THE 2002 (TEN-YEAR) ANNUAL REPORT OF THE MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) PROGRAM IN YOSEMITE NATIONAL PARK

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EXECUTIVE SUMMARY

Overview

Since 1989, The Institute for Bird Populations has been coordinating the Monitoring Avian Productivity and Survivorship (MAPS) 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 recently documented declines in North American landbird populations. The system of national parks provides a group of ideal locations for this large-scale, long-term biomonitoring, because they contain large areas of breeding habitat for year-round resident and both short-distance and Neotropical migratory landbirds that are subject to varying local landscape-related and global climate-related effects.

A second objective of MAPS is to provide standardized population and demographic data for the landbirds found in local areas or on federally managed public lands, such as national parks, national forests, and military installations. In this light, the MAPS program has been operated in Yosemite National Park for the past ten years (13 years at one station) with the hope that it will serve as an integral part of the park's Long-Term Ecological Monitoring (LTEM) program. It is expected that information from MAPS will be capable of aiding research and management efforts within the park to protect and enhance the park's avifauna and ecological integrity.

The goal of this report is to: (a) provide a close look at 2001-2002 annual changes in adult population size and post-fledging productivity from MAPS data in Yosemite National Park; (b) summarize ten years of MAPS data from four stations (five years of data from a fifth station) along an elevation gradient in Yosemite National Park; (c) identify declining species in Yosemite National Park that are in need of management actions and conservation strategies to reverse their declines; (d) identify the probable proximate, demographic causes (productivity or survival) for these population declines in Yosemite; and (e) suggest future analyses designed to confirm these causes and to identify and formulate management actions and conservation strategies to reverse these population declines that can be implemented at several spatial scales: in Yosemite National Park, in the greater Sierra Nevada ecosystem, and in montane western North America as a whole.

Adult Population Sizes and Productivity in 2002

The Institute for Bird Populations operated five MAPS stations in 2002 in Yosemite National Park at the same locations at which they were operated from 1990 (Hodgdon Meadow), 1993 (Big Meadow, Crane Flat Meadow, White Wolf Meadow), or 1998 (Gin Flat East Meadow) through 2001. A total of 2245.8 net-hours was accumulated during the summer of 2002, during which 2503 captures of 65 species were recorded.

Populations of adult birds in Yosemite National Park increased very slightly and non-significantly between 2001 and 2002 by +2.9% for all species pooled. Productivity (proportion of young in the catch) for all species pooled, however, increased substantially and near-significantly by +0.137 from 0.503 in 2001 to 0.640 in 2002, to reach the highest level ever recorded at Yosemite National Park in any of the ten years of study. The increase in productivity in 2002 occurred at all five stations but reached its maximum extent at middle elevation stations (Crane Flat and Hodgdon Meadow). Although the increase in productivity was station-wide, it tended not to be species-wide.

Previous MAPS reports have documented an alternating cycle of population increases and decreases at Yosemite between about 1996 and 2001, with increases and decreases in productivity that were exactly out of phase with those of population size. This alternating cycle of population and productivity increases and decreases has frequently been seen at many MAPS locations across the continent, but was not observed at Yosemite during 1993-1996 and was not observed in 2002, when productivity increased substantially for the second year in a row. We believe that the alternating out-of-phase pattern in productivity and population size relates to density-dependent effects on productivity and recruitment along with lower productivity of first-time breeders. Populations that show this alternating two-year dynamic often also show a strong “productivity-population correlation,” whereby changes in productivity in a given year are followed by corresponding changes in adult population size the following year.

The productivity-population correlation was positive at Yosemite for 14 of 24 species and for all species pooled, and both significant correlations were positive, thus generally supporting the concept that changes in productivity one year do bring about corresponding changes in population size the next year, at least for certain species. However, these productivity-population correlations at Yosemite were weaker than those at other national parks, including both Denali and Shenandoah. Indeed, this dynamic appears to be less strongly manifest at locations, such as Yosemite, that are characterized by high interannual variation in weather and snowpack, than in locations where weather is more predictable year-round. It is possible that the relatively unstable (El Niño dominated) weather that affected Yosemite in the early to mid 1990's gave way to more consistent (La Niña dominated) weather late in the 1990’s through 2001, but began returning to El Niño dominated weather in 2002 which for reasons we do not yet understand, was associated with excellent productivity.

