higher in pines; Fig. 7B), Ovenbird (lower in pines; Fig. 8B), Common Yellowthroat (lower in mixed pine/oak; Fig. 9B), and Chipping Sparrow (higher in pines; Fig. 11B); and for productivity of Black-capped Chickadee (higher in mixed pine/oak; Fig. 2H), Hermit Thrush (lower in mixed pine/oak; Fig. 4H), Ovenbird (lower in pine forest; Fig. 8H), and Eastern Towhee (lower in both pine/oak and pines; Fig. 10H). These are generally expected results given the life histories and habitat preferences of these species.

Relative to the reference understory type, significant or near-significant differences were noted for breeding populations of Tufted Titmouse (higher in sparser understory; Fig. 3C), Gray Catbird (higher in sparser understory; Fig. 6C), Common Yellowthroat (higher in denser understory; Fig. 9C), and American Goldfinch (higher in sparser understory; Fig. 12C); and for productivity of Gray Catbird (higher in sparser understory; Fig. 2I) and Eastern Towhee (higher in denser understory; Fig. 10I). Thus, there was a general tendency toward higher population sizes in sparser than in denser understory, but no overall tendency for differences in productivity as a function of understory.

Relative to the reference housing-density category, significant or near-significant differences were noted for breeding populations of Tufted Titmouse (higher in high-density housing areas; Fig. 3D), Pine Warbler (higher in low-density housing areas; Fig. 7D), Common Yellowthroat (higher in high-density housing areas; Fig. 9D), Chipping Sparrow (higher in low-density housing areas; Fig. 11D), and American Goldfinch (higher in low-density housing areas; Fig. 11D); and for productivity of Gray Catbird (higher in high-density housing areas; Fig. 2J), Ovenbird (higher in high-density housing areas; Fig. 8J), and Eastern Towhee (higher in low-density housing areas; Fig. 10J). Thus, there was no overall tendency toward higher population sizes or productivity in either high or low housing density.

Differences by station among species often followed those of all species pooled, where significantly higher breeding populations were noted at Marconi Beach, significantly lower populations were noted at Blueberry Hill, and significantly higher productivity rates were noted at Nauset School and Blueberry Hill than at the reference station, Longnook Beach. Many other significant or near-significant differences, at variance with these patterns, were noted (Figs. 2-12 E-F), generally similar to the significant habitat and housing-density differences noted above.

E. Five-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 nine of the 11 species ($P = 0.065$, two-sided binomial test), as well as all species pooled, were negative over the five years, 1999-2003, with only Black-capped Chickadee and Chipping Sparrow showing positive trends. Moreover, the decreasing trends for seven (Tufted Titmouse, Hermit Thrush, American Robin, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the nine species, as well as all species pooled, were substantial ($r \leq -0.5$). The five-year decline of American Robin was significant, while the declines of Common Yellowthroat, American Goldfinch, and all species pooled were nearly significant. By contrast, just one species, Black-capped Chickadee, showed a substantial ($r \geq +0.5$), but non-significant, increase. The annual percentage change (*APC*) in declining species between 1999 and 2003 varied from -16.0% per year for American Robin to -4.2% for Ovenbird, and was a nearly-significant -4.7% for all species pooled. The annual percentage changes in the two increasing species were +3.6 for Black-capped Chickadee and +3.8 for Chipping Sparrow. For eight of the 11 species and all species pooled, 1999 had the highest, or tied for the highest, capture rate of adults over the five-year period.

Five-year (1999-2003) productivity trends (Fig. 14) were negative for six of the 11 species and for all species pooled, and were positive for five species. The trends for five (Black-capped Chickadee, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the six species with negative productivity trends, as well as all species pooled, were substantial ($r \leq -0.5$), with those of Gray Catbird and Eastern Towhee being significant. The trends of two (Hermit Thrush and American Robin) of the five species with positive productivity trends were also substantial ($r \geq 0.5$), with that of Hermit Thrush being nearly significant. The 1999-2003 productivity trends varied from -0.077 for Eastern Towhee to +0.043 for Hermit Thrush, and was -0.019 for all species pooled.

In order to determine the effects of the various habitat characteristics on the population trends of Cape Cod landbirds, we calculated population trends for all species pooled at each of the six individual Cape Cod MAPS stations (Fig. 15), and ran multivariate ANOVA analyses (Fig. 16) on the resulting Annual Percentage Changes (*APC*s) and *r* values as a function of the three habitat variables (canopy type, understory type, and housing density class). Because of the relatively small sample sizes for most species at the individual Cape Cod MAPS stations, we did not calculate population trends for individual species at individual stations.

Figure 15 presents population trends for all species pooled at each of the six individual MAPS stations. Each of the two stations in oak forest habitat had substantial negative population trends; the negative trend was nearly significant at the Longnook Beach station. The trends for the two pitch pine woodland stations were also negative, but not nearly as negative as those in oak forest habitat. Interestingly, the population trends at the two mixed oak/pine woodland stations were much less negative than at any of the other stations; the trend actually was positive at the Blueberry Hill station.

Multivariate ANOVA analyses confirmed that oak forest habitat tended to be associated with more negative population trends than either of the other two habitats types, nearly significantly so compared to mixed oak/pine woodland (Fig. 16). Similar results were obtained using either the Annual Percentage Change (*APC*) or the *r* value of the population trends. There was a very slight and non-significant tendency for more negative population trends to be associated with sparse mixed understory rather than dense blueberry understory. Housing density class clearly had no effect on the population trends of all species pooled. Interestingly, for all species pooled, the results of the ANOVAs for population trends (Fig. 16) more closely mirrored the ANOVAs for productivity than the ANOVAs for population size (Fig. 1), suggesting that productivity might be the driving force for most of the population trends on the Cape Cod National Seashore.

Estimates of Adult Survivorship

Using five years of data from all six stations combined, estimates of apparent adult survival probability, recapture probability, and proportion of residents could be obtained for nine of the 11 target species breeding at Cape Cod, an increase from the seven species after four years of data had been collected. Estimates could not be obtained for the remaining two species, American Robin and American Goldfinch, due to insufficient between-year recaptures.

Because of the existence of floaters, failed breeders, and dispersing adults, transient models, which account for the proportion of residents in the population, produce less biased estimates of adult survivorship than do non-transient models. Thus, we only present the results of transient models. Table 9 indicates that, for seven of nine species, the time-constant transient model ($\phi p \tau$) was selected over all time-dependent transient models (by having a $QAIC_C$ that was at least 2.0 $QAIC_C$ units lower than any other model). For Tufted Titmouse, models showing time-dependence in both survival ($\phi_t p \tau$) and capture probability ($\phi p_t \tau$) were equivalent to (within 2.0 $QAIC_C$ units of) the fully time-constant model, and for Hermit Thrush the model showing time-dependence in proportion of residents ($\phi p \tau_t$) was equivalent to the time-constant model.

$\Delta QAIC_C$ (see Methods), a measure of the degree to which adult survival varied with time over the five-year period, ranged from -1.7 in Tufted Titmouse (indicating that time-dependent survival was the selected model; see below) to 7.9 in Gray Catbird (indicating only slight time-dependence in survival). $\Delta QAIC_C$ averaged 4.4 for the nine species (Table 9), indicating a moderate amount of time-dependence in survival overall.

For each target species, Table 10 presents the maximum-likelihood estimates and standard errors for adult survival probability, recapture probability, and the proportion of residents for the fully time-constant model and for equivalent time-dependent models selected in Table 9, along with precision (Coefficients of Variation, CV) of the estimates of survival probability. Survivorship estimates for the nine species (Table 10), using time-constant models, ranged from a low of 0.167 for Tufted Titmouse to a high of 0.677 for Eastern Towhee, with a mean of 0.506. Recapture probability ranged from a low of 0.172 for Eastern Towhee to a high of 1.000 for Tufted Titmouse, with a mean of 0.488. Proportion of residents varied from a low of 0.247 for Ovenbird to a high of 1.000 for Tufted Titmouse and Chipping Sparrow, with a mean of 0.631.

Tufted Titmouse was the only species for which time-dependent survival was the selected model. Overwintering survival for this species was very low during 2001-02 and 2002-03 and higher (but still relatively low) during 1999-2000 and 2000-01 (Table 10). This variation likely reflects overwintering conditions in New England. Recapture probability for Tufted Titmouse showed the same pattern, being relatively low in 2002 and 2003 and relatively high in 2000 and 2001. For Hermit Thrush, proportion of residents was low in 2001 and 2002 and was relatively high in 1999 and 2000. We currently have no explanation for variation in recapture probability or proportion of residents, although it is apparent that population dynamics have changed during the last two years of the study in comparison to the first two years.

Productivity and Survival as a Function of Body Mass

It has been shown that both productivity and survival in birds vary with body mass: on average, the larger the bird the lower the productivity and the higher the survival. Thus, to assess whether or not productivity or survival in a given species is higher or lower than expected, body mass must be accounted for. Figure 17 shows (A) mean productivity indices and (B) time-constant annual adult survival rate estimates on Cape Cod National Seashore as a function of mean body mass (log transformed) for the nine target species for which survival could be estimated using data from all six stations combined (survival-rate estimates could not be obtained for American Robin or American Goldfinch). The purpose of this analysis was to determine which species on Cape Cod showed higher or lower productivity or survival than might be expected given their body mass. Two regression lines are presented on each graph, one (solid) for the nine target species using data from Cape Cod National Seashore, and one (dashed) using data from 210 (productivity) and 89 (survival) species for which these parameters could be estimated from MAPS data collected from stations distributed across the entire North American continent.

It is apparent from Figure 17 that, in general, productivity at Cape Cod was much lower than in North America as a whole, although the relation between productivity and body mass at Cape Cod was similar (i.e., had a similar slope) to the relation between productivity and body mass for North America as a whole. In contrast, the regression line for adult survival rate at Cape Cod was very similar in both slope and actual values to that for North America as a whole.

Seven of the nine species shown in Figure 17 (species alpha codes in bold uppercase letters) showed population declines (see Fig. 13). Six of these seven species, Hermit Thrush (HETH), Gray Catbird (GRCA), Pine Warbler (PIWA),Ovenbird (OVEN), Common Yellowthroat (COYE), and Eastern Towhee (EATO), showed substantially lower-than-expected productivity, at least as compared to the relationship between productivity and body mass over North America as a whole. Pine Warbler also showed lower-than-expected adult survival, while adult survival rates for the other five species were as expected or higher than expected. Of the seven declining species, only Tufted Titmouse (TUTI) showed as-expected or higher-than-expected productivity; its survival rate, however, was much lower than expected.

The remaining two species (Black-capped Chickadee and Chipping Sparrow; shown in Fig. 15 in regular lowercase letters) showed population increases (*s*ee Fig.13). Both of these species showed as-expected productivity and as-expected or, in the case of Black-capped Chickadee at least, higher-than-expected adult survival. Thus, it appears that very low productivity is driving the population declines of six of the seven declining species, while very low adult survival is driving the population decline of the seventh species and contributing to the population decline of one of the other six species. Higher than expected adult survival (coupled with as-expected productivity) appears to be driving the substantial population increase in Black-capped Chickadee. It is interesting that Chipping Sparrow has the weakest (most stable; r = +0.295) population trend of any of the nine species as well as the most as-expected vital rates, with slightly high adult survival tending to counter-balance slightly low productivity.

Causes of Population Declines and Increases Based on Demographic Data

Based on a synthesis of productivity indices, productivity trends, survival estimates, $\Delta QAIC_C$ values, and, especially, the productivity and survival values at Cape Cod relative to continent-wide relationships for productivity and survivorship as a function of body mass, we made assessments as to whether population declines or increases at Cape Cod were driven by productivity on the breeding grounds, survival presumably during migration and/or on the winter grounds, or both (Table 11). As an example, for Gray Catbird, a species with a substantially decreasing population (-13.9% per year; Fig. 13), productivity was very low (0.05; based on the 5-year mean for all stations pooled from Table 8), the productivity trend showed a decreasing tendency (-0.043 per year; Fig. 14), survival was moderate to high (0.547; Table 10), $\Delta QAIC_C$ was relatively high (+7.9; Table 9) indicating little annual variation in survival, and productivity was much lower than expected while survival was as expected relative to body mass (Fig. 17). In this case, the evidence strongly suggests that dramatically low productivity has been driving the substantial population decline for Gray Catbird on Cape Cod National Seashore.

We conclude that low productivity is driving the population declines of six (Hermit Thrush, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, and Eastern Towhee) of the seven substantially declining species, while low adult survival, especially during some years, is driving the decline of Tufted Titmouse and contributing to the decline in Pine Warbler; and that slightly or definitely high survival is driving the slight and substantial population increases of Chipping Sparrow and Black-capped Chickadee, respectively, on Cape Cod National Seashore.

DISCUSSION OF RESULTS AND CONCLUSIONS

Five-Year (1999-2003) Population Dynamics and Vital Rates of Cape Cod's Landbirds
The numbers of adults captured, the numbers of young captured, and productivity all declined between 2002 and 2003, thus continuing the very similar declines recorded between 2001 and 2002. The decrease in numbers of young captured between 2002 and 2003 was significant, but appeared to result primarily from significant decreases in two common species, Black-capped Chickadee and Tufted Titmouse. Except for an increase in the number of adults at Higgins House, the decreases in all three parameters occurred at all six stations and thus appeared to be park-wide. The substantial decreases in both population size and productivity during the final two years of the study were mirrored by multivariate ANOVAs of adult population size and multivariate logistic regression analyses of productivity that indicated that both of these measures were greater, and often significantly greater, during the first year of the study, 1999, than during the each of the four subsequent years.

All of these results were further reflected in the substantial five-year declines in both population size and productivity of landbirds on Cape Cod National Seashore. Indeed, population trends for nine of 11 target species, as well as all species pooled, were negative over the five years, 1999-2003, with only two species showing positive trends. Moreover, the decreasing trends for seven (Tufted Titmouse, Hermit Thrush, American Robin, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the nine species, as well as all species pooled, were substantial ($r \leq -0.5$), with the five-year declines of three species and all species pooled being significant or nearly significant. By contrast, just one species, Black-capped Chickadee, showed a substantial ($r \geq 0.5$), but non-significant, increase. The annual percentage change between 1999 and 2003 in populations of all species pooled was -4.7%, which suggests that total landbird populations on the Cape Cod National Seashore declined by as much as 18% between 1999 and 2003, a very substantial amount over such a short time period.

Likewise, five-year (1999-2003) productivity trends were negative for six of the 11 species and all species pooled. The trends for five (Black-capped Chickadee, Gray Catbird, Common Yellowthroat, Eastern Towhee, and American Goldfinch) of the six species with negative productivity trends, as well as all species pooled, were substantial ($r \leq -0.5$), with those of Gray Catbird and Eastern Towhee being significant. In contrast, the trends of only two (Hermit Thrush and American Robin) of the five species with positive productivity trends were substantial ($r \geq 0.5$), with that of Hermit Thrush being nearly significant. The five-year productivity trend for all species pooled was -0.019 per year, which suggests that productivity of landbirds on Cape Cod National Seashore declined by as much as 37%, from about 0.208 to about 0.132, between 1999 and 2003.

It is also important to point out that total population size of landbirds (as indexed by the mean number of captures of adults of all species pooled at all stations combined over the five years) on Cape Cod National Seashore (55.2 birds per 600 net hours [b/600nh]) was low compared to most other MAPS locations across North America, and was even lower than other locations along the Atlantic Seaboard, where populations tend to be lower than at other locations in North America. For example, indices of adult population size at 11 locations in western North America ranged from 87.3 b/600nh on Mt. Baker National Forest (WA) to 229.6 b/600nh in Yosemite National Park (CA) and averaged 122.7 b/600nh (112.1 b/600nh after eliminating the exceptionally high index from Yosemite), more than twice as high as the index for Cape Cod National Seashore. Indices of adult population size at six locations in the Midwest ranged from 58.4 b/600nh at Fort Knox (KY) to 128.1 b/600nh at Crane Naval Surface Warfare Center (IN) and averaged 98.2 b/600nh; and ranged from 60.5 b/600nh at Fort Belvoir (VA) to 97.5 b/600nh at Shenandoah National Park (VA) and averaged 76.5 b/600nh at seven other locations in the Appalachians and along the Atlantic Seaboard. Only at three locations in Texas, where they ranged from 41.4 b/600nh at Camp Swift to 71.2 b/600nh at Fort Hood and averaged 53.5 b/600nh, were population sizes as low as on the Cape Cod National Seashore.

It should also be noted that mean productivity (as indexed by the mean proportion of young in the catch for all species pooled at all stations combined over the five years (0.17) on Cape Cod National Seashore was also low compared to most other MAPS locations across North America. Again, for example, productivity at 11 locations in western North America ranged from 0.15 at Siuslaw National Forest (OR) to 0.49 at Denali National Park (AK) and averaged 0.32; ranged from 0.24 at Camp Bowie to 0.46 at Fort Hood and averaged 0.32 at three locations in Texas; ranged from 0.17 at Fort Knox (KY) to 0.30 at Crane NSWC (IN) and averaged 0.24 at six locations in the Midwest; and ranged from 0.12 at Fort Bragg (NC) to 0.47 at NSGA Sugar Grove (WV) and averaged 0.26 at seven other locations in the Appalachians and along the Atlantic Seaboard.

As mentioned in last year's report, species richness was also low on Cape Cod National Seashore compared to other MAPS locations. This may be a biogeographic result of the narrow peninsular nature of Cape Cod, a geographic characteristic that generally tends to lead to low species richness for much the same reasons that islands have low species richness. It is possible that the total population sizes detected on Cape Cod National Seashore are a result, at least in part, of the low species richness. The fact that productivity also tends to be low on Cape Cod National Seashore compared to other MAPS locations suggests that landbird habitat on Cape Cod may be sub-optimal and may relate to a low species richness and/or abundance of 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.

It is also possible that the substantial population declines documented during the five years of this study are part of a longer-term decline. If this is the case, then the low population sizes documented on Cape Cod could be a result of the declines and represent substantially depressed populations. Recall that we have documented an 18% decline in total populations on Cape Cod between 1999 and 2003. If these declines have been ongoing for only nine years, that is since 1995, they would have resulted in a 32% decline in the total population size. Interestingly, the index of total population size on Cape Cod, 55.2 b/600nh, is 28% lower than then mean index for the seven other locations in the Appalachians and along the Atlantic Seaboard, a result roughly in accordance with the projected decline. If these population declines of -4.7% per year have indeed been on-going for more than the five years documented here, and have been caused by anthropogenic factors, then they should be cause for considerable concern on Cape Cod National Seashore and concerted efforts should be undertaken immediately to begin to reverse them.