Population Trends of Yosemite’s Birds

Populations of adult birds of all species pooled in Yosemite National Park have shown a substantial and near-significant decrease of -1.5% per year over the ten years 1993-2002. While this may not seem to be large annual decline, it suggests that Yosemite’s landbird populations have declined by over 14% during the past decade. Moreover, substantial ten-year declines were observed in nine species (Red-breasted Sapsucker, Western Wood-Pewee, Dusky Flycatcher, Hermit Warbler, Chipping Sparrow, Dark-eyed Junco, Black-headed Grosbeak, Lazuli Bunting, and Lesser Goldfinch), with the declines of all except the sapsucker and junco being significant or nearly significant. In contrast, substantial ten-year increases were observed in only five species (Mountain Chickadee, Yellow-rumped Warbler, MacGillivray’s Warbler, Western

Tanager, and Song Sparrow), of which three, those for the two warblers and the tanager, were significant.

Comparison of long-term (1966-2002) and more recent (1980-2002) BBS population trends for the entire Sierra Nevada physiographic strata for the 24 target species whose ten-year population trends are available from MAPS data for Yosemite National Park reveals a number of interesting observations. Five (Western Wood-Pewee, Hermit Warbler, Chipping Sparrow, Dark-eyed Junco, and Black-headed Grosbeak) of the nine species with substantial ten-year declines in Yosemite National Park also had both long-term and more recent Sierra-wide BBS population declines; these five species, along with Dusky Flycatcher, which showed more recent Sierra-wide and Yosemite declines, are clearly in need of active management and conservation measures. Two (Red-breasted Sapsucker and Lesser Goldfinch) of the nine species had substantial ten-year declines in Yosemite National Park and long-term, but not more recent, Sierra-wide BBS population declines. Yosemite MAPS data suggest that the population decline for the sapsucker may be abating, while the goldfinch continues to decline in Yosemite. Finally, Lazuli Bunting showed a substantial decline in Yosemite National Park but increasing populations Sierra-wide, both long-term and recent. All three of these latter species should continue to be monitored closely, both in Yosemite and Sierra-wide.

Six (Warbling Vireo, Brown Creeper, Golden-crowned Kinglet, Yellow Warbler, Lincoln’s Sparrow, Purple Finch) of the seven species that showed non-substantial (generally highly fluctuating) decreasing trends in Yosemite National Park from MAPS data also showed both long-term and more recent decreasing Sierra-wide BBS trends. We suspect that the declines of these species noted in Yosemite are real and reflect widespread Sierra declines, and we suggest that they also need to be closely monitored. Only one species that showed a non-substantial decreasing trend from Yosemite MAPS data (Cassin’s Vireo) showed both a long-term and more recent increasing Sierra-wide trend. This and the Lazuli Bunting are the only species that appear to be declining in Yosemite but increasing in the Sierra as a whole.

In contrast, six species that showed ten-year increasing population trends from Yosemite MAPS data, including three species with substantial increases (Mountain Chickadee, MacGillivray’s Warbler, and Western Tanager) and three species with non-substantial increases (American Robin, Cassin’s Finch, and Pine Siskin), showed both long-term and more recent Sierra-wide BBS declines. It seems likely that the relatively pristine habitat conditions in Yosemite National Park has led to increasing populations in Yosemite, despite decreasing populations Sierra-wide. This hypothesis can be tested when several more years of MAPS data are available from stations both inside and outside of Yosemite National Park. Finally, we mention two species that showed substantial ten-year increasing population trends from Yosemite MAPS data (Yellow-rumped Warbler and Song Sparrow) and appear to be increasing throughout the entire Sierra according to both long-term and more recent BBS data.

Trends in Productivity in Yosemite National Park

In contrast to population trends, only one species, Lesser Goldfinch, showed a substantial ten-year (1993-2002) declining productivity trend, which was highly significant, while ten species

(Red-breasted Sapsucker, Mountain Chickadee, Brown Creeper, American Robin, Yellow Warbler, Hermit Warbler, Black-headed Grosbeak, Lazuli Bunting, Purple Finch, and Pine Siskin) showed substantial increasing productivity trends, which were significant or nearly significant for Red-breasted Sapsucker, Mountain Chickadee, Yellow Warbler, Black-headed Grosbeak, Purple Finch, and Pine Siskin. The productivity trend for all species pooled was almost substantially positive, with an average absolute increase of +0.017 per year. In part, this increasing trend in productivity was driven by high productivity during the two most recent years of the study; as mentioned above, productivity in 2002 was the highest recorded for all ten years of the study. Although 16 of 24 species showed increases in productivity while 16 of 24 species showed decreases in adult population trends, there was not an inverse relationship between trends in productivity and adult population size. For example, of the four species with significantly increasing productivity (Red-breasted Sapsucker, Mountain Chickadee, Yellow Warbler, Pine Siskin), two (sapsucker and warbler) had decreasing and two (chickadee and siskin) had increasing population trends.