Using five years of mark-recapture data, we obtained estimates of annual adult apparent survival rates, recapture probabilities, and proportions of residents among newly captured adults for nine of the 11 target species breeding on the Cape Cod National Seashore. The mean time-constant survival-rate estimate for the nine species, 0.506, was relatively high compared to other MAPS locations, with estimates for all of the nine species except Tufted Titmouse and Pine Warbler being greater than 0.525, in itself a relatively high survival rate for a small landbird. Because only five years of mark-recapture data were available (only one more than the minimum number of years [four] needed to be able to obtain an estimate using the transient model), however, the precision of the survival-rate estimates was low. Despite this low precision, $\Delta QAIC_C$ values averaged 4.4 for the nine species, indicating a moderate amount of time-dependence in survival overall, with Tufted Titmouse showing a high degree of time-dependence. Simulations by Rosenberg (1996) and Rosenberg et al. (1999), suggest that maximum precision of survival rate estimates may not be obtained until 12 or more years of data are available. Obviously, many additional years of data will be necessary to provide survival-rate estimates with more precision and to investigate in detail time-dependence in survival.

Determining the Cause of the Population Declines at Cape Cod National Seashore

A primary goal of MAPS is to determine the proximate demographic cause(s) of population declines in target 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, for each of the declining species at Cape Cod, five-year mean productivity indices and productivity trends, mean annual adult apparent survival rates and a measure of their interannual variability, and, especially, their productivity and survival values at Cape Cod relative to continent-wide relationships for productivity and survivorship as a function of body mass. Examination of these data indicates that low and often declining breeding productivity at Cape Cod appears to be more of a factor than low survival at or away from Cape Cod in causing the declines of six of seven declining species: Hermit Thrush, Gray Catbird, Pine Warbler, Ovenbird, Common Yellowthroat, and Eastern Towhee, although very low annual adult survival also appears to be driving the decline in Pine Warbler. Tufted Titmouse was the only declining species having productivity that was as expected or higher than expected relative to its body mass. Very low annual adult survival rates, especially during the latter two winters (2001-02 and 2002-03) of this study, appear to be the primary demographic cause of population decline in Tufted Titmouse, a species that is near to the northeastern limit of its range on Cape Cod. Because Tufted Titmouse is a permanent resident species, the ultimate environmental cause for its poor survival may be attributable to problems on the Seashore, as is the case for the other six species showing declines due to low productivity. The one substantially increasing species, Black-capped Chickadee, showed as-expected productivity and higher-than-expected survival. Productivity in this species, however, declined substantially, so we might expect its population to begin to decline in future years. Thus, overall, it appears that poor productivity and, in one case, poor survival at Cape Cod National Seashore, has resulted in declines in landbird populations there.

We must re-emphasize that the population trends, productivity trends, and adult apparent survival-rate estimates presented here are based on only five years of data from six stations. Thus, the short-term patterns identified may not be representative of the true long-term, large-scale population dynamics. However, these preliminary results indicate that there may be serious problems with the productivity of landbirds on Cape Cod National Seashore and with their resulting population trends that will require careful and continued monitoring and, possibly, the implementation of management actions in the near future.

Landbird Habitat Use Patterns on Cape Cod and Their Relationship to Declining Trends
Examination of the effects of habitat characteristics, based on multivariate ANOVA analyses of population size and logistic regression analyses of productivity, suggest that, overall (i.e., for all species pooled and for many individual species), after controlling for all other variables, higher breeding populations of landbirds occurred in habitats having an oak canopy rather than a mixed oak/pine or pitch pine canopy, and having a sparse mixed understory rather than a dense blueberry understory, while housing density had little effect. In contrast, higher productivity occurred in mixed pine/oak woodland than in oak forest or pitch pine woodland, while both understory and housing density had little effect. These results differed from those of obtained from univariate analyses, thus underscoring the importance of multivariate adjustments.

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. Analogous multivariate logistic regression analyses of productivity indicated that the various target species tended to have their highest productivity in their preferred habitat.

Because highest population sizes for all species pooled and for most individual species occurred in oak forest habitat, and because most species showed population declines, it is not surprising that eight of the nine declining species had populations that were as high or higher in oak forest habitat than in habitats with other canopy types. Among declining species, only Pine Warbler, a pine specialist, preferred mixed pine/oak woodland and, especially, pitch pine woodland over oak forest habitat. Interestingly, one (Chipping Sparrow) of the two non-declining species had its highest numbers in pitch pine woodland rather than oak forest, while the other (Black-capped Chickadee) showed no clear preference for oak forest over the other two habitats, suggesting that declining species may tend to be more associated with oak forests than with other habitats.

In order to see more clearly the relationship between habitat (canopy types) and population trends, we calculated population trends for all species pooled at each of the six individual Cape Cod MAPS stations, and ran multivariate ANOVA analyses on the resulting Annual Percentage Changes (*APC*s) and r values as a function of the three habitat variables (canopy type, understory type, and housing density class). Both of the two stations in oak forest habitat had substantially more negative population trends than those at any of the other stations; the negative trend was nearly significant at the oak forest station, Longnook Beach. Multivariate ANOVA analyses also showed that more negative population trends tended to be associated with oak forest habitat than with either of the other two habitats types and were near-significantly more negative for oak forest than for mixed oak/pine woodland. These results suggest that, for all species pooled, ecological problems associated with oak forest habitat may be adversely affecting the population dynamics of landbirds on Cape Cod National Seashore. Interestingly, for all species pooled, the results of the ANOVAs for population trends (Fig. 16) more closely mirrored the ANOVAs for productivity (Fig. 1) than the ANOVAs for population size (Fig. 1), providing additional evidence that productivity is the primary driving force for the population trends on Cape Cod National Seashore.

To investigate the effect of habitat (canopy type) on the population dynamics of individual species of landbirds on Cape Cod, we classified the 11 target species into three groups based on multivariate ANOVA analyses of indices of adult population size in each of the three canopy types: (1) oak specialists (Tufted Titmouse, Gray Catbird, Ovenbird, and Common Yellowthroat) that had higher population sizes in oak forest than in the other two canopy types; (2) pitch pine specialists (Pine Warbler and Chipping Sparrow) that had higher population sizes in pitch pine woodland than in the other two canopy types; and (3) habitat generalists (Black-capped Chickadee, Hermit Thrush, American Robin, Eastern Towhee, and American Goldfinch) that occurred in all three habitat types in roughly similar numbers. We then calculated mean annual percentage changes (*APC*s) and mean r values for each of the three groups. Clearly, the four oak forest specialists experienced much more negative population trends (mean $APC = -9.7$, mean $r = -0.660$) than the two pitch pine specialists (mean $APC = -0.4$, mean $r = -0.071$), while the habitat generalists had intermediate population trends (mean $APC = -7.1$, mean $r = -0.502$) that were, however, much more similar to the oak specialists than to the pitch pine specialists. This provides further evidence that declining populations tend to be associated more with oak forest than with pitch pine habitat, and that ecological problems that are negatively affecting landbird populations may exist in oak forest habitat on the Cape Cod National Seashore. Oak habitat itself appears to be declining on Cape Cod and elsewhere along the Atlantic Seaboard. Indeed, oak habitat appears generally to be declining throughout North America. Moreover, because the three most abundant species at the Cape Cod MAPS stations were a habitat generalist (Black-capped Chickadee) and the two pitch pine specialists (Pine Warbler and Chipping Sparrow), two of which had positive population trends and the remaining one had the second lowest negative population trend, the mean population trend of the 11 target species (mean $APC = -6.8$) was considerably more negative than the overall population trend for all species pooled ($APC = -4.7$).

Despite the fact that both of the MAPS stations in oak forest habitat – the canopy type with the highest population sizes for all species pooled and for most individual species – had a dense blueberry understory rather than a sparse mixed understory, multivariate ANOVAs controlling for canopy type and housing density showed that the highest population sizes for all species pooled and for most individual species tended to be associated with a sparse mixed understory rather than a dense blueberry understory. As expected, most declining species as well as both non-declining species had as-high or higher population sizes in sparse mixed understories than dense blueberry understories. Common Yellowthroat, a strongly declining species, was the only species that had substantially larger population sizes in dense blueberry, rather than sparse mixed, understories. Thus, unlike canopy type, understory type did not seem to be a factor contributing to the population declines of landbirds at Cape Cod. For all species pooled, multivariate analyses of population trends as a function of habitat characteristics also confirmed that understory type did not greatly influence population trends on Cape Cod National Seashore.

Multivariate ANOVAs controlling for both canopy type and understory showed that population size of all species pooled were independent of housing density, and roughly equal numbers of species tended to have higher populations sizes in high (six species, two of which were significant or nearly significant) and low (five species, three of which were significant or nearly significant) housing density habitats. As expected, roughly equal numbers of both declining and non-declining species had higher population sizes in high (five declining species of which two were significant, and one non-declining species that was not significant) and low (five declining species of which two were significant, and one non-declining species that was significant) housing densities. Thus, like understory type and unlike canopy type, housing density did not appear to be a factor contributing to population declines of landbirds at Cape Cod. Again, for all species pooled, multivariate analyses of population trends as a function of habitat characteristics also confirmed that housing density class did not greatly influence population trends on Cape Cod National Seashore.

As perhaps expected, multivariate logistic regression analyses of productivity indices showed that, in general, the various species tended to have their highest productivity in their preferred habitat. Thus, three of four oak forest specialist species had significantly lower productivity in pitch pine woodland than in oak forest (Tufted Titmouse and Ovenbird) or mixed pine/oak woodland (Gray Catbird); the remaining species (Common Yellowthroat) was captured in adequate numbers for analysis only in oak forest habitat. In addition, Chipping Sparrow, a pitch pine specialist, had lower (but not significantly so) productivity in oak forest than in either pine-oak or pitch pine woodland, while Pine Warbler the other pitch pine specialist, was only captured in adequate numbers for analysis in pitch pine woodland. Of the five habitat generalists, one (Black-capped Chickadee) had lower productivity and two (Hermit Thrush and Eastern Towhee) had higher productivity in oak woodland than in other habitats, while the remaining two (American Robin and American Goldfinch) had insufficient data for multivariate logistic regression analyses of productivity. Interestingly, one (50%; Chipping Sparrow) of the two pitch pine specialists, one (33%; Black-capped Chickadee) of the three generalist species, and only one (25%; Tufted Titmouse) of the four oak specialist species had as-expected or higher-than-expected productivity (relative to body mass), lending additional support to the hypothesis that ecological problems in oak forests are leading to the low avian productivity that is driving the population declines of birds on the Cape Cod National Seashore.

In general, productivity did not differ between declining and non-declining species either as a function of understory type or housing density, although three of the four species with substantial population declines tended to have lower productivity in high rather than low housing density habitat while the one species with a substantial population increase (Black-capped Chickadee) tended to have higher productivity in high housing density habitat, suggesting that higher housing density may be weakly associated with lower productivity in species with strongly declining populations.

Thus, overall, the multivariate analyses demonstrate a pattern where declining species tend to be rather strongly associated with (have higher population sizes and more negative population trends) in oak forest habitats, and show a weak tendency, at least for substantially declining species, to have lower productivity in high housing-density areas. This suggests (1) that overall ecological problems may be occurring in the oak forests on Cape Cod National Seashore, and (2) that declining species breeding in higher housing-density areas may be suffering from lower productivity in those areas. We have no explanation at this time concerning what problems may be limiting productivity and survival of the birds inhabiting oak-habitats of Cape Cod National Seashore, but suggest that additional study and management actions are warranted to address these problems. Regarding lower productivity in high-density areas, one possible explanation may be that pets such as cats associated with the housing may be preying upon nestling and fledgling birds in these areas. Interestingly, two of the three species that had did not have deficient (lower-than-expected) productivity on Cape Cod National Seashore were cavity-nesting species (Black-capped Chickadee, Tufted Titmouse) that tend to suffer less nest and fledgling predation than species with open cup nests. That there is only a weak association between high housing density and lowered productivity and declining populations may indicate that even the low density housing is sufficient to produce substantially lowered productivity. Moreover, housing density alone may not provide a reliable indicator of pet density or of the intensity of disturbance associated with the presence of houses. We suggest that the Seashore attempt to raise awareness about potential impact that predation by cats and other pets in the housing areas may have on landbird populations.

Conclusions

The operation of six MAPS stations in a range of habitat types on Cape Cod National Seashore for five years, 1999-2003, has produced the following important results:

(1) Mean annual indices of total adult population size on Cape Cod National Seashore are about 28% lower than the mean at other MAPS locations in the Appalachians and along the Atlantic Seaboard and at least 50% lower than at MAPS locations in western United States.

(2) Indices of adult population size have decreased substantially on Cape Cod National Seashore over the five years, 1999-2003, with nine of 11 target species showing declines and all species pooled declining by a near-significant -4.7% per year. If declines of this magnitude have been operating since 1995, they could be responsible for the 28% lower population sizes found on the Seashore compared to other eastern locations.

(3) Strikingly low productivity on Cape Cod National Seashore for most species appears to be the primary cause of the severe population declines of most target species on the Seashore, although low annual adult apparent survival rates, at least in some years, appear to be driving or contributing to the declines in two species. For the most part, however, annual adult apparent survival rates for species on Cape Cod National Seashore are at least as high as at other locations at comparable latitudes elsewhere in United States.

(4) The overall negative trend in productivity over the five years for all species pooled and for the majority of species suggests that population declines will likely worsen in the near future, a situation that calls for continued monitoring of the population trends and vital rates of the landbirds on Cape Cod National Seashore.

(5) Multivariate ANOVA analyses of adult population size as a function of year and three habitat characteristics (canopy type, understory type, housing density class) for the 11 target species produced patterns that were in agreement with known life history traits and habitat preferences for these species. Analogous multivariate logistic regression analyses of productivity indicated that the various target species tended to have their highest productivity in their preferred habitat.

(6) Multivariate analyses of population size and productivity indicate that oak forest and sparse mixed understory tended to support higher population sizes, with housing density having little effect on population size, while mixed oak/pine woodland tended to have the higher productivity, with both understory type and housing density having little effect on productivity.

(7) For all species pooled, multivariate ANOVA analyses showed that more negative population trends tended to be associated with oak forest habitat than with either of the other two habitat (canopy) types, and that understory type and housing density class did not greatly influence population trends on Cape Cod National Seashore. These results suggest that, for all species pooled, ecological problems associated with oak forest habitat may be adversely affecting the population dynamics of landbirds on Cape Cod National Seashore. Interestingly, for all species pooled, the results of the ANOVAs for population trends (Fig. 16) more closely mirrored the ANOVAs for productivity (Fig. 1) than the ANOVAs for population size (Fig. 1), providing additional evidence that productivity might be the primary driving force for the population trends on Cape Cod National Seashore.

(8) Among the 11 target species, the four oak forest specialists (as determined from mutivariate ANOVA analyses of population size) experienced much more negative population trends than the two pitch pine specialists, while the five habitat generalists had intermediate population trends that were more similar to the oak specialists than to the pitch pine specialists. This suggests that declining populations tend to be associated more with oak forest than with pitch pine woodland, and that ecological problems that are negatively affecting landbird populations may exist in oak forest habitat on the Cape Cod National Seashore.

(9) Multivariate analyses of productivity provided weak evidence that species experiencing substantial population declines had lower productivity in higher housing density areas, suggesting that factors associated with housing, perhaps cats and other pets, could be contributing to low productivity. This possibility is supported by the fact that two of the three target species that are not experiencing deficient productivity on Cape Cod are cavity nesters which are generally less susceptible to nest and fledgling predation.

The initial goal of the first five years of the MAPS Program on Cape Cod National Seashore, to monitor the population sizes and primary demographic parameters of Cape Cod's landbirds in order to provide critical information to aid our understanding of the ecological processes leading from environmental stressors to population responses, has been achieved. With only five years of data, we have been able to provide population trends showing substantial declines in most of the landbird species, productivity indices showing that deficient reproductive success is the likely driving force for many of the population declines, initial estimates of annual adult survival rates that, overall, do not seem to be deficient, and analyses of habitat characteristics that may be influencing the declining trends on the Seashore. Thus, we have shown that the indices and estimates of demographic parameters produced by MAPS are extremely useful for the management and conservation of landbirds at this specific location. In combination with similar data from other areas, we suggest that the demographic information produced by MAPS can be equally useful across all of North America.

Suggestions for Future Work

Finally, these results lead us to suggest that landbird populations on Cape Cod National Seashore are experiencing significant problems that likely have their origin on the Seashore itself and that, if uncorrected, may become more severe in the near future. We suggest that the Seashore take the following steps to address this problem:

(1) Initiate or continue population trend monitoring of landbirds, including the 11 target species analyzed here, over the entire Seashore to determine whether the five-year population declines documented here are continuing and are part of a larger-scale, longer-term phenomenon. The Institute for Bird Population (IBP) has considerable experiencing designing and implementing large-scale, long-term population monitoring protocols for use in national parks, and will be available to help achieve this step.

(2) If the declines are found to be continuing or are part of a long-term trend, initiate research, building upon the results presented here, to identify the ultimate environmental cause(s) of the declines and formulate management actions to reverse the declines. Two avenues can be taken to implement this step. First, because MAPS data indicates, for most species, that low productivity is the proximate demographic cause of the decline, an hypothesis-driven project utilizing nest monitoring of individually color-banded birds of several target species in several key habitats to determine the environmental cause(s) of the deficient productivity would be appropriate. Second, to aid in the formulation of management actions, analyses of MAPS data from the six stations on Cape Cod National Seashore and all other stations along the Atlantic Seaboard of northeastern United States and southeastern Canada as a function of station-specific and landscape-scale habitat characteristics would also be appropriate. Again, IBP has considerable experience with both of these approaches (e.g., see Siegel & DeSante [2003] for nest monitoring approaches and Nott [2000] and Nott et al. [2003b] for modeling demographic parameters as a function of GIS-based, remote-sensed landscape variables) and will be available to help achieve this step.

(3) Lastly, it is imperative to monitor the effectiveness of any management actions implemented to reverse population declines. Because any such management actions ultimately aim to reverse declines by enhancing one or more specific vital rates (i.e., productivity, recruitment, or survival), truly appropriate effectiveness monitoring requires detailed monitoring of the targeted vital rate(s) (DeSante et al. in press). The operation of appropriately sited MAPS stations may well be one of the most useful and cost-effective methods available to monitor the effectiveness of management actions, because both the targeted vital rate (productivity) and the resulting population trend can be monitored simultaneously.

We conclude, therefore, that the MAPS protocol has been well-suited to provide one component of Cape Cod's long-term ecological monitoring program (Roman and Barrett 1999), and can be used to provide critical data to aid in resolving problems associated with declining landbird populations along the Eastern Seaboard. We hope that the results of the MAPS program on Cape Cod National Seashore can be used to prompt management actions on the Seashore to restore oak habitats and raise awareness about potential impacts that predation by cats and other pets in the housing-areas may have on landbird populations.

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Table 1. Summary of the 2003 MAPS program on Cape Cod National Seashore.

Station					Avg	2003 operation		
Name	Code	No.	Major Habitat Type	Latitude-longitude	Elev. (m)	Total number of net-hours[1]	No. of periods	Inclusive dates
Longnook Beach	LOBE	15610	Oak forest with dense blueberry understory; kettles; high housing density[2]	42˚01'08"N,-70˚02'57"W	46	341.0 (284.7)	7	5/31 - 8/03
Oak Dunes	OADU	15609	Oak forest with dense blueberry understory; low housing density[2]	41˚58'39"N,-70˚00'41"W	30	327.0 (322.3)	7	6/07 - 8/04
Nauset School	NASC	15605	Mixed pine/oak woodland with sparse mixed understory; kettles; high housing density[2]	41˚51'21"N,-69˚57'59"W	15	319.3 (316.2)	7	5/26 - 8/02
Blueberry Hill	BLHI	15607	Mixed pine/oak woodland with dense blueberry understory; low housing density[2]	41˚56'16"N,-69˚59'45"W	15	288.7 (269.8)	7	6/04 - 8/01
Higgins House	HIHO	15608	Pitch-pine woodland with sparse mixed understory; kettles; high housing density[2]	41˚57'25"N,-70˚03'38"W	15	318.7 (310.8)	7	5/30 - 7/31
Marconi Beach	MABE	15606	Pitch-pine woodland with sparse mixed understory; low housing density[2]	41˚53'37"N,-69˚58'21"W	12	338.0 (302.7)	7	5/28 - 7/30
ALL STATIONS COMBINED						1932.7(1806.5)	7	5/26 - 8/04

[1] Total net-hours in 2003. Net-hours in 2003 that could be compared in a constant-effort manner to 2002 are shown in parentheses.
[2] Housing densities are measured over the area enclosed in a 2 km radius with the station at the center of the circle.

Table 2. Capture summary for the six individual MAPS stations operated on Cape Cod National Seashore in 2003.
N = Newly Banded, U = Unbanded, R = Recaptures of banded birds.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach		
Species	N	U	R	N	U	R	N	U	R	N	U	R	N	U	R	N	U	R
Ruby-throated Hummingbird								1			1			1				
Downy Woodpecker										3								
Northern Flicker	1																	
Eastern Wood-Pewee									2							1		
Great Crested Flycatcher	1																	
Red-eyed Vireo				1														
Blue Jay										3						1		
Black-capped Chickadee	5	1	5	1			5		6	1		1	9		1	5	2	1
Tufted Titmouse	3						2		2									
White-breasted Nuthatch							1											
Veery																1		
Hermit Thrush			1			1				1			4		1	2		
American Robin							2			1	1		2		1			
Gray Catbird				1			4		1									
Cedar Waxwing																3		
Blackburnian Warbler							1											
Pine Warbler				3			5			2		1	4			4		2
Black-and-white Warbler				1		2										1		
Ovenbird	6		2	5		3	2			2		2				1		
Common Yellowthroat	5		3	1	1		1									1		
Unidentified Warbler		1																
Scarlet Tanager							1											
Eastern Towhee	2		1							1	1	1				2		
Chipping Sparrow							1						4	1		11		7
Northern Cardinal							3									1		
Common Grackle							1											
Brown-headed Cowbird							1											
Baltimore Oriole										1								

Table 2. (cont.) Capture summary for the six individual MAPS stations operated on Cape Cod National Seashore in 2003.
N = Newly Banded, U = Unbanded, R = Recaptures of banded birds.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach		
Species	N	U	R	N	U	R	N	U	R	N	U	R	N	U	R	N	U	R
American Goldfinch							1						2			6		3
ALL SPECIES POOLED	23	2	12	13	1	6	31	1	11	15	3	5	25	2	3	40	2	13
Total Number of Captures		37			20			43			23			30			55	
Number of Species	7	1	5	7	1	3	15	1	4	9	3	4	6	2	3	14	1	4
Total Number of Species		8			8			17			10			7			14	

Table 3. Numbers of aged individual birds captured per 600 net-hours and proportion of young in the catch at the six individual MAPS stations operated on Cape Cod National Seashore in 2003.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach		
Species	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.
Downy Woodpecker										6.2	0.0	0.00						
Northern Flicker	1.8	0.0	0.00															
Eastern Wood-Pewee							3.8	0.0	0.00							1.8	0.0	0.00
Great Crested Flycatcher	1.8	0.0	0.00															
Red-eyed Vireo				1.8	0.0	0.00												
Blue Jay										2.1	4.2	0.67				1.8	0.0	0.00
Black-capped Chickadee	14.1	0.0	0.00	1.8	0.0	0.00	15.0	5.6	0.27	4.2	0.0	0.00	18.8	0.0	0.00	10.7	0.0	0.00
Tufted Titmouse	5.3	0.0	0.00				5.6	1.9	0.25									
White-breasted Nuthatch							0.0	1.9	1.00									
Veery																1.8	0.0	0.00
Hermit Thrush	1.8	0.0	0.00	1.8	0.0	0.00				2.1	0.0	0.00	5.6	1.9	0.25	1.8	1.8	0.50
American Robin							1.9	1.9	0.50	2.1	0.0	0.00	3.8	0.0	0.00			
Gray Catbird				1.8	0.0	0.00	9.4	0.0	0.00									
Cedar Waxwing																3.6	0.0	0.00
Pine Warbler				5.5	0.0	0.00	7.5	1.9	0.20	6.2	0.0	0.00	7.5	0.0	0.00	7.1	0.0	0.00
Black-and-white Warbler				3.7	0.0	0.00										1.8	0.0	0.00
Ovenbird	8.8	1.8	0.17	9.2	0.0	0.00	1.9	1.9	0.50	8.3	0.0	0.00				1.8	0.0	0.00
Common Yellowthroat	10.6	0.0	0.00	1.8	0.0	0.00	1.9	0.0	0.00							1.8	0.0	0.00
Scarlet Tanager							1.9	0.0	0.00									
Eastern Towhee	5.3	0.0	0.00							2.1	0.0	0.00				3.6	0.0	0.00
Chipping Sparrow							0.0	1.9	1.00				7.5	0.0	0.00	21.3	3.6	0.14
Northern Cardinal							5.6	0.0	0.00							1.8	0.0	0.00
Common Grackle							1.9	0.0	0.00									
Brown-headed Cowbird							1.9	0.0	0.00									
Baltimore Oriole										2.1	0.0	0.00						

Table 3. (cont.) Numbers of aged individual birds captured per 600 net-hours and proportion of young in the catch at the six individual MAPS stations operated on Cape Cod National Seashore in 2003.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach		
Species	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.	Ad.	Yg.	Prop. Yg.
American Goldfinch							1.9	0.0	0.00				3.8	0.0	0.00	12.4	0.0	0.00
ALL SPECIES POOLED	49.3	1.8	0.03	27.5	0.0	0.00	60.1	16.9	0.22	35.3	4.2	0.11	47.1	1.9	0.04	72.8	5.3	0.07
Number of Species	8	1		8	0		13	7		9	1		6	1		14	2	
Total Number of Species		8			8			15			9			6			14	

Table 4. Summary of results for all six Cape Cod National Seashore MAPS stations combined in 2003.

Species	Birds captured: Newly banded	Un-banded	Recap-tured	Birds/600 nethours: Adults	Young	Prop. Young
Ruby-throated Hummingbird		3				
Downy Woodpecker	3			0.9	0.0	0.00
Northern Flicker	1			0.3	0.0	0.00
Eastern Wood-Pewee	1		2	0.9	0.0	0.00
Great Crested Flycatcher	1			0.3	0.0	0.00
Red-eyed Vireo	1			0.3	0.0	0.00
Blue Jay	4			0.6	0.6	0.50
Black-capped Chickadee	26	3	14	10.9	0.9	0.08
Tufted Titmouse	5		2	1.9	0.3	0.14
White-breasted Nuthatch	1			0.0	0.3	1.00
Veery	1			0.3	0.0	0.00
Hermit Thrush	7		3	2.2	0.6	0.22
American Robin	5	1	1	1.2	0.3	0.20
Gray Catbird	5		1	1.9	0.0	0.00
Cedar Waxwing	3			0.6	0.0	0.00
Blackburnian Warbler	1					
Pine Warbler	18		3	5.6	0.3	0.05
Black-and-white Warbler	2		2	0.9	0.0	0.00
Ovenbird	16		7	5.0	0.6	0.11
Common Yellowthroat	8	1	3	2.8	0.0	0.00
Unidentified Warbler		1				
Scarlet Tanager	1			0.3	0.0	0.00
Eastern Towhee	5	1	2	1.9	0.0	0.00
Chipping Sparrow	16	1	7	5.0	0.9	0.16
Northern Cardinal	4			1.2	0.0	0.00
Common Grackle	1			0.3	0.0	0.00
Brown-headed Cowbird	1			0.3	0.0	0.00
Baltimore Oriole	1			0.3	0.0	0.00
American Goldfinch	9		3	3.1	0.0	0.00
ALL SPECIES POOLED	147	11	50	49.1	5.0	0.09
Total Number of Captures		208				
Number of Species	27	6	13	25	9	
Total Number of Species		28			26	

Table 5. Percentage changes between 2002 and 2003 in the numbers of individual ADULT birds captured at six constant-effort MAPS stations on Cape Cod National Seashore.

							All six stations combined					
								Number of adults				
Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	n[1]	2002	2003	Percent change	SE[2]	
Downy Woodpecker			-100.0	++++[3]			2	1	3	200.0	600.0	
Hairy Woodpecker		-100.0	-100.0		-100.0		3	4	0	-100.0	88.9	
Northern Flicker	++++[3]						1	0	1	++++[3]		
Eastern Wood-Pewee	-100.0		-33.3			++++[3]	3	4	3	-25.0	39.0	
Great Crested Flycatcher	++++						1	0	1	++++		
Red-eyed Vireo		++++[3]					1	0	1	++++		
Blue Jay			-100.0	++++		++++	3	3	2	-33.3	100.0	
Black-capped Chickadee	40.0	-85.7	-20.0	-66.7	233.3	25.0	6	35	33	-5.7	32.1	
Tufted Titmouse	++++		-40.0	-100.0			3	7	4	-42.9	26.7	
Red-breasted Nuthatch			-100.0				1	1	0	-100.0		
White-breasted Nuthatch				-100.0			1	1	0	-100.0		
Hermit Thrush	-80.0	-50.0		-50.0	-50.0	-50.0	5	17	7	-58.8	8.0	***
American Robin	-100.0		-50.0	++++	100.0		4	5	4	-20.0	53.5	
Gray Catbird		0.0	25.0		-100.0	-100.0	4	7	6	-14.3	32.8	
Cedar Waxwing						++++	1	0	2	++++		
Blue-winged Warbler		-100.0					1	1	0	-100.0		
Pine Warbler		-25.0	++++[3]	-50.0	0.0	-40.0	5	19	17	-10.5	29.0	
Black-and-white Warbler		++++	-100.0				2	1	2	100.0	400.0	
Ovenbird	100.0	++++	-50.0	0.0			4	7	12	71.4	103.2	
Common Yellowthroat	50.0	-50.0	0.0			0.0	4	8	9	12.5	28.3	
Scarlet Tanager	-100.0		++++				2	2	1	-50.0	100.0	
Eastern Towhee	0.0	-100.0		-50.0		++++	4	5	4	-20.0	33.9	
Chipping Sparrow					33.3	0.0	2	13	14	7.7	11.8	
Northern Cardinal			200.0			-100.0	2	2	3	50.0	150.0	
Common Grackle			++++				1	0	1	++++		
Brown-headed Cowbird		-100.0	++++		-100.0		3	2	1	-50.0	75.0	
Baltimore Oriole			-100.0	++++			2	1	1	0.0	200.0	

Table 5. (cont.) Percentage changes between 2002 and 2003 in the numbers of individual ADULT birds captured at six constant-effort MAPS stations on Cape Cod National Seashore.

Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	n[1]	All six stations combined: Number of adults 2002	Number of adults 2003	Percent change	SE[2]
American Goldfinch	-100.0		++++	-100.0	++++[3]	-22.2	5	12	10	-16.7	27.5
ALL SPECIES POOLED	-8.7	-28.6	-11.1	-32.0	25.0	-3.0	6	158	142	-10.1	6.9
No. species that increased[4]	6(3)	3(3)	7(5)	4(4)	4(1)	5(4)				11(5)	
No. species that decreased[5]	5(4)	8(4)	11(6)	7(3)	4(3)	5(2)				16(4)	
No. species remained same	1	1	1	1	1	2				1	
Total Number of Species	12	12	19	12	9	12				28	
Proportion of increasing (decreasing) species	(0.417)	(0.667)	(0.579)	(0.583)	0.444	(0.417)				(0.571)	
Sig. of increase (decrease)[6]	(0.806)	(0.194)	(0.324)	(0.387)	0.746	(0.806)				(0.286)	

[1] Number of stations at which at least one adult bird was captured in either year.
[2] Standard error of the % change in the number of adult birds captured.
[3] Increase indeterminate (infinite) because no adult was captured during 2002.
[4] No. of species for which adults were captured in 2003 but not in 2002 are in parentheses.
[5] No. of species for which adults were captured in 2002 but not in 2003 are in parentheses.
[6] Statistical significance of the one-sided binomial test that the proportion of increasing (decreasing) species is not greater than 0.50.
*** $P < 0.01$; ** $0.01 < P < 0.05$; * $0.05 < P < 0.10$.

Table 6. Percentage changes between 2002 and 2003 in the numbers of individual YOUNG birds captured at six constant-effort MAPS stations on Cape Cod National Seashore.

							All six stations combined					
								Number of young				
Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	n[1]	2002	2003	Percent change	SE[2]	
Downy Woodpecker			-100.0				1	4	0	-100.0		
Hairy Woodpecker							0	0	0			
Northern Flicker							0	0	0			
Eastern Wood-Pewee	-100.0						1	1	0	-100.0		
Great Crested Flycatcher							0	0	0			
Red-eyed Vireo							0	0	0			
Blue Jay				++++[3]			1	0	2	++++[3]		
Black-capped Chickadee			-66.7	-100.0	-100.0	-100.0	4	16	3	-81.3	11.0	***
Tufted Titmouse	-100.0		-66.7	-100.0			3	7	1	-85.7	12.2	**
Red-breasted Nuthatch							0	0	0			
White-breasted Nuthatch			++++[3]				1	0	1	++++		
Hermit Thrush	-100.0				++++[3]	++++[3]	3	2	2	0.0	150.0	
American Robin			++++			-100.0	2	1	1	0.0	200.0	
Gray Catbird							0	0	0			
Cedar Waxwing							0	0	0			
Blue-winged Warbler							0	0	0			
Pine Warbler		-100.0	++++				2	1	1	0.0	200.0	
Black-and-white Warbler							0	0	0			
Ovenbird	++++[3]		++++				2	0	2	++++		
Common Yellowthroat							0	0	0			
Scarlet Tanager							0	0	0			
Eastern Towhee							0	0	0			
Chipping Sparrow			++++			0.0	2	2	3	50.0	100.0	
Northern Cardinal							0	0	0			
Common Grackle							0	0	0			
Brown-headed Cowbird							0	0	0			
Baltimore Oriole			-100.0				1	2	0	-100.0		

Table 6. (cont.) Percentage changes between 2002 and 2003 in the numbers of individual YOUNG birds captured at six constant-effort MAPS stations on Cape Cod National Seashore.

Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	All six stations combined: n[1]	Number of young: 2002	Number of young: 2003	Percent change	SE[2]	
American Goldfinch	-100.0						1	1	0	-100.0		
ALL SPECIES POOLED	-83.3	-100.0	-50.0	-50.0	-66.7	-40.0	6	37	16	-56.8	6.7	***
No. species that increased[4]	1(1)	0(0)	5(5)	1(1)	1(1)	1(1)				4(3)		
No. species that decreased[5]	4(4)	1(1)	4(2)	2(2)	1(1)	2(2)				6(4)		
No. species remained same	0	0	0	0	0	1				3		
Total Number of Species	5	1	9	3	2	4				13		
Proportion of increasing (decreasing) species	(0.800)	(1.000)	(0.444)	(0.667)	(0.500)	(0.500)				(0.462)		
Sig. of increase (decrease)[6]	(0.188)	n/a[7]	(0.746)	(0.500)	(0.750)	(0.688)				(0.709)		

[1] Number of stations at which at least one young bird was captured in either year.
[2] Standard error of the % change in the number of young birds captured.
[3] Increase indeterminate (infinite) because no young bird was captured during 2002.
[4] No. of species for which young birds were captured in 2003 but not in 2002 are in parentheses.
[5] No. of species for which young birds were captured in 2002 but not in 2003 are in parentheses.
[6] Statistical significance of the one-sided binomial test that the proportion of increasing (decreasing) species is not greater than 0.50.
[7] A minimum of two species must be available to do a binomial test for significance.
*** $P < 0.01$; ** $0.01 < P < 0.05$; * $0.05 < P < 0.10$.

Table 7. Percentage changes between 2002 and 2003 in the PROPORTION OF YOUNG in the catch at six constant-effort MAPS stations on Cape Cod National Seashore.

								All six stations combined			
								Proportion young			
Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	n[1]	2002	2003	Absol. change	SE[2]
Downy Woodpecker			+-+-+[3]	+-+-+[3]			2	0.800	0.000	-0.800	
Hairy Woodpecker		+-+-+[3]	+-+-+		+-+-+[3]		3	0.000	------[4]	+-+-+[3]	
Northern Flicker	+-+-+[3]						1	------[4]	0.000	+-+-+	
Eastern Wood-Pewee	+-+-+		0.000			+-+-+[3]	3	0.200	0.000	-0.200	0.208
Great Crested Flycatcher	+-+-+						1	------	0.000	+-+-+	
Red-eyed Vireo		+-+-+					1	------	0.000	+-+-+	
Blue Jay			+-+-+	+-+-+		+-+-+	3	0.000	0.500	0.500	0.217
Black-capped Chickadee	0.000	0.000	-0.201	-0.250	-0.500	-0.333	6	0.314	0.083	-0.230	0.116
Tufted Titmouse	-1.000		-0.125	+-+-+			3	0.500	0.200	-0.300	0.142
Red-breasted Nuthatch			+-+-+				1	0.000	------	+-+-+	
White-breasted Nuthatch			+-+-+	+-+-+			2	0.000	1.000	1.000	0.000
Hermit Thrush	-0.286	0.000		0.000	0.250	0.500	5	0.105	0.222	0.117	0.121
American Robin	+-+-+		0.500	+-+-+	0.000	+-+-+	5	0.167	0.200	0.033	0.247
Gray Catbird		0.000	0.000		+-+-+	+-+-+	4	0.000	0.000	0.000	0.000
Cedar Waxwing						+-+-+	1	------	0.000	+-+-+	
Blue-winged Warbler		+-+-+					1	0.000	------	+-+-+	
Pine Warbler		-0.200	+-+-+	0.000	0.000	0.000	5	0.050	0.056	0.006	0.070
Black-and-white Warbler		+-+-+	+-+-+				2	0.000	0.000	0.000	0.000
Ovenbird	0.333	+-+-+	0.500	0.000			4	0.000	0.143	0.143	0.107
Common Yellowthroat	0.000	0.000	0.000			0.000	4	0.000	0.000	0.000	0.000
Scarlet Tanager	+-+-+		+-+-+				2	0.000	0.000	0.000	0.000
Eastern Towhee	0.000	+-+-+		0.000		+-+-+	4	0.000	0.000	0.000	0.000
Chipping Sparrow			+-+-+		0.000	0.000	3	0.133	0.177	0.043	0.091
Northern Cardinal			0.000			+-+-+	2	0.000	0.000	0.000	0.000
Common Grackle			+-+-+				1	------	0.000	+-+-+	
Brown-headed Cowbird		+-+-+	+-+-+		+-+-+		3	0.000	0.000	0.000	0.000
Baltimore Oriole			+-+-+	+-+-+			2	0.667	0.000	-0.667	++++

Table 7. (cont.) Percentage changes between 2002 and 2003 in the PROPORTION OF YOUNG in the catch at six constant-effort MAPS stations on Cape Cod National Seashore.