A very weak relationship was found between annual productivity for all species pooled and the El Niño/Southern Oscillation (ENSO) Index, such that productivity tended to be higher during El Niño years. A similar but much stronger relationship between productivity and ENSO was found, at least for Neotropical migratory species, at 36 MAPS stations on six national forests in the Pacific Northwest, where productivity for temperate-wintering species appeared to be driven primarily by the North Atlantic Oscillation (Nott et al. 2002a). Clearly factors other than the El Niño/Southern Oscillation are affecting productivity of Yosemite's birds. One of these factors seems to be timing of melting of the snowpack (which, surprisingly, is not always correlated with ENSO), with a tendency toward lower productivity associated with earlier melting snowpacks at lower elevations and higher productivity associated with earlier melting snowpacks at the highest elevations. Additional analyses utilizing substantially more years of data will be necessary to unravel the relationships among productivity of Yosemite's birds, elevation, weather conditions, and climate cycles.

Demographics of Yosemite's Birds Along an Elevation Gradient

Ten years (1993-2002) of data from four MAPS stations (and five years from a fifth) along an elevation gradient on the west slope of the Sierra Nevada in Yosemite National Park have shown that species richness (number of species), total adult population size, productivity, and adult population trend each varied with elevation in unique ways. Total species richness of adult birds was highest at the lowest elevation (Big Meadow -- 60 species), lowest at the highest elevation (White Wolf Meadow -- 34 species), and clearly decreased with increasing elevation. In marked contrast to total species richness, mean annual number of adults of all species pooled (essentially an index of total bird density) was highest at intermediate elevations (Crane Flat -- 302.8 birds per 600 net-hours) and decreased progressively both at lower (Hodgdon -- 264.0; Big Meadow -- 208.2) and higher (Gin Flat East -- 171.1; White Wolf -- 140.0) elevations.

In further contrast, mean annual productivity for all species pooled was highest at still higher elevations (Gin Flat East -- 0.63) and, again, decreased progressively both at lower (Crane Flat -- 0.49; Hodgdon -- 0.46; Big Meadow -- 0.43) and higher (White Wolf -- 0.48) elevations.

Excluding Gin Flat East, which has only been operated for five years, productivity showed a positive correlation with elevation. Station-specific ten-year population trends for all species pooled also correlated positively with elevation, being nearly flat (-0.1% per year) at White Wolf, where two of three target species increased, and substantially and highly significantly negative (-6.3% per year) at Big Meadow, where four of six target species decreased significantly. As expected from these two results, station-specific ten-year population trends for all species pooled for the four long-running stations correlated positively with mean annual productivity for all species pooled for those stations. Although none of these correlations was significant (due to the small number of stations), they suggest that the increasingly negative population trends at lower elevation stations may have been driven by the increasingly lower productivity at those same stations, especially during drought years with meager snowpacks. Predictions from global climate models and recent weather data suggest that the Sierra is becoming increasingly arid and that this drying tendency may be accelerating. Data from MAPS suggest that, in general, avian populations in the Sierra will be adversely affected by such climate change. This hypothesis underscores the importance of long-term avian demographic monitoring data in Yosemite National Park where, unlike the situation in the national forests of the Sierra Nevada, avian population and demographic changes are not greatly affected by concurrent land-use changes.

Survival Rates of Yosemite's Birds

It is important to note that productivity is not necessarily the only or even major driving force for long-term population trends, even when annual changes in productivity can be shown to drive annual changes in population size. This is because it is the overall relation between average productivity and average mortality that determines overall population trends. Thus, in order to fully investigate the effects of productivity on long-term population trends and determine the causes of population change, we must also consider annual survival rates.