								All six stations combined			
								Proportion young			
Species	Longnk. Beach	Oak Dunes	Nauset School	Blueb. Hill	Higgins House	Marconi Beach	n[1]	2002	2003	Absol. change	SE[2]
American Goldfinch	+-+-+		+-+-+	+-+-+	+-+-+	0.000	5	0.077	0.000	-0.077	0.095
ALL SPECIES POOLED	-0.161	-0.046	-0.114	-0.033	-0.092	-0.046	6	0.190	0.101	-0.089	0.063
No. species that increased	1	0	2	0	1	1				7	
No. species that decreased	2	1	2	1	1	1				6	
No. species remained same	3	4	4	4	3	4				7	
Total Number of Species[5]	6	5	8	5	5	6				20	
Proportion of increasing (decreasing) species	(0.333)	(0.200)	(0.250)	(0.200)	(0.200)	(0.167)				(0.300)	
Sig. of increase (decrease)[6]	(0.891)	(0.969)	(0.965)	(0.969)	(0.969)	(0.984)				(0.979)	

[1] Number of stations at which at least one aged bird was captured in either year.
[2] Standard error of the change in the proportion of young.
[3] The change in the proportion of young is undefined at this station because no aged individual of the species was captured in one of the two years.
[4] Proportion of young not given because no aged individual of the species was captured in the year shown.
[5] Species for which the change in the proportion of young is undefined are not included.
[6] Statistical significance of the one-sided binomial test that the proportion of increasing (decreasing) species is not greater than 0.50.
*** $P < 0.01$; ** $0.01 \leq P < 0.05$; * $0.05 \leq P < 0.10$

Table 8. Mean numbers of aged individual birds captured per 600 net-hours and proportion of young in the catch at the six individual MAPS stations operated on Cape Cod National Seashore averaged over the five years, 1999-2003. Data for each species are included only from stations that lie within the breeding range of the species.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach			All stations pooled		
Species	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]
Red-bellied Woodpecker							0.3	0.0	0.00										*0.0*	*0.0*	*0.00*
Downy Woodpecker	0.0	0.9	1.00	1.2	0.3	0.11	1.2	2.3	0.67	1.6	1.5	0.60	0.3	0.3	0.50	0.6	0.0	0.00	0.8	0.9	0.46
Hairy Woodpecker	0.3	0.0	0.00	1.2	0.0	0.00	0.6	0.0	0.00	0.9	0.3	0.25	0.6	0.0	0.00	0.0	0.3	1.00	0.6	0.1	0.13
Northern Flicker	0.4	0.0	0.00	0.3	0.0	0.00				0.3	0.0	0.00							0.2	0.0	0.00
Eastern Wood-Pewee	3.2	0.3	0.08				2.2	0.0	0.00	0.0	0.3	1.00				0.6	0.0	0.00	1.0	0.1	0.07
Acadian Flycatcher				0.3	0.0	0.00													*0.0*	*0.0*	*0.00*
Eastern Phoebe	0.7	0.7	0.50										0.6	0.0	0.00				0.2	0.1	0.25
Great Crested Flycatcher	0.4	0.0	0.00				0.3	0.0	0.00	0.9	0.0	0.00							0.3	0.0	0.00
Red-eyed Vireo				0.4	0.0	0.00							0.7	0.0	0.00				0.2	0.0	0.00
Blue Jay	0.6	0.0	0.00	1.5	0.0	0.00	2.0	0.3	0.11	1.9	1.1	0.42	0.9	0.0	0.00	0.9	0.0	0.00	1.3	0.2	0.15
Tree Swallow							0.3	0.0	0.00										*0.0*	*0.0*	*0.00*
Black-capped Chickadee	9.3	2.6	0.12	9.6	0.9	0.05	15.3	6.1	0.25	9.3	4.0	0.18	14.3	4.4	0.25	12.8	4.7	0.25	11.8	3.8	0.23
Tufted Titmouse	4.1	2.5	0.39	1.5	2.6	0.25	8.1	5.3	0.35	1.8	0.9	0.35	0.7	0.0	0.00	0.3	0.3	0.50	2.8	2.0	0.36
Red-breasted Nuthatch							0.3	0.6	0.50	0.6	0.6	0.33	1.3	0.6	0.33	0.3	0.3	0.50	0.4	0.3	0.30
White-breasted Nuthatch	0.3	0.3	0.50	0.0	0.3	1.00	0.0	1.3	1.00	0.9	0.9	0.38							0.2	0.5	0.63
Brown Creeper										0.6	1.8	0.43	0.3	0.0	0.00				0.1	0.3	0.43
Veery																0.4	0.0	0.00	0.1	0.0	0.00
Hermit Thrush	4.6	0.7	0.06	4.2	0.6	0.10	3.2	0.0	0.00	1.6	0.0	0.00	6.5	0.4	0.05	3.3	0.6	0.15	3.9	0.4	0.10
American Robin	2.5	0.3	0.08				3.9	0.4	0.10	0.7	0.0	0.00	4.2	0.6	0.07	3.4	0.6	0.28	2.5	0.3	0.12
Gray Catbird				1.3	0.0	0.00	8.6	1.2	0.08				2.2	0.0	0.00	0.6	0.0	0.00	2.1	0.2	0.05
Cedar Waxwing	2.0	0.0	0.00										0.3	0.0	0.00	1.0	0.0	0.00	0.5	0.0	0.00
Blue-winged Warbler				0.3	0.0	0.00													0.1	0.0	0.00
Yellow Warbler													0.3	0.0	0.00				*0.0*	*0.0*	*0.00*
Pine Warbler	0.3	0.0	0.00	5.3	0.3	0.04	3.6	0.4	0.05	5.5	0.3	0.05	9.8	0.0	0.00	9.1	0.3	0.03	5.6	0.2	0.04
Black-and-white Warbler	0.6	0.0	0.00	2.5	0.0	0.00	0.3	0.0	0.00				0.6	0.0	0.00	0.4	0.0	0.00	0.7	0.0	0.00
Ovenbird	7.1	0.9	0.07	6.6	0.0	0.00	3.9	0.4	0.10	4.7	0.0	0.00	0.3	0.0	0.00	1.2	0.0	0.00	4.0	0.2	0.04
Common Yellowthroat	11.4	0.6	0.04	2.5	0.0	0.00	0.7	0.0	0.00	1.2	0.3	0.25				0.7	0.0	0.00	2.7	0.1	0.04
Scarlet Tanager	1.3	0.0	0.00	0.3	0.0	0.00	0.4	0.0	0.00	0.6	0.0	0.00							0.4	0.0	0.00
Eastern Towhee	3.2	0.0	0.00	2.7	0.6	0.15	0.6	0.0	0.00	2.6	0.0	0.00	0.7	0.0	0.00	2.2	0.0	0.00	2.0	0.1	0.06
Chipping Sparrow	1.0	0.3	0.25				0.6	0.4	0.33				9.7	3.2	0.15	17.9	5.1	0.21	4.9	1.5	0.20

Table 8. (cont.) Mean numbers of aged individual birds captured per 600 net-hours and proportion of young in the catch at the six individual MAPS stations operated on Cape Cod National Seashore averaged over the five years, 1999-2003. Data for each species are included only from stations that lie within the breeding range of the species.

	Longnook Beach			Oak Dunes			Nauset School			Blueberry Hill			Higgins House			Marconi Beach			All stations pooled		
Species	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]	Ad.	Yg.	Prop. Yg.[1]
Field Sparrow																0.3	0.0	0.00	*0.0*	*0.0*	*0.00*
Northern Cardinal							2.9	0.9	0.12	0.3	0.0	0.00	0.3	0.0	0.00	1.5	0.0	0.00	0.9	0.1	0.10
Common Grackle							0.4	0.0	0.00										0.1	0.0	0.00
Brown-headed Cowbird	1.0	0.0	0.00	0.9	0.0	0.00	0.4	0.0	0.00	0.3	0.0	0.00	0.3	0.0	0.00	0.6	0.0	0.00	0.6	0.0	0.00
Baltimore Oriole	0.3	0.0	0.00				0.3	0.9	0.83	0.4	0.0	0.00							0.2	0.2	0.50
American Goldfinch	2.4	0.3	0.17	1.5	0.0	0.00	3.3	0.0	0.00	1.8	0.0	0.00	2.3	0.0	0.00	12.9	0.0	0.00	4.1	0.1	0.01
ALL SPECIES POOLED	56.9	10.6	0.14	44.0	5.6	0.08	63.4	20.2	0.24	38.5	12.2	0.20	57.3	9.5	0.13	71.0	12.2	0.14	55.2	11.7	0.17
Number of Species	22	12		19	7		25	13		21	11		22	6		21	8		36	21	
Total Number of Species		23			20			26			22			22			22			36	

[1] Years for which the proportion of young was undefined (no aged birds were captured in the year) are not included in the mean proportion of young.

[2] For numbers presented in italics, the mean number of adults or young is greater than 0.1 at one or more stations, but over the entire location the mean number is less than 0.05. The species is counted in the number of species over all stations pooled.

Table 9. Summary statistics for survival analyses with temporally variable survival and recapture probabilities and proportion of residents in transient models using five years (1999-2003) of mark-recapture data from six MAPS stations on Cape Cod National Seashore. $QAIC_C$[1] and (GOF)[2] are presented for all models.

	Transient Models								
Species	$\phi p \tau$[3]	$\phi_t p \tau$[4]	$\phi p_t \tau$[5]	$\phi p \tau_t$[6]	$\phi_t p_t \tau$[7]	$\phi_t p \tau_t$[8]	$\phi p_t \tau_t$[9]	$\phi_t p_t \tau_t$[10]	$\Delta QAIC_C$[11]
Black-capped Chickadee	33.8* (0.149)	38.8 (0.125)	39.7 (0.077)	37.4 (0.242)	42.0 (0.119)	43.1 (0.152)	42.8 (0.178)	47.7 (0.025)	4.9
Tufted Titmouse	26.7* (0.815)	25.0* (1.000)	26.3* (0.997)	29.0 (0.952)	30.6 (0.998)	33.1 (0.999)	34.2 (0.989)	36.3 (0.997)	-1.7
Hermit Thrush	35.8* (0.836)	38.2 (0.943)	39.2 (0.900)	36.5* (0.985)	42.6 (0.911)	42.2 (0.990)	42.7 (0.981)	44.9 (0.980)	2.4
Gray Catbird	23.5* (0.969)	31.4 (0.920)	30.3 (0.959)	30.6 (0.952)	36.4 (0.935)	40.2 (0.903)	38.9 (0.961)	42.7 (0.952)	7.9
Pine Warbler	28.9* (0.917)	34.3 (0.872)	33.2 (0.925)	34.7 (0.848)	36.7 (0.916)	38.8 (0.899)	37.2 (0.971)	41.8 (0.815)	5.4
Ovenbird	29.9* (0.262)	33.4 (0.370)	36.2 (0.170)	33.8 (0.331)	38.3 (0.269)	42.8 (0.000)	39.6 (0.335)	43.5 (0.196)	3.5
Common Yellowthroat	36.4* (0.457)	40.2 (0.529)	39.9 (0.553)	39.3 (0.604)	45.3 (0.443)	43.2 (0.830)	44.1 (0.756)	46.1 (0.815)	3.8
Eastern Towhee	25.0* (0.876)	31.9 (0.833)	33.2 (0.741)	31.4 (0.866)	37.4 (0.818)	41.1 (0.771)	40.4 (0.828)	40.0 (0.996)	6.9
Chipping Sparrow	34.7* (0.743)	40.9 (0.583)	40.6 (0.614)	41.1 (0.567)	44.0 (0.583)	48.0 (0.377)	47.2 (0.439)	48.6 (0.460)	6.3

[1] Akaike Information Criterion ($QAIC_C$) given as -2(log-likelihood) + 2(number of estimable parameters) with corrections for small sample sizes and overdispersion of data.

Table 9. (cont.) Summary statistics for survival analyses with temporally variable survival and recapture probabilities and proportion of residents in transient models using five years (1999-2003) of mark-recapture data from six MAPS stations on Cape Cod National Seashore. $QAIC_C$[1] and (GOF)[2] are presented for all models.

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[2] Goodness-of-fit is a measure of how well the actual distribution of data fits the theoretical distribution calculated using the estimates provided by the model. The larger the value provided by the GOF test the better the model describes the data.

[3] $\phi p \tau$ Model: Transient model with temporally-constant survival probability, recapture probability, and proportion of residents (invariable from year to year).

[4] $\phi_t p \tau$ Model: Transient model with temporally-variable survival probability; and temporally-constant recapture probability and proportion of residents.

[5] $\phi p_t \tau$ Model: Transient model with temporally-variable recapture probability; and temporally-constant survival probability and proportion of residents.

[6] $\phi p \tau_t$ Model: Transient model with temporally-variable proportion of residents; and temporally-constant survival and recapture probabilities.

[7] $\phi_t p_t \tau$ Model: Transient model with temporally-variable survival and recapture probabilities; and temporally-constant proportion of residents.

[8] $\phi_t p \tau_t$ Model: Transient model with temporally-variable survival probability and proportion of residents; and temporally-constant recapture probability.

[9] $\phi p_t \tau_t$ Model: Transient model with temporally-variable recapture probability and proportion of residents; and temporally-constant survival probability.

[10] $\phi_t p_t \tau_t$ Model: Transient model with temporally-variable survival probability, recapture probability, and proportion of residents.

[11] $\Delta QAIC_C$ is defined as the difference in $\Delta QAIC_C$ between the $\phi p \tau$ model and the $\phi_t p \tau$ model.

* The selected models are the model with the lowest $QAIC_C$ and the models with $QAIC_C$s within 2.0 units of the model with the lowest $QAIC_C$.

Table 10. Estimates of adult survival and recapture probabilities and proportion of residents using both temporally variable and time-constant models for nine species breeding at MAPS stations on Cape Cod National Seashore obtained from five years (1999-2003) of mark-recapture data.

Species	Num. sta2.[1]	Num. ind.[2]	Num. caps.[3]	Num. ret.[4]	Model[5]	$QAIC_C$[6]	Survival probability[7]	Surv. C.V.[8]	Recapture probability[9]	Proportion of residents[10]
Black-capped Chickadee	6	191	261	35	$\phi p \tau$	33.8	0.665 (0.103)	15.5	0.342 (0.091)	0.435 (0.129)
Tufted Titmouse	6	46	63	8	$\phi p \tau$	26.7	0.167 (0.917)	550.4	1.000 (5.600)	1.000 (0.726)
					$\phi_t p \tau$	25.0	a0.267 (0.651)	243.8	1.000 (2.582)	1.000 (0.699)
							b0.375 (0.992)	264.5		
							c0.000 (0.243)	n/a[11]		
							d0.125 (0.350)	280.0		
					$\phi p_t \tau$	26.3	0.292 (0.209)	71.6	a1.000 (0.000)	1.000 (0.718)
									b1.000 (0.723)	
									c0.000 (0.801)	
									d0.270 (0.310)	
Hermit Thrush	6	57	103	18	$\phi p \tau$	35.8	0.552 (0.105)	19.1	0.728 (0.151)	0.286 (0.133)
					$\phi p \tau_t$	26.5	0.540 (0.102)	18.9	0.755 (0.141)	a0.532 (0.288)
										b0.474 (0.311)
										c0.000 (0.000)
										d0.000 (0.000)
Gray Catbird	3	34	42	5	$\phi p \tau$	23.5	0.547 (0.270)	49.4	0.294 (0.250)	0.597 (0.600)
Pine Warbler	6	97	130	9	$\phi p \tau$	28.9	0.229 (0.132)	57.8	0.409 (0.303)	0.978 (0.741)
Ovenbird	4	59	95	11	$\phi p \tau$	29.9	0.613 (0.145)	23.6	0.642 (0.188)	0.247 (0.126)
Common Yellowthroat	4	38	70	11	$\phi p \tau$	36.4	0.574 (0.144)	25.2	0.613 (0.195)	0.392 (0.211)
Eastern Towhee	6	33	41	5	$\phi p \tau$	25.0	0.677 (0.293)	43.3	0.172 (0.173)	0.747 (0.784)
Chipping Sparrow	4	82	116	11	$\phi p \tau$	34.7	0.526 (0.193)	36.7	0.196 (0.131)	1.000 (0.631)

Table 10. (cont.) Estimates of adult survival and recapture probabilities and proportion of residents using both temporally variable and time-constant models for nine species breeding at MAPS stations on Cape Cod National Seashore obtained from five years (1999-2003) of mark-recapture data.

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[1] Number of super-stations where the species was a regular or usual breeder at which adults of the species were captured.
[2] Number of adult individuals captured at stations where the species was a regular or usual breeder (i.e., number of capture histories).
[3] Total number of captures of adult birds of the species at stations where the species was a regular or usual breeder.
[4] Total number of returns. A return is the first recapture in a given year of a bird originally banded at the same station in a previous year.
[5] Models included are those selected by $QAIC_C$ (those models marked with * in Table 9) plus the $\phi p \tau$ model in all cases. See Table 9 for definitions of the models.
[6] Akaike Information Criterion ($QAIC_C$) given as -2(log-likelihood) + 2(number of estimable parameters) with corrections for small sample size and over dispersion of data.
[7] Survival probability presented as the maximum likelihood estimate (standard error of the estimate).
a The survival probability between the years 1999-2000 in a temporally variable model.
b The survival probability between the years 2000-2001 in a temporally variable model.
c The survival probability between the years 2001-2002 in a temporally variable model.
d The survival probability between the years 2002-2003 in a temporally variable model.
[8] The coefficient of variation for survival probability.
[9] Recapture probability presented as the maximum likelihood estimate (standard error of the estimate).
a The recapture probability in 2000 in a temporally variable model.
b The recapture probability in 2001 in a temporally variable model.
c The recapture probability in 2002 in a temporally variable model.
d The recapture probability in 2003 in a temporally variable model.
[10] The proportion of residents among newly captured adults presented as the maximum likelihood estimate (standard error of the estimate).
a The proportion of residents in the adult population in 1999 in a temporally variable model.
b The proportion of residents in the adult population in 2000 in a temporally variable model.
c The proportion of residents in the adult population in 2001 in a temporally variable model.
d The proportion of residents in the adult population in 2002 in a temporally variable model.

* CV cannot be calculated with a survival probability of 0.000.

Table 11. Assessment of vital rates for nine target species showing decreasing or increasing 5-year (1999-2003) population trends at the six stations combined on Cape Cod National Seashore.

Species	Trend (r) and significance[1]	Productivity	Survival Probability
A. Decreasing Species			
Tufted Titmouse	-11.2 (-0.635)	high	very low
Hermit Thrush	- 7.7 (-0.650)	low, increasing	as expected
Gray Catbird	-13.6 (-0.780)	low, decreasing	as expected
Pine Warbler	- 4.6 (-0.437)	very low	very low
Ovenbird	- 4.2 (-0.371)	very low	high
Common Yellowthroat	- 9.7 (-0.852) *	very low, decreasing	high
Eastern Towhee	- 8.6 (-0.668)	low, decreasing	high
B. Increasing Species			
Black-capped Chickadee	+ 3.6 (+0.549)	as expected, decreasing	very high
Chipping Sparrow	+ 3.8 (+0.295)	as expected	as expected

[1] Significance of the declines in adult population levels. *** $P < 0.01$; ** $0.01 \leq P < 0.05$; * $0.05 \leq P < 0.10$.

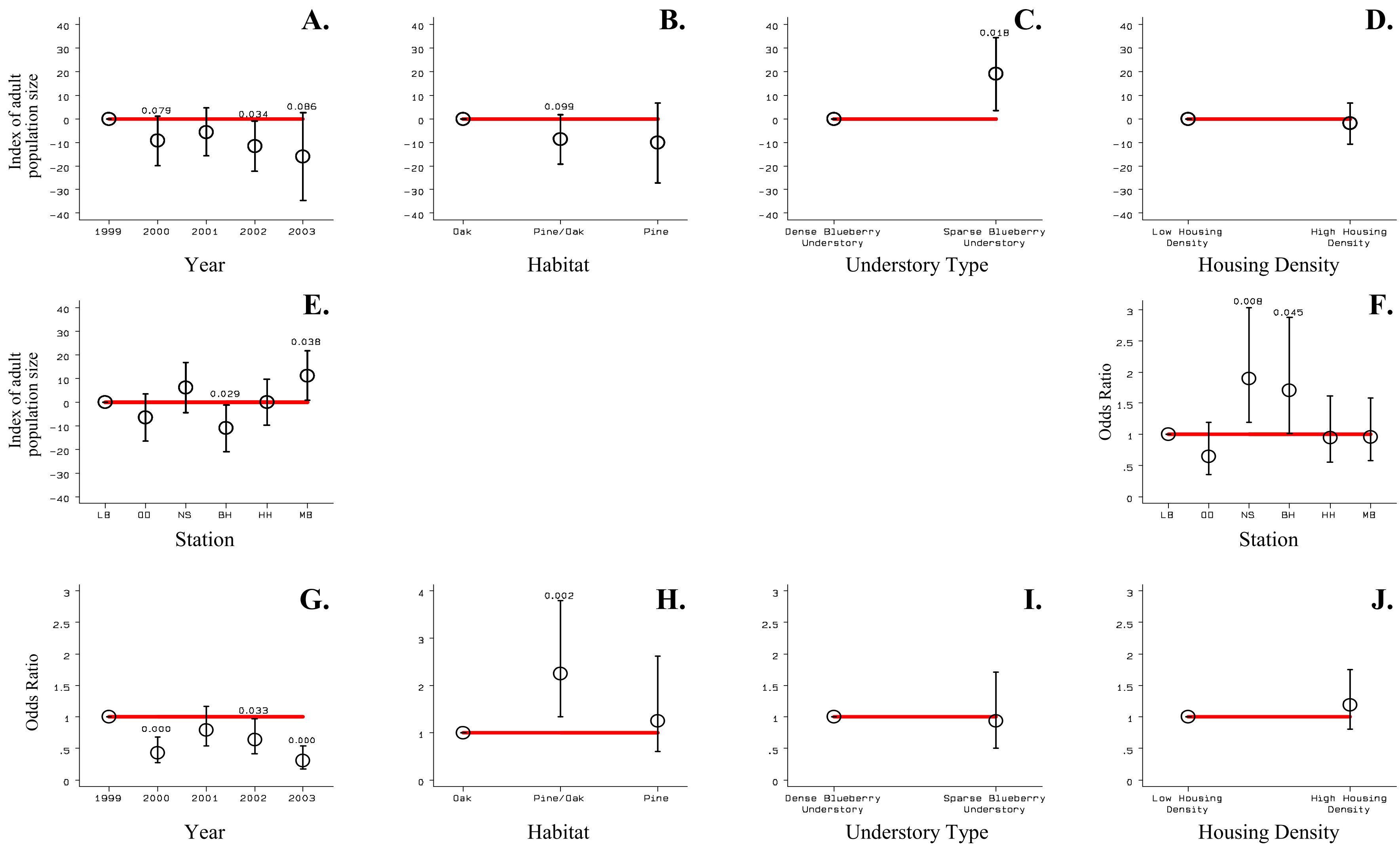

Figure 1. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **all species pooled**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

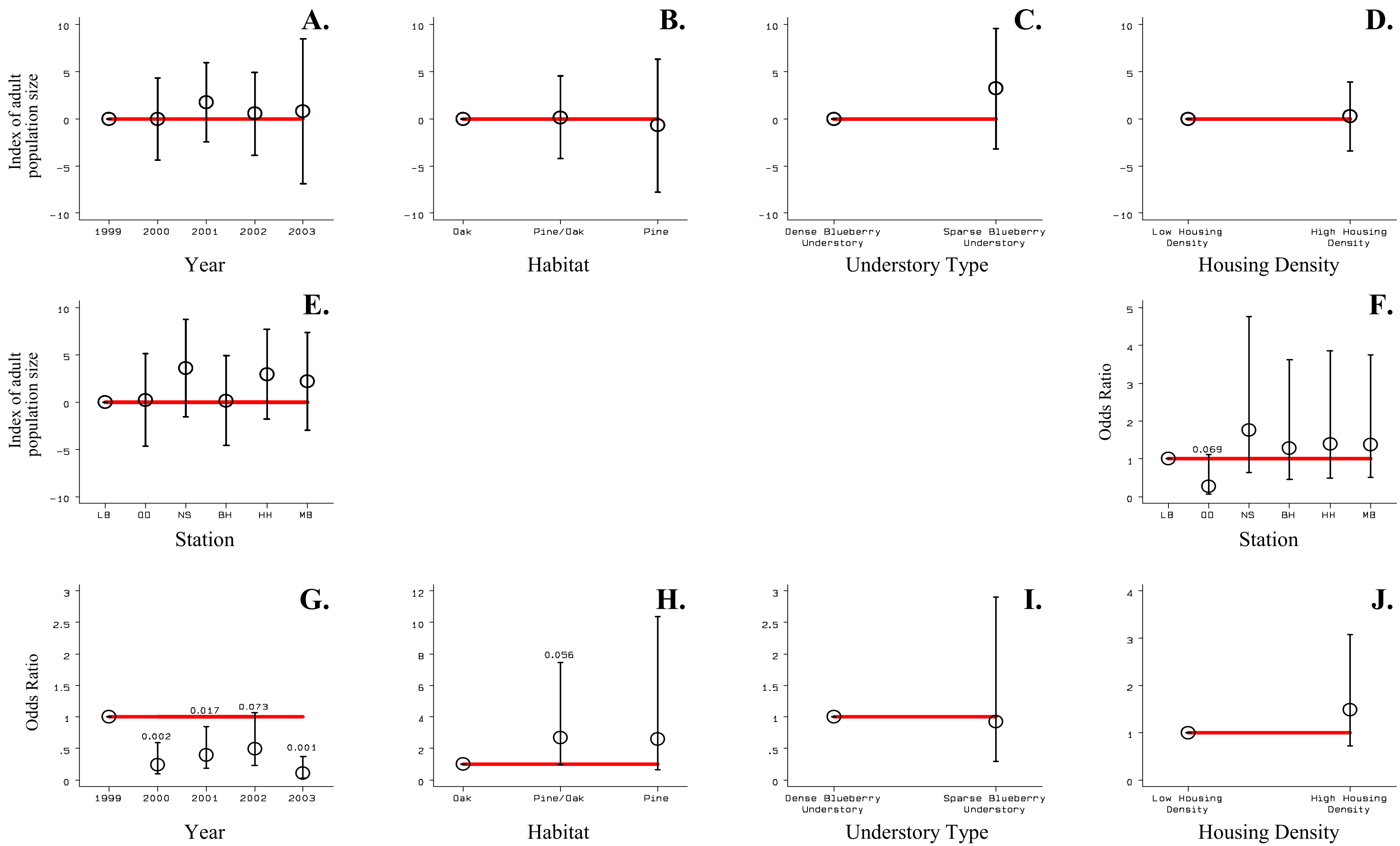

Figure 2. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Black-capped Chickadee**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

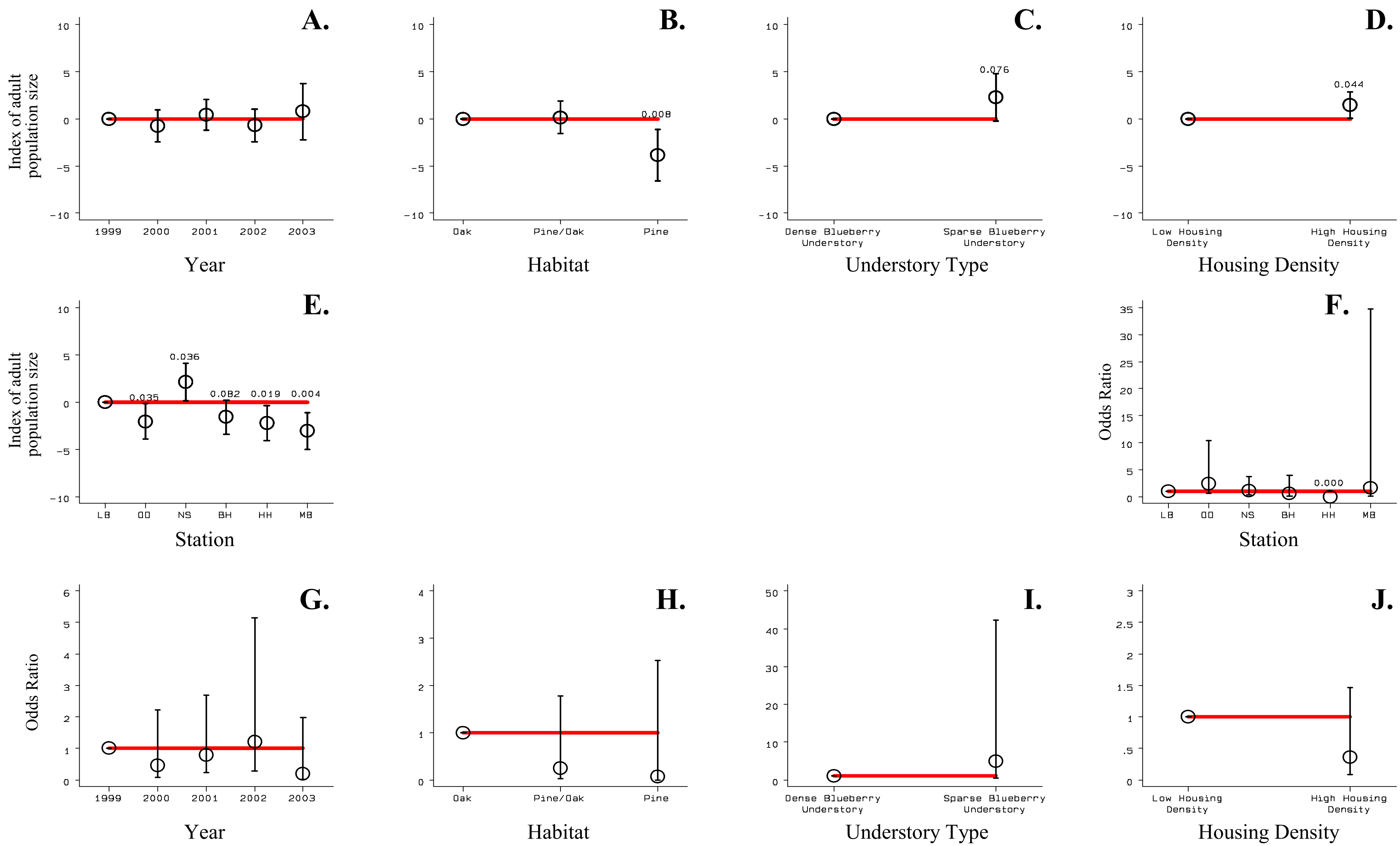

Figure 3. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Tufted Titmouse**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

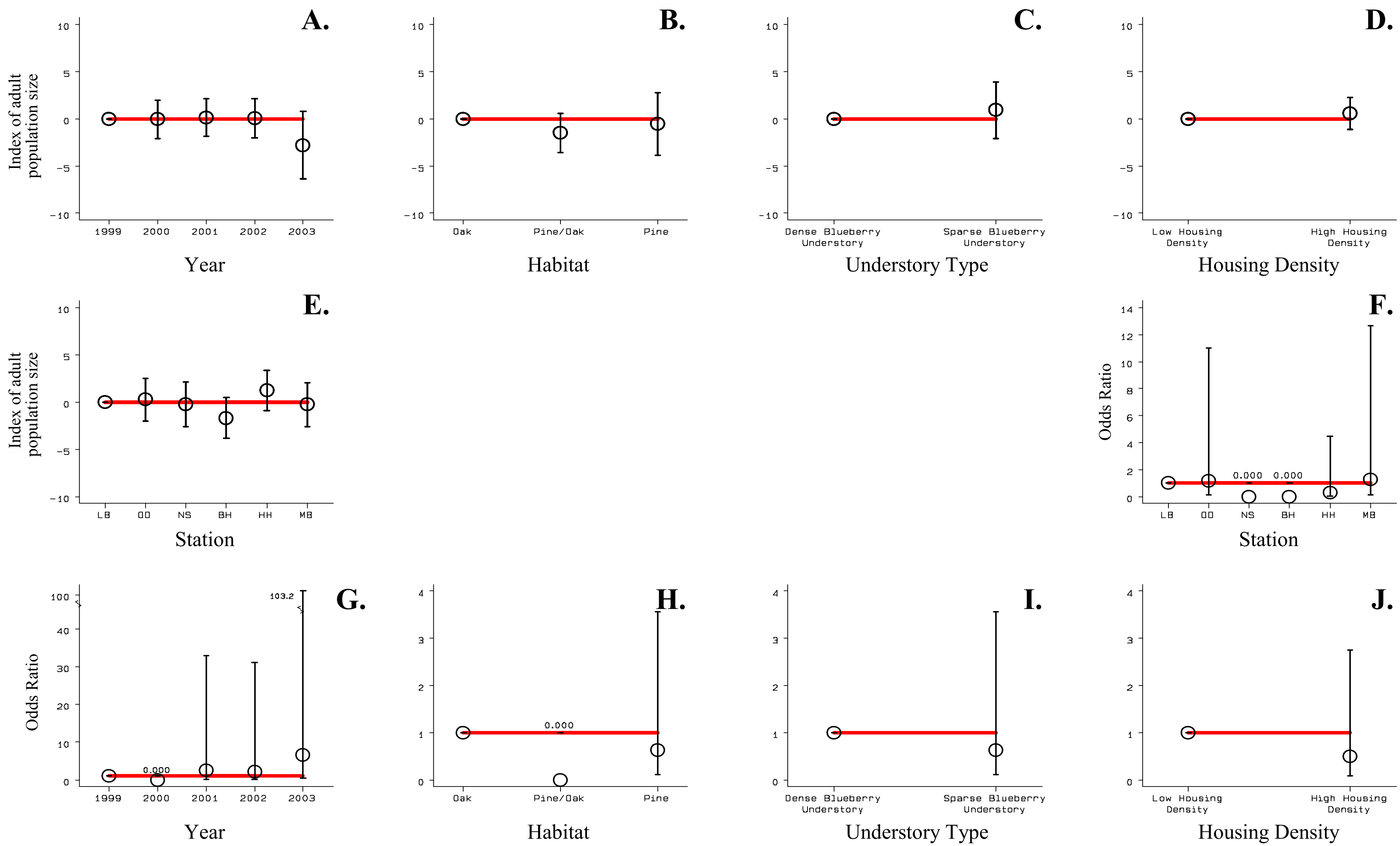

Figure 4. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Hermit Thrush**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