We were able to obtain estimates of annual adult apparent survival rates (φ) for 19 target species at Yosemite using ten years data from all five stations combined. As mentioned in previous reports, increased years of data have resulted in increased numbers of species for which survival estimates could be obtained. In addition, the mean precision of these survival-rate estimates has increased substantially with each additional year of data. For example, the mean CV(φ) for 16 species whose adult survival rates could be estimated from seven (1993-1999), nine (1993-2001), and ten (1993-2002) years of data decreased from 23.9% for seven years of data, to 16.7% for nine years of data, and to 15.4% for ten years of data. These results suggest that maximum precision may not be obtained until 12 or more years of data are available, a result in agreement with theoretical predictions. Despite the relatively good precision obtained for most species with CV(φ)<30% (mean CV(φ)=13.5%), $\Delta QAIC_C$ (a measure for selection of time-dependent models) values were relatively high (>2.0) in all but one (Dark-eyed Junco) of these 14 species. This suggests that there is relatively little interannual variation in survival for most Yosemite species.

Causes of Population Changes in Yosemite's Birds

In order to help determine the causes of changes in landbird populations at Yosemite, one of the primary goals of MAPS, we have examined patterns of productivity and survival as a function of body mass for 18 target species to evaluate which of the two factors may be unexpectedly low or high and, thus, which factor is likely to be more influential in driving population trends. For both productivity and survival, the regression lines based on data from the 18 species target at Yosemite were quite similar to those based on data from North America as a whole, although productivity for the smaller species (thus for most species), and, perhaps, survival for the few larger species appeared to be substantially higher at Yosemite than for North America as a whole. This might be expected considering the protected nearly pristine nature of the park.

For each of the 18 target species, we combined these data on Yosemite productivity and survival values relative to continent-wide relationships for productivity and survivorship as a function of body mass, with all other demographic data available from all stations combined, including a synthesis of actual productivity indices, productivity trends, productivity-population correlations, actual adult apparent survival estimates, and $\Delta QAIC_C$ values, and we made assessments as to whether population changes were due to low productivity on the breeding grounds, low survival (probably during migration and/or on the winter grounds), both, or neither. Results of our analyses suggest that decreasing or low productivity (at least during the time that corresponded to the major portion of the decline) likely drove the population declines of six (Red-breasted Sapsucker, Western Wood-Pewee, Dusky Flycatcher, Chipping Sparrow, Lazuli Bunting, and Lesser Goldfinch) of the nine declining species, while increasing or high productivity likely drove the population increases of four (Mountain Chickadee, Yellow-rumped Warbler, MacGillivray's Warbler, and Song Sparrow) of the five increasing species. In contrast, low adult survival appeared to be contributing to the population decline of only one species (Dusky Flycatcher), while high adult survival apparently did not contribute to the increase of any species. Neither productivity nor adult survivorship appeared to be driving the population declines of Hermit Warbler, Dark-eyed Junco, and Black-headed Grosbeak, nor the population increase of Western Tanager. We can only surmise that other factors not currently estimated by MAPS (e.g., low intrinsic recruitment or low first-year survival rates) are causing the population changes in these four species.

Future Analyses

In four or five more years, when we will have accumulated 14 or 15 consecutive years of data from each of the four long-running stations, we hope to be able to estimate annual recruitment rates for both second-year and older birds, and to use these estimates to make inferences regarding first-year survival rates, as well as the amounts of immigration and emigration in the populations. Our aim is to be able to conduct some of these analyses at the spatial scale of the four individual stations. This may yield especially important results at Yosemite, where the stations span such a significant elevation range and the population dynamics appear to be influenced by elevation.

We have recently initiated two additional broad-scale analyses to help us further understand the population dynamics of landbirds and potential management actions to assist bird populations. First, by modeling spatial variation in vital rates as a function of spatial variation in population trends, we are beginning to gain insight as to the proximate demographic causes of population trends within a species at multiple spatial scales (DeSante et al. 2001). We hope to undertake such analyses (e.g., between Sierra stations within and outside of Yosemite) sometime in the future, when we will have accumulated about 14 or 15 years of data. Second, we have found that patterns of landscape structure detected within a two- to four-kilometer radius area of each station are good predictors not only of the numbers of birds of each species captured but, more importantly, of their productivity levels and population trends as well (Nott 2000). These types of analyses can provide extremely powerful tools to identify and formulate management actions aimed at reversing declining populations and maintaining stable or increasing populations of landbirds, because they can address the particular vital rate responsible for the decline. We plan to conduct similar analyses for the target species in the Sierra, by modeling productivity as a function of various landscape characteristics that vary along a gradient from the pristine landscapes found in Yosemite National Park to the much more heavily managed landscapes on Sierran national forests where we also have MAPS stations. Again, we plan to conduct such analyses after we have accumulated some 14 or 15 years of data.