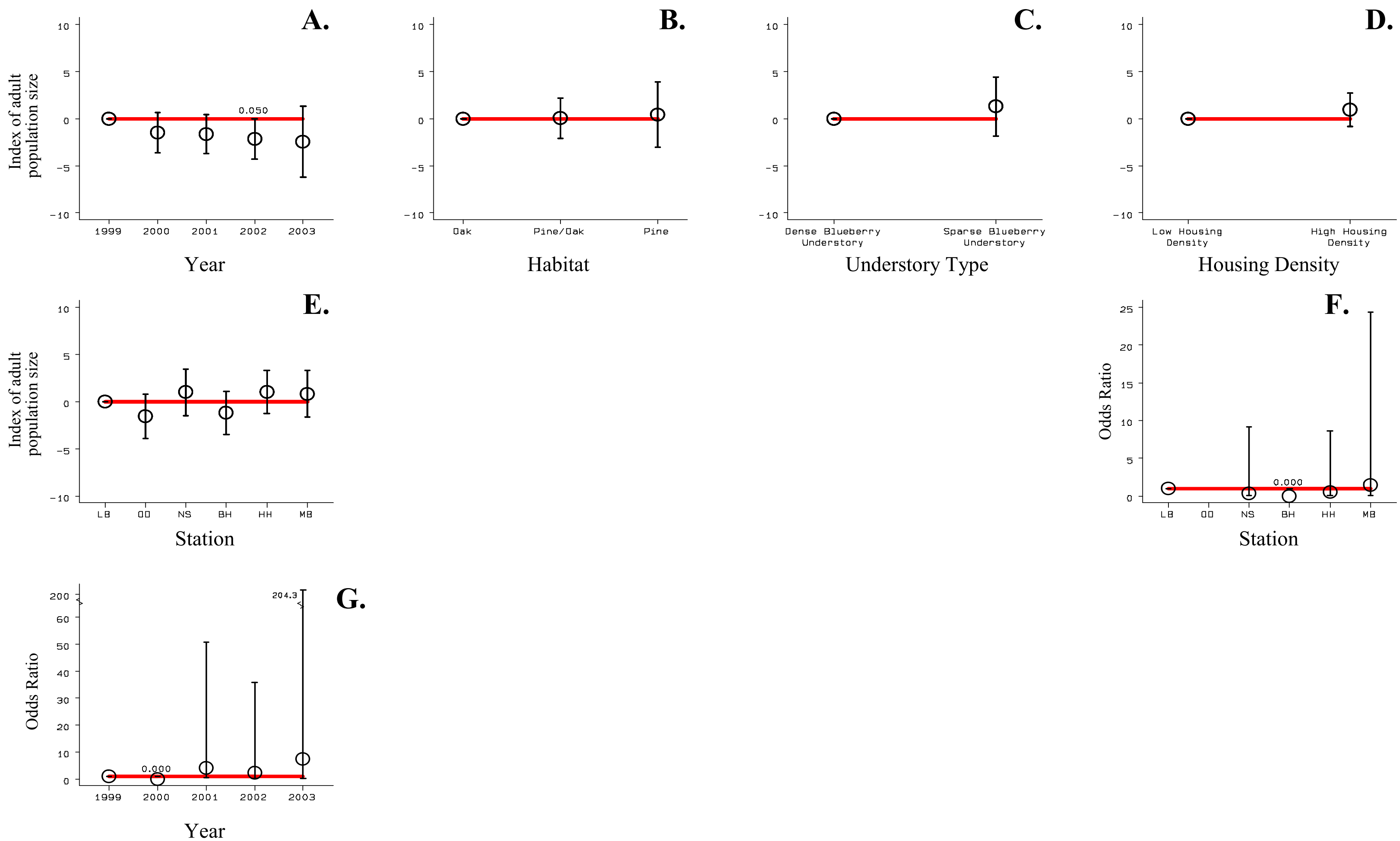

Figure 5. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F&G), with 95% confidence intervals, for **American Robin**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year and station for figures E, F, and G. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

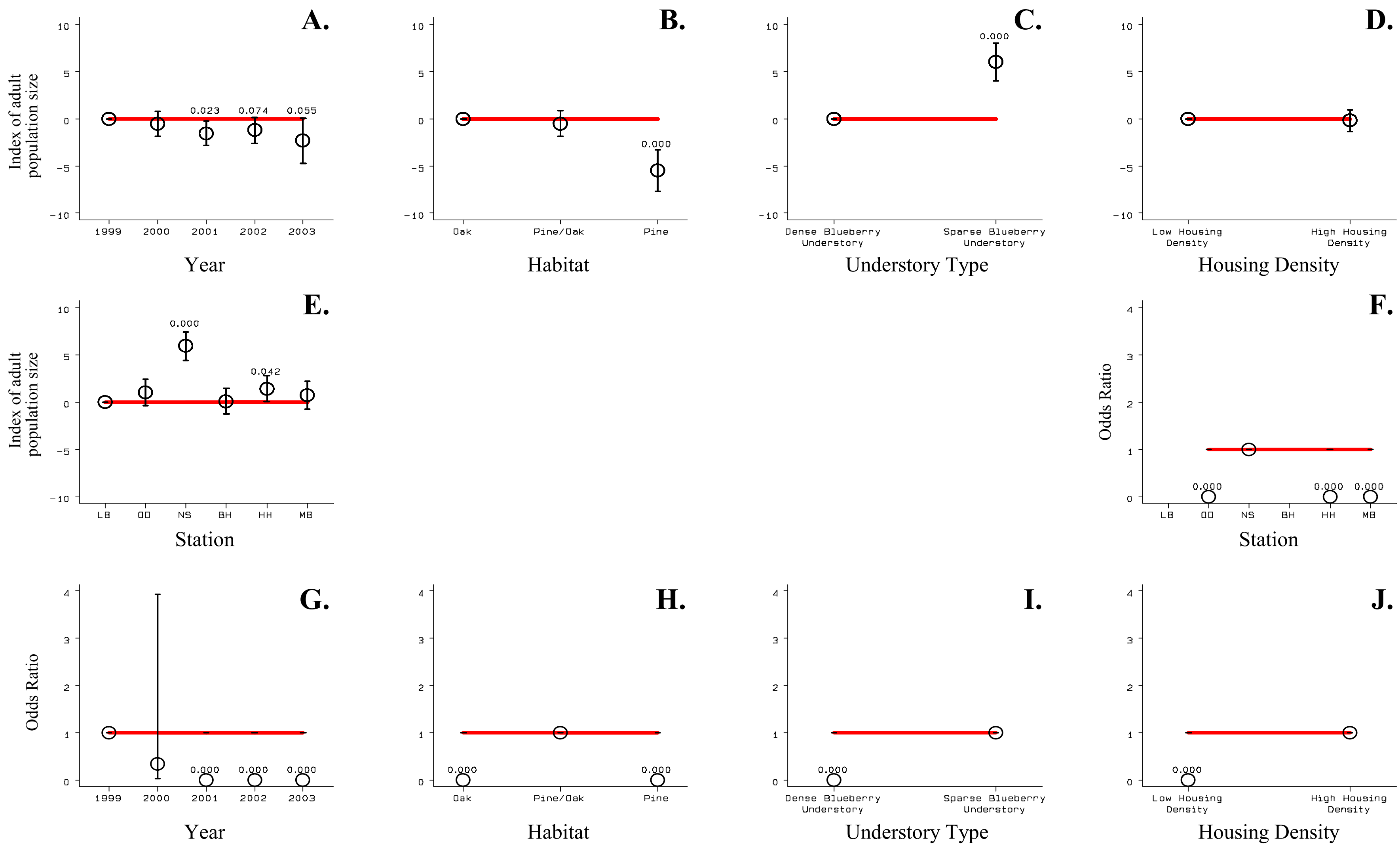

Figure 6. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Gray Catbird**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

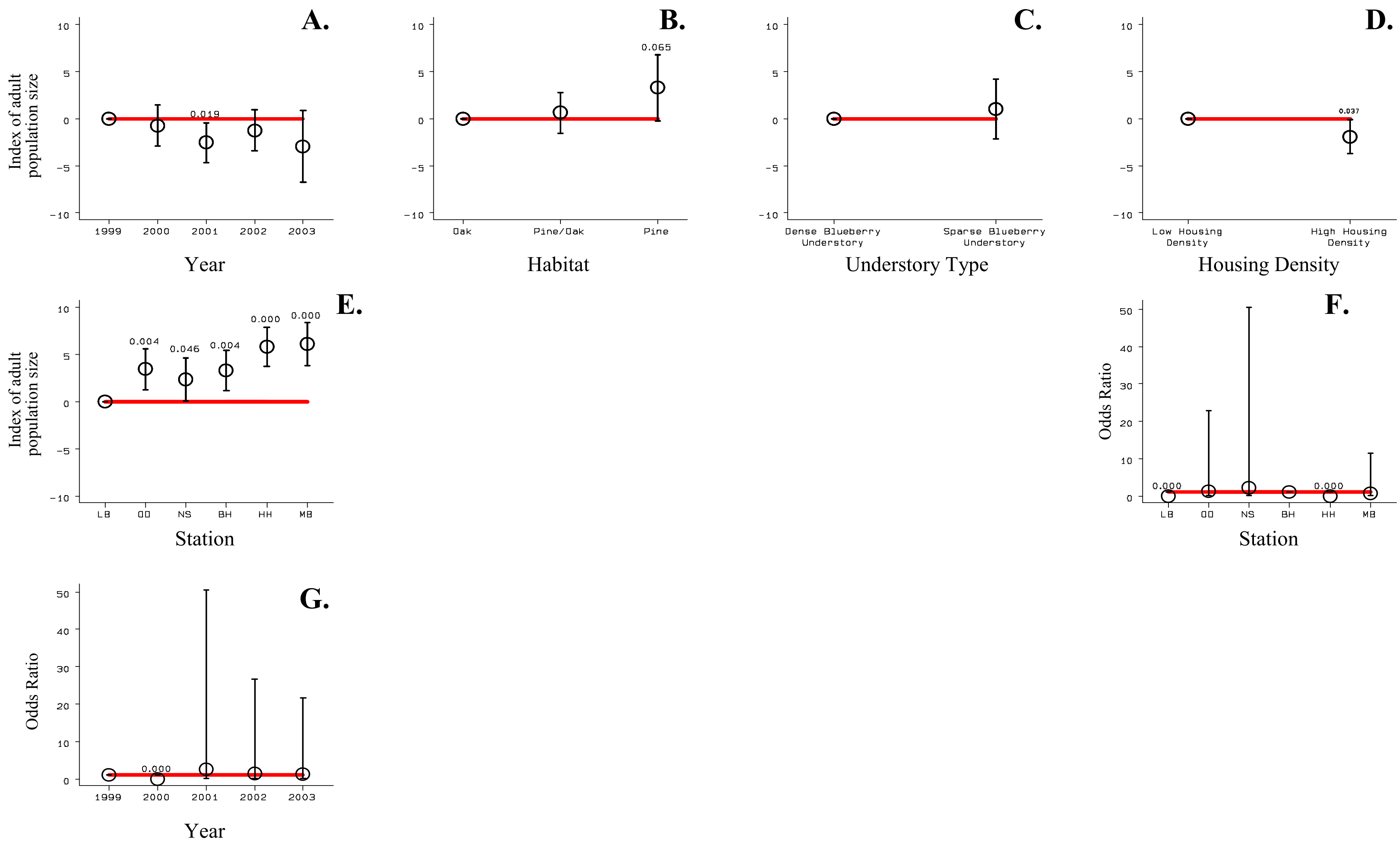

Figure 7. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F&G), with 95% confidence intervals, for **Pine Warbler**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year and station for figures E, F, and G. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

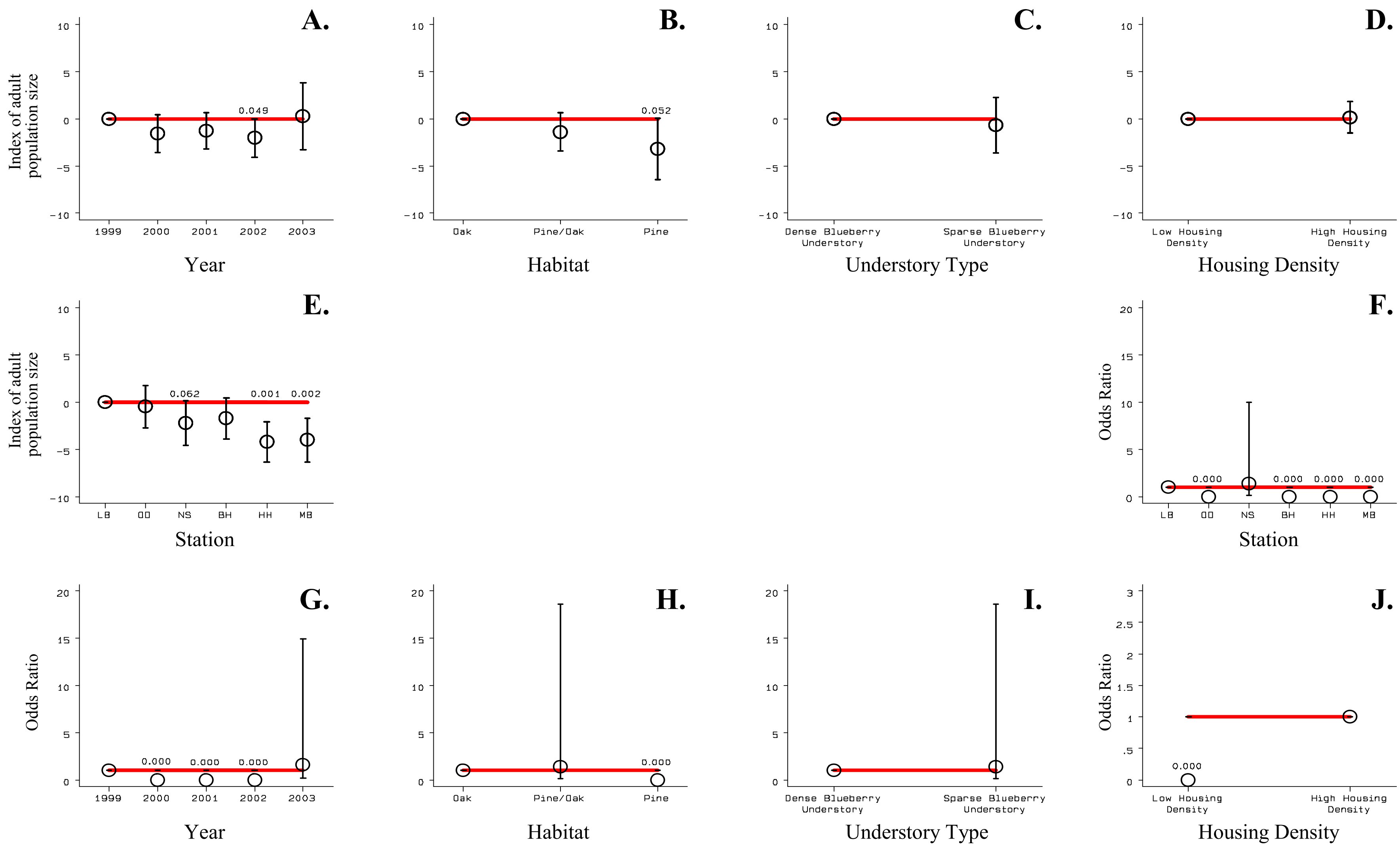

Figure 8. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Ovenbird**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

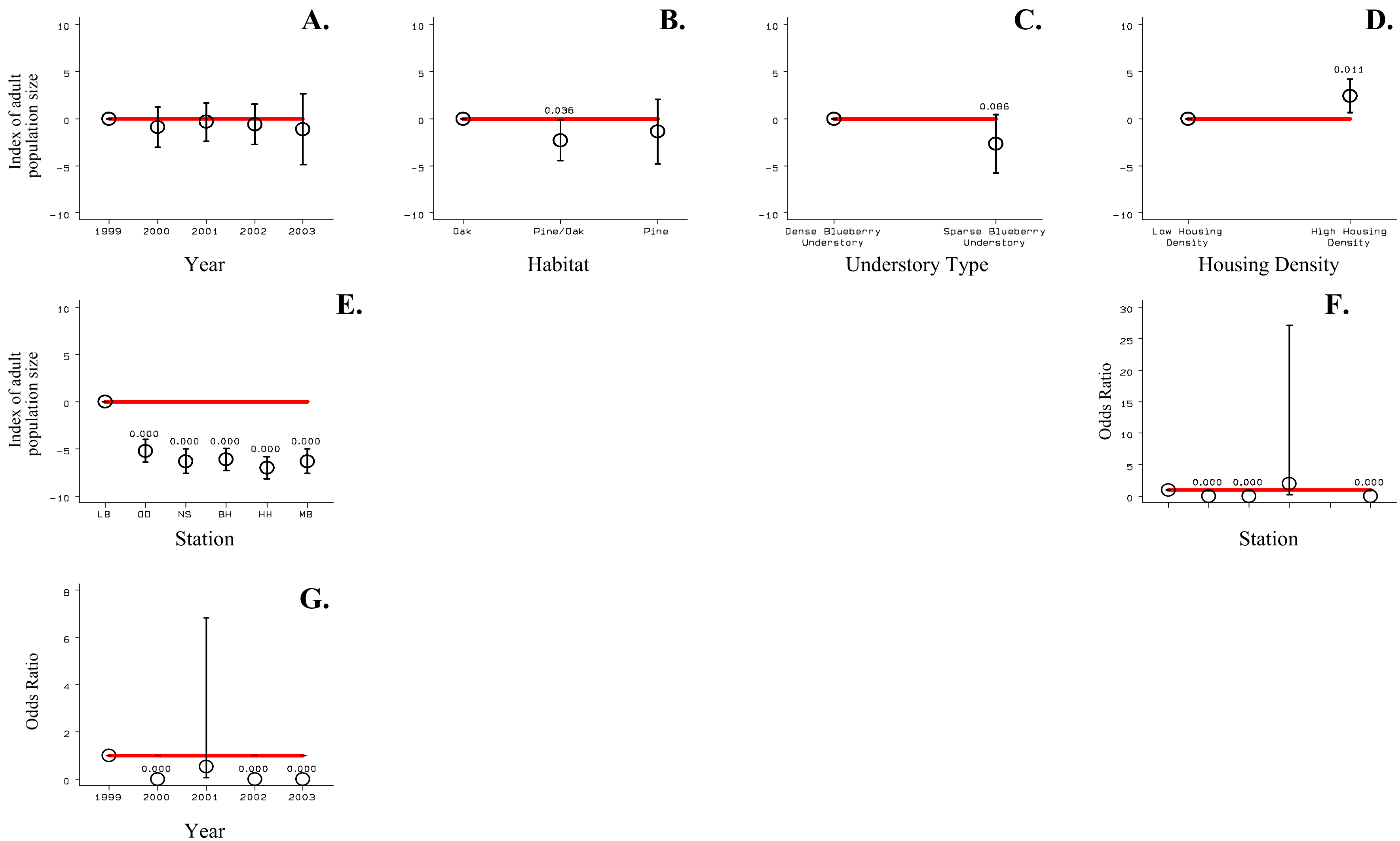

Figure 9. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F&G), with 95% confidence intervals, for **Common Yellowthroat**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year and station for figures E, F, and G. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

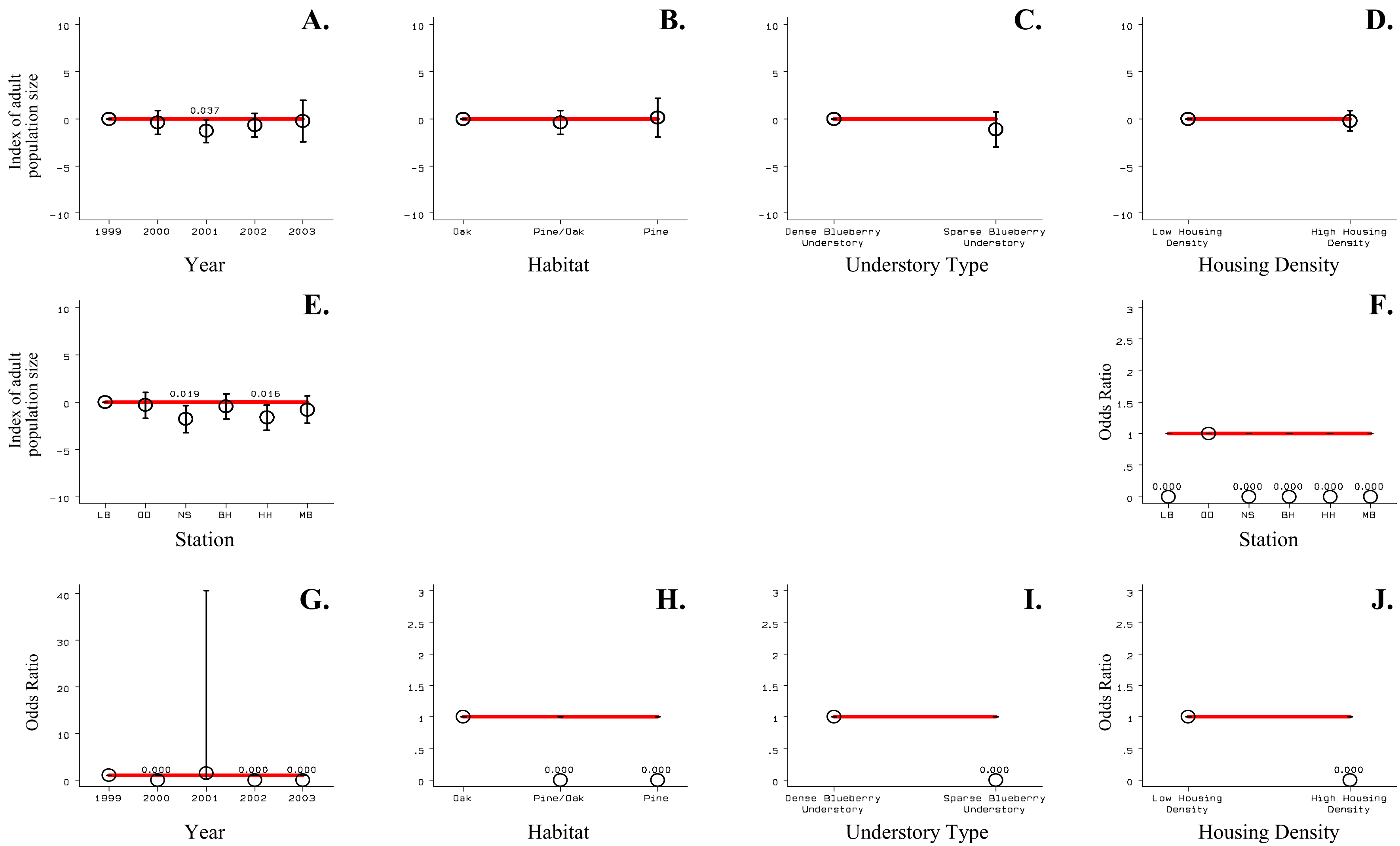

Figure 10. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Eastern Towhee**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

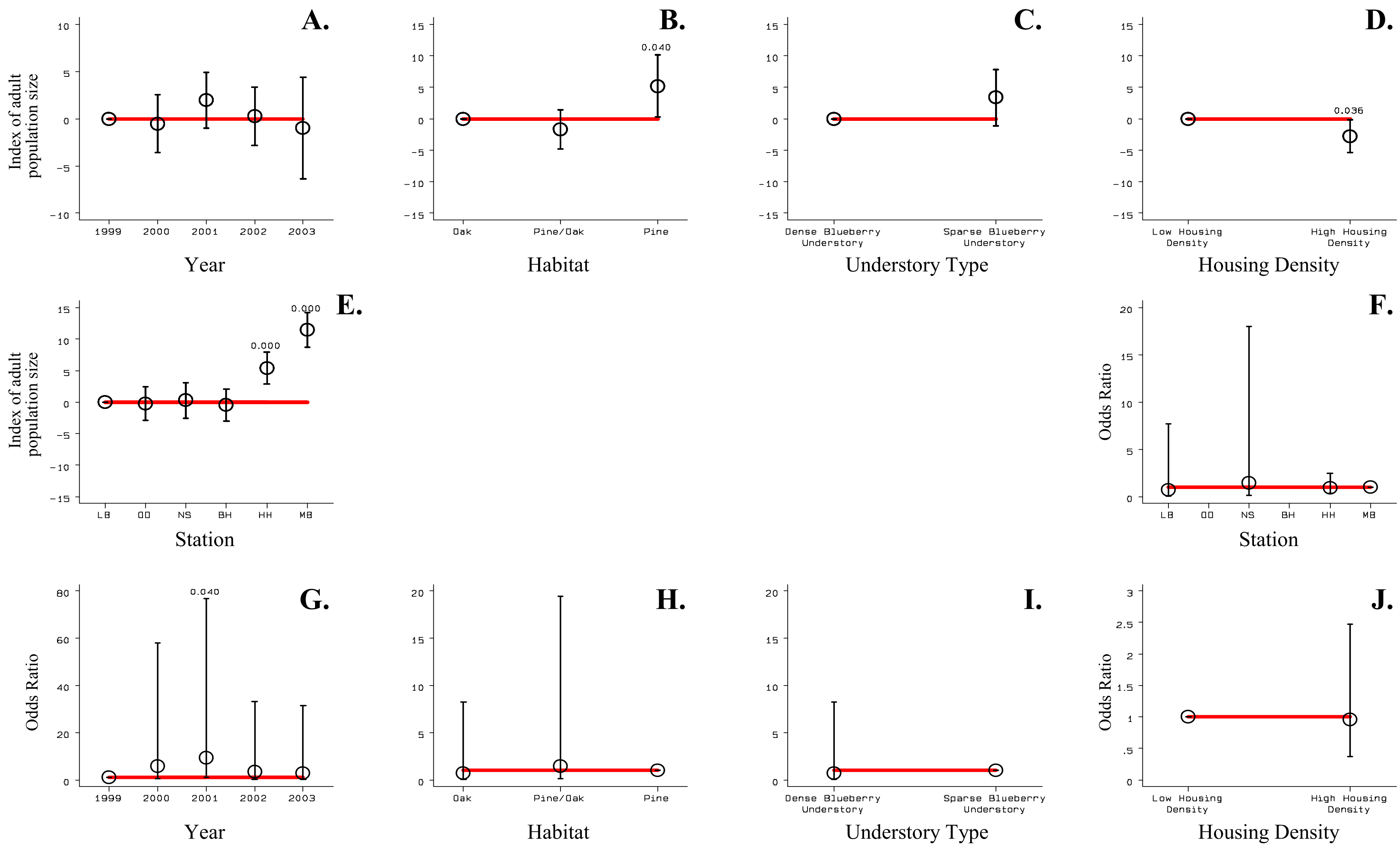

Figure 11. Relative mean numbers of adults (A-E) and odds ratios for productivity indices (F-J), with 95% confidence intervals, for **Chipping Sparrow**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA and the odds ratios for each design variable were estimated using multivariate logistic regression, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D and G-J, and station (controlling for year only; see text), for figures E and F. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

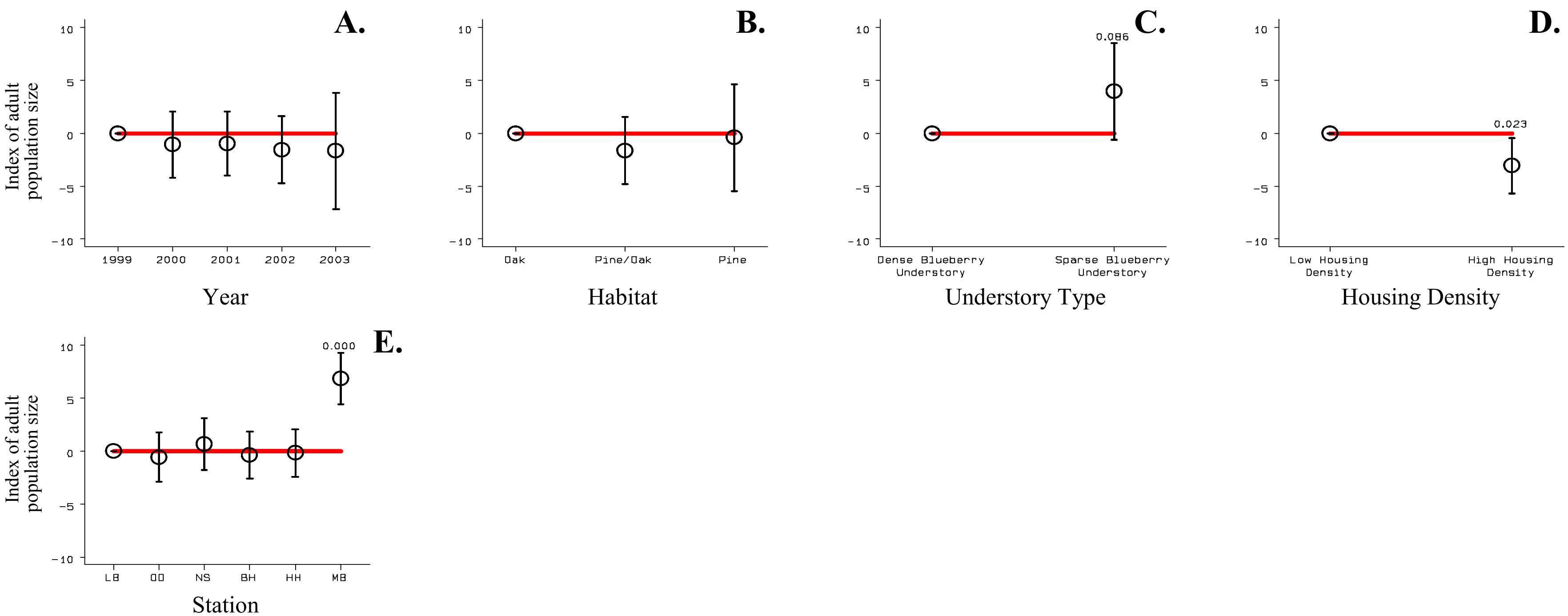

Figure 12. Relative mean numbers of adults with 95% confidence intervals, for **American Goldfinch**, captured at six stations on Cape Cod National Seashore. Relative mean numbers were estimated using multivariate ANOVA, thus controlling for the other variables while calculating the differences in the target variable. The variables included were year, habitat, understory and housing density, for figures A-D, and station (controlling for year only; see text), for figure E. For each variable, the estimates are compared to a reference point (lacking a 95% confidence interval), and the reference point and a reference line are plotted for ease of comparison. LB - Longnook Beach, OD - Oak Dunes, NS - Nauset School, BH - Blueberry Hill, HH - Higgins House, MB - Marconi Beach

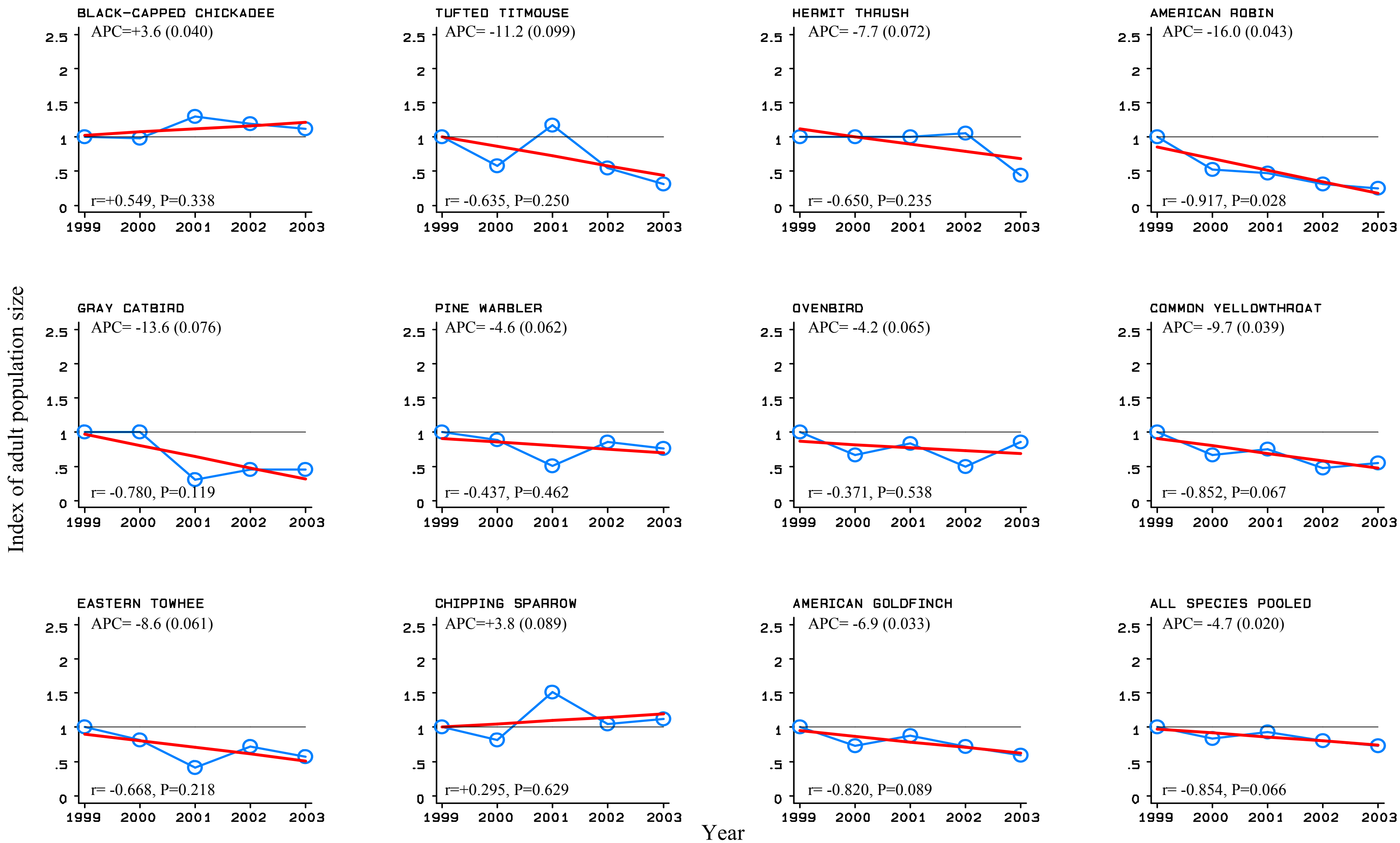

Figure 13. Population trends for 11 species and all species pooled on Cape Cod National Seashore over the five years 1999-2003. The index of population size was arbitrarily defined as 1.0 in 1999. Indices for subsequent years were determined from constant-effort between-year changes in the number of adult birds captured from stations where the species was a regular or usual breeder and summer resident. The annual percentage change in the index of adult population size was used as the measure of the population trend (APC), and it and the standard error of the slope (in parentheses) are presented on each graph. The correlation coefficient (r) and significance of the correlation coefficient (P) are also shown on each graph.

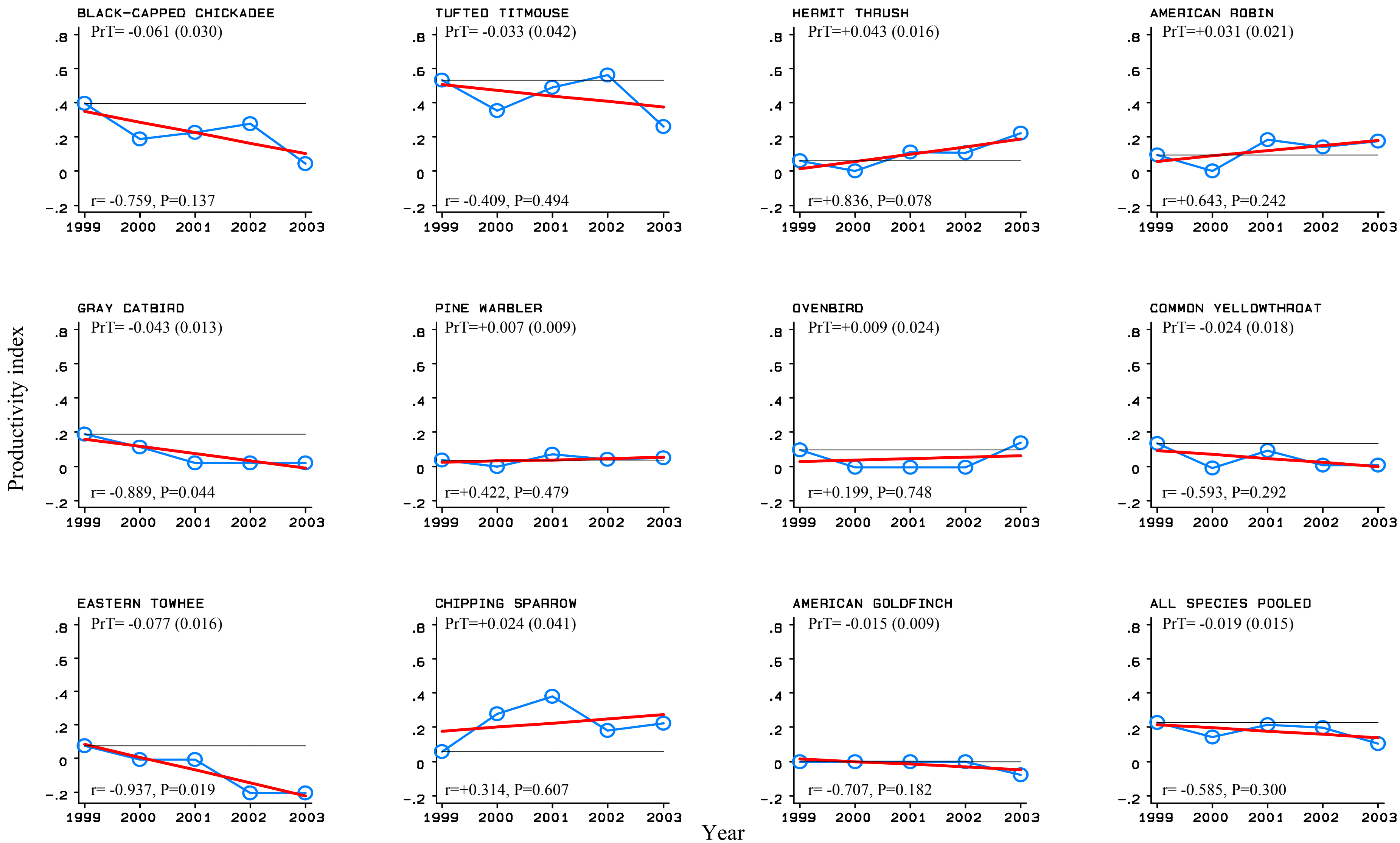

Figure 14. Trend in productivity for 11 species and all species pooled on Cape Cod National Seashore over the five years 1999-2003. The productivity index was defined as the actual productivity value in 1999. Indices for subsequent years were determined from constant-effort between-year changes in proportion of young in the catch from stations where the species was a regular or usual breeder and summer resident. The slope of the regression line for annual change in the index of productivity was used as the measure of the productivity trend (PrT), and it and the standard error of the slope (in parentheses) are presented on each graph. The correlation coefficient (r) and significance of the correlation coefficient (P) are also shown on each graph.