Because of the pronounced elevation factor at Yosemite and the complex effects of weather on population size and productivity, we will need to incorporate elevation-specific habitat analyses and account for weather on an annual basis. For example, elevation effects on adult population size also reflect the effects of dry years (greater population sizes at higher elevations due to lack of snow pack and warmer temperatures) vs. wet years (greater population sizes at lower elevations due to higher food productivity and cooler temperatures). Thus, landscape-level analyses at Yosemite will necessarily involve interactions between elevation and weather as well as habitat characteristics. It is the complexity of these interactions that create the need for long-term (at least 15 years) data.

Conclusions

Analyses of ten years of MAPS data from four stations along an elevation gradient in Yosemite National Park, plus five years of data from a fifth station, have shown that bird populations in Yosemite have decreased over the ten years with substantially more species decreasing than increasing. These data have also shown that species richness, total bird density, productivity, and population trends all vary with elevation in generally different ways. We have also demonstrated how MAPS data can be used to measure and assess the effects of productivity and survivorship as driving forces for the varying avian population trends documented in Yosemite National Park, both overall and at the individual species level. In future analyses, we hope to include estimates of first-year recruitment and indices of first-year survival in order to more fully understand what parameters are most affecting population changes in each target species.

This report demonstrates that the indices and estimates of primary demographic parameters provided by the Yosemite MAPS Program are providing critical information that can be extremely useful for the management and conservation of landbirds in Yosemite and, in combination with similar data from other areas, throughout the Sierra Nevada and across the whole of North America. The results highlighted above have also revealed that the population dynamics of the breeding birds of Yosemite National Park are complex, as are the likely causes of the dynamics and, for those trends deemed problematic, their solutions. This complexity, in turn, underscores the importance of standardized, long-term data. Once about 14 or 15 years of data have accumulated and the precision of our estimates improves further, time-dependence in estimates becomes more readily apparent, and long-term trends are more clearly established, we will be able to incorporate weather and climate data as well as landscape-level habitat data as additional co-variates in logistic regression analyses of productivity and in survivorship models. We are confident that, with these additional years of data, we will be able to further our understanding of the population dynamics of Yosemite's birds and shed more light on the complex paths leading from stressors to population responses.

Results from the first ten years of the MAPS Program in Yosemite National Park (13 years at the Hodgdon Meadow station), as documented in this report, thus indicate that meaningful station-specific indices of adult population size and post-fledging productivity, reasonably precise park-wide estimates of annual apparent survival rates of adults, and important information on annual changes, longer-term trends, and elevation differences in these indices and estimates are being obtained for at least 24 target species. We conclude that the MAPS protocol is very well-suited to provide a critical component of the Park Service's Long-Term Ecological Monitoring program in Yosemite National Park. Based on the above information, we recommended that the operation of the five MAPS stations currently active in Yosemite National Park be sustained indefinitely into the future, and that a comprehensive analysis of all Sierran MAPS data (including Yosemite's) be conducted after about 14 or 15 years of data have been accumulated, that is, depending on the availability of additional funding for these analyses, after the 2006 or 2007 field season.

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 and other NPS units. A pilot study to develop and evaluate field and analytical techniques to accomplish these objectives was first implemented in four national parks across the United States. The goals of this pilot program were 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 was that methods evaluated be useful in other national parks across the United States. This program is referred to as a Long-term Ecological Monitoring (LTEM) Program.

The development of an effective long-term ecological monitoring program in the national parks 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 can provide invaluable information for monitoring natural ecological processes and for evaluating the effects of large-scale, even global, environmental changes. The national parks 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 can provide information that is crucial for efforts to preserve natural resources and biodiversity at multiple spatial scales, ranging from the local scale to the continental or even global scale.

Landbirds

Landbirds, because of their high body temperature, rapid metabolism, and high ecological position on most food webs, may be excellent indicators of the effects of local, regional, and global environmental change on 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.