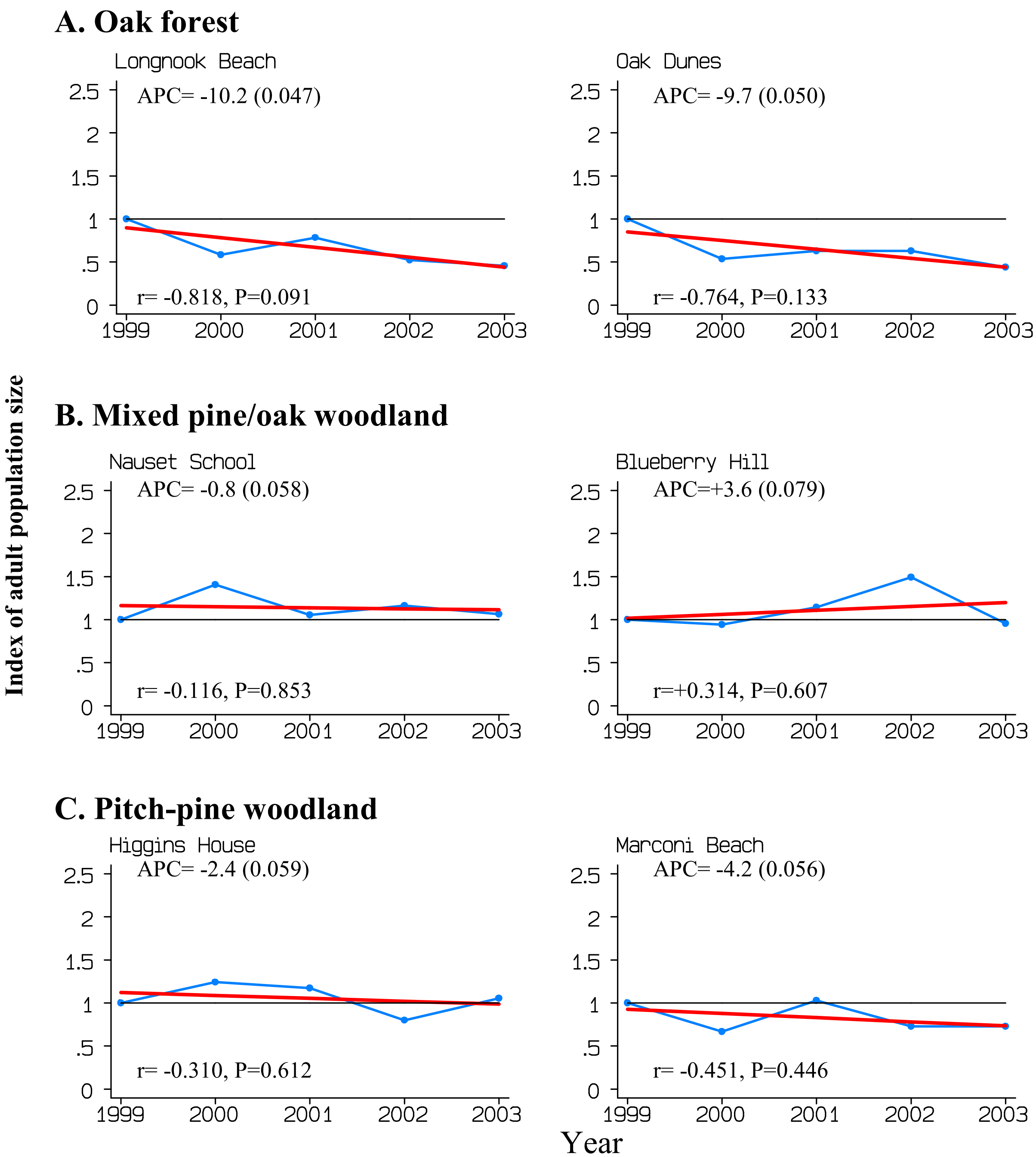

Figure 15. Population trends for **all species pooled** at each of the six individual MAPS stations on Cape Cod National Seashore over the five years 1999-2003. The index of population size was arbitrarily defined as 1.0 in 1999. Indices for subsequent years were determined from constant-effort between-year changes in the number of adult birds captured at stations where the species was a regular or usual breeder and summer resident. The annual percentage change in the index of adult population size was used as the measure of the population trend (APC), and it and the standard error of the slope (in parentheses) are presented on each graph. The correlation coefficient (r) and significance of the correlation coefficient (P) are also shown on each graph.

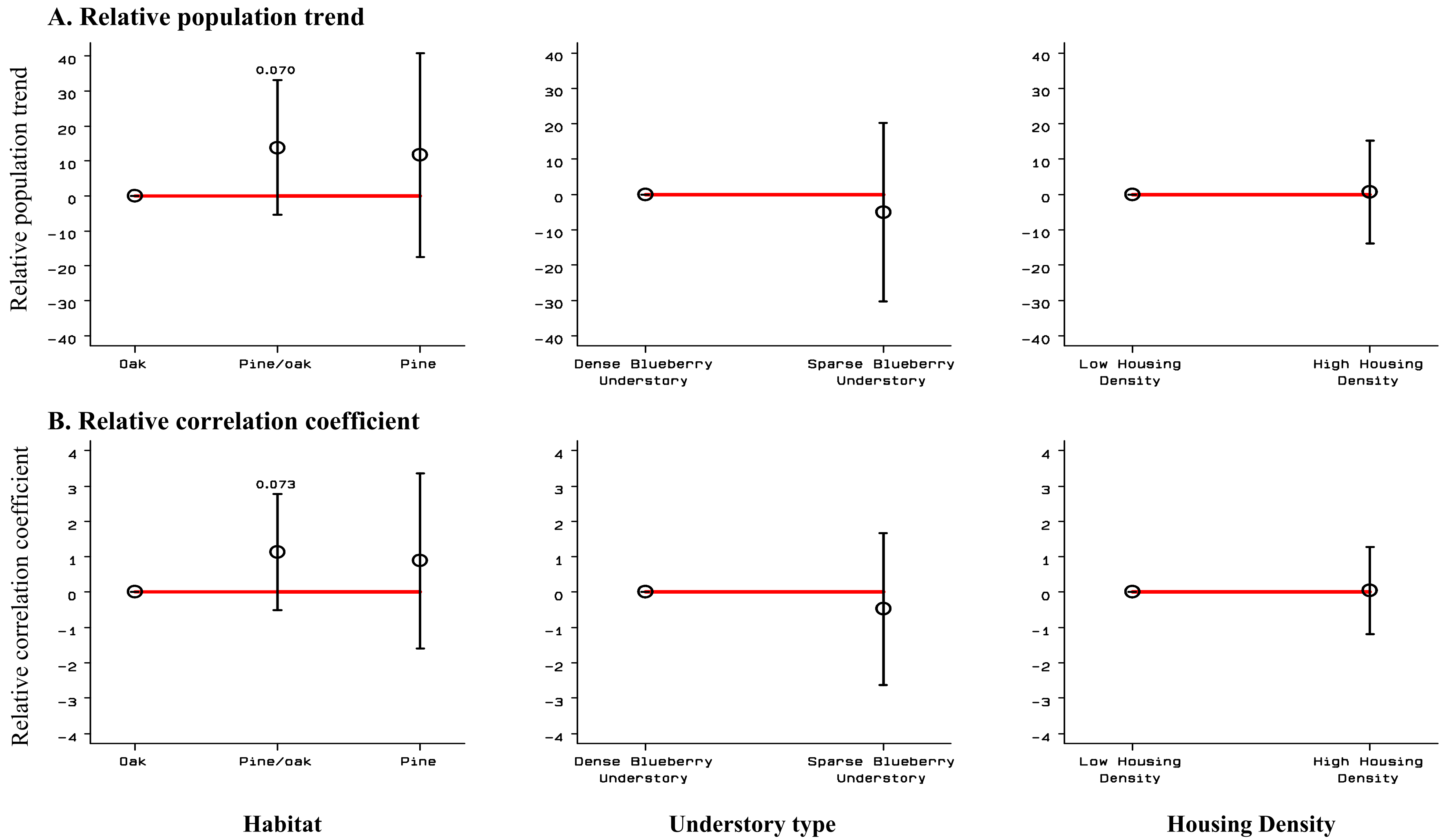

Figure 16. Relative population trends and relative correlation coefficients, with 95% confidence intervals, for **all species pooled**, captured at six stations on Cape Cod National Seashore. Relative population trends and relative correlation coefficients were estimated from multivariate ANOVA analyses of the Annual Percentage Change (*APC*) and correlation coefficients (*r*), respectively, of chained indices of adult population size as a function of three habitat variables, habitat (canopy type), understory type, and housing density class. For each variable (controlling for the other two variables), the estimates are compared to a reference point set to 0.0 (lacking a 95% confidence interval). The reference point and a reference line are plotted for ease of comparison.

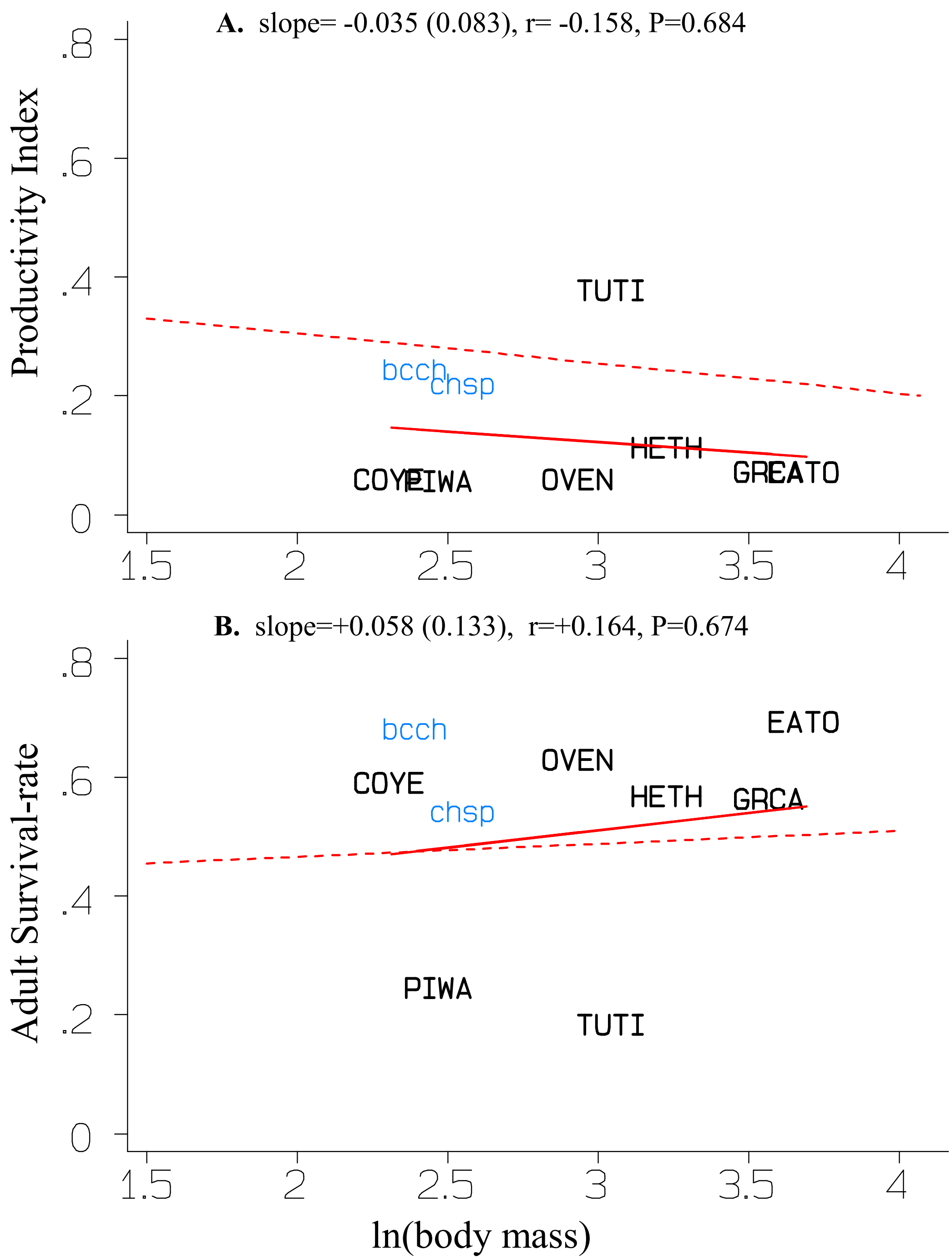

Figure 17. Regressions of (**A**) mean productivity index and (**B**) time-constant annual adult survival rate at Cape Cod National Seashore on the natural log of body mass for nine target species for the five years 1999-2003. Four-letter codes (see Appendix) in bold upper-case letters represent species that had decreasing ($r \leq -0.5$) population trends; those in non-bold upper-case letters had increasing ($r \geq +0.5$) population trends; and those in lower-case letters had relatively stable or widely fluctuating (absolute $r < 0.5$) trends. Regression lines are presented for the nine target species at Cape Cod(solid line) and for all species throughout all of North America (dashed line; see text). The slope, the r-value, and P-value are presented for the regression for the nine target species at Cape Cod.

Appendix. Numerical listing (in AOU checklist order) of all the species sequence numbers, species alpha codes, and species names for all species banded or encountered during the five years, 1999-2003, of the MAPS Program on the six stations ever operated on Cape Cod National Seashore.

NUMB	SPEC	SPECIES NAME
00100	COLO	Common Loon
00860	DCCO	Double-crested Cormorant
01010	GBHE	Great Blue Heron
01300	TUVU	Turkey Vulture
01460	CAGO	Canada Goose
01695	UNTE	Unidentified Teal
02015	UNDU	Unidentified Duck
02020	OSPR	Osprey
02170	NOHA	Northern Harrier
02200	SSHA	Sharp-shinned Hawk
02210	COHA	Cooper's Hawk
02380	RSHA	Red-shouldered Hawk
02400	BWHA	Broad-winged Hawk
02460	RTHA	Red-tailed Hawk
03040	WITU	Wild Turkey
03160	NOBO	Northern Bobwhite
03900	GRYE	Greater Yellowlegs
04590	LAGU	Laughing Gull
04710	HERG	Herring Gull
04810	GBBG	Great Black-backed Gull
04865	UNGU	Unidentified Gull
04940	COTE	Common Tern
04980	LETE	Least Tern
05570	MODO	Mourning Dove
06400	BBCU	Black-billed Cuckoo
06410	YBCU	Yellow-billed Cuckoo
06680	EASO	Eastern Screech-Owl
06800	GHOW	Great Horned Owl
06980	LEOW	Long-eared Owl
07400	CHSW	Chimney Swift
08630	RTHU	Ruby-throated Hummingbird
09110	BEKI	Belted Kingfisher
09550	RBWO	Red-bellied Woodpecker
09650	DOWO	Downy Woodpecker
09660	HAWO	Hairy Woodpecker
09800	YSFL	Yellow-shafted Flicker
09915	UNWO	Unidentified Woodpecker
11390	EAWP	Eastern Wood-Pewee
11460	ACFL	Acadian Flycatcher
11610	EAPH	Eastern Phoebe

Appendix. (cont.) Numerical listing (in AOU checklist order) of all the species sequence numbers, species alpha codes, and species names for all species banded or encountered during the five years, 1999-2003, of the MAPS Program on the six stations ever operated on Cape Cod National Seashore.

NUMB	SPEC	SPECIES NAME
11760	GCFL	Great Crested Flycatcher
12030	EAKI	Eastern Kingbird
12720	BHVI	Blue-headed Vireo
12780	PHVI	Philadelphia Vireo
12790	REVI	Red-eyed Vireo
12930	BLJA	Blue Jay
13190	AMCR	American Crow
13270	FICR	Fish Crow
13340	PUMA	Purple Martin
13410	TRES	Tree Swallow
13490	NRWS	Northern Rough-winged Swallow
13510	BANS	Bank Swallow
13540	BARS	Barn Swallow
13570	BCCH	Black-capped Chickadee
13660	TUTI	Tufted Titmouse
13690	RBNU	Red-breasted Nuthatch
13700	WBNU	White-breasted Nuthatch
13730	BRCR	Brown Creeper
14000	CARW	Carolina Wren
14560	EABL	Eastern Bluebird
14780	VEER	Veery
14820	HETH	Hermit Thrush
14830	WOTH	Wood Thrush
15000	AMRO	American Robin
15130	GRCA	Gray Catbird
15150	NOMO	Northern Mockingbird
15200	BRTH	Brown Thrasher
15550	CEDW	Cedar Waxwing
15630	BWWA	Blue-winged Warbler
15650	TEWA	Tennessee Warbler
15730	NOPA	Northern Parula
15750	YWAR	Yellow Warbler
15760	CSWA	Chestnut-sided Warbler
15770	MAWA	Magnolia Warbler
15800	MYWA	Myrtle Warbler
15830	BTNW	Black-throated Green Warbler
15860	BLBW	Blackburnian Warbler
15910	PIWA	Pine Warbler
15930	PRAW	Prairie Warbler
15970	BLPW	Blackpoll Warbler

Appendix. (cont.) Numerical listing (in AOU checklist order) of all the species sequence numbers, species alpha codes, and species names for all species banded or encountered during the five years, 1999-2003, of the MAPS Program on the six stations ever operated on Cape Cod National Seashore.

NUMB	SPEC	SPECIES NAME
16030	BAWW	Black-and-white Warbler
16080	OVEN	Ovenbird
16150	COYE	Common Yellowthroat
16300	CAWA	Canada Warbler
16495	UNWA	Unidentified Warbler
16830	SCTA	Scarlet Tanager
17820	EATO	Eastern Towhee
18020	CHSP	Chipping Sparrow
18050	FISP	Field Sparrow
18230	SOSP	Song Sparrow
18320	SCJU	Slate-colored Junco
18560	NOCA	Northern Cardinal
18600	RBGR	Rose-breasted Grosbeak
18670	INBU	Indigo Bunting
18730	RWBL	Red-winged Blackbird
18870	COGR	Common Grackle
18960	BHCO	Brown-headed Cowbird
19160	BAOR	Baltimore Oriole
19350	PUFI	Purple Finch
19370	HOFI	House Finch
19510	AMGO	American Goldfinch
20085	UNBI	Unidentified Bird