Recent analyses of data from several of these programs, particularly the BBS, suggest that populations of many landbirds, including forest-, scrubland-, and grassland-inhabiting species, 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). A 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 monitoring programs at NPS units using protocols developed by the Monitoring Working Group of PIF. Clearly, the 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) 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 timelags 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-level habitat characteristics or degree of habitat disturbance. The detection of such differences can lead to immediate management implementation within a national park, 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 providing long-term demographic data on landbirds (DeSante et al. 1995). The design of the MAPS program was patterned after the very successful British Constant Effort Sites (CES) Scheme that has been operated by the British Trust for Ornithology since 1981 (Peach et al. 1996). The MAPS program was endorsed in 1991 by both the Monitoring Working Group of PIF and the USDI Bird Banding Laboratory, and a four-year pilot project (1992-1995) was approved by the USDI Fish and Wildlife Service and National Biological Service (now the Biological Resources Division [BRD] of the U.S. Geological Survey [USGS]) to evaluate its utility and effectiveness for monitoring demographic parameters of landbirds. A peer review of the program and of the evaluation of the pilot project was completed by a panel assembled by USGS/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 ten years, for example, IBP has been contracted to operate up to five MAPS stations in Yosemite National Park, as well as six in Denali, five in Shenandoah, and two in Kings Canyon national parks, and six on Cape Cod National Seashore. 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 Program and, subsequently, to implement its use as part of that program.

Goals and Objectives of MAPS

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

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

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

(B) annual estimates of adult population size, adult survival rates, proportions of residents among newly captured adults, recruitment rates into the adult population, and population growth rates from modified Cormack-Jolly-Seber analyses of mark-recapture data on adult birds.

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

(A) 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

(B) 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.

III. 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 geographic 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 geographic areas (perhaps based on BBS physiographic strata, such as the Sierra Nevada, Cascade Mountains, Central valley, or California Foothills), 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 areas, 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 goals laid out for the NPS's Long-Term Ecological Monitoring Program. Accordingly, the operation of MAPS stations at Yosemite National Park has been included in the development of a LTEM Program for the Park. It is expected that information from the MAPS program will be capable of aiding research and management efforts within Yosemite National Park 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. 2001a). (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. 2002a). These results indicate that MAPS is capable of achieving, and in some cases is already achieving, its objectives and goals.

The 2002 Report on the Yosemite MAPS Program

In this report we summarize results of the MAPS program at five stations in Yosemite National Park from 1993 (1998 at Gin Flat East Meadow and additionally from 1990 for Hodgdon Meadow) through 2002. We present annual changes in the numbers of adult and young birds and in productivity indices between 2001 and 2002. We present 10-year (5-year at Gin Flat East) mean indices of adult population size and productivity at each individual station and for all stations combined for each species and for all species pooled. We present temporal trends in adult population size at each station and for all stations combined and productivity trends at the park-wide scale for 24 target species and all species pooled. We model annual adult apparent survival rates for 19 of the 24 target species. Finally, we model productivity and survivorship as a function of body mass, and consider all values, relationships, and trends in these vital rates in order to suggest demographic causes of the population trends observed in Yosemite's birds.

METHODS

Establishment and Operation of Stations

Five MAPS stations were re-established in Yosemite National Park in 2002, at the same locations they were originally established. The five stations, located along an elevation gradient from highest to lowest, were as follows: 1) White Wolf Meadow, set in a wet montane meadow with red fir/lodgepole pine forest at 2402 m elevation; 2) Gin Flat East Meadow, located in a wet montane meadow with mixed red fir and lodgepole pine at 2073 m elevation; 3) Crane Flat Meadow, located in a wet montane meadow with willow/aspen thickets and mixed coniferous forest at 1875 m elevation; 4) Hodgdon Meadow, located in a wet montane meadow with willow/dogwood thickets, mixed coniferous forest and a patch of California Black Oak woodland at 1408 m elevation; and 5) Big Meadow, in riparian willows and mixed coniferous forest in an open dry meadow at 1311 m elevation. The Hodgdon Meadow station was established and first operated in 1990, the Gin Flat East Meadow station in 1998, and the other three stations in 1993. See Table 1 for details of habitats and operation of each station in 2002.

Through the efforts of three intensively trained field biologist interns of The Institute for Bird Populations, Meghan Williams, Natasha Schorb, and Emily Earll, trained and supervised by IBP staff field biologist Pilar Velez, these five MAPS banding stations were operated during 2002 (and in all preceding years) in accordance with the highly standardized banding protocols developed for the MAPS Program throughout North America (DeSante et al. 2002).

A total of ten net sites (14 at the Hodgdon Meadow station) were re-established at each of the stations in 2002 at the exact same locations where they were established and operated in each of the preceding years. One 12-m-long, 30-mm-mesh, nylon mist net was erected at each of the ten net sites at four of the stations on each day of operation. At Hodgdon Meadow, seven of the 14 net sites were operated on one day with the remaining seven net sites operated on a second day. Each of the stations were operated for six morning hours per day (beginning at about local sunrise) during one day (two days for Hodgdon Meadow) in each of eight consecutive 10-day periods between May 21 and August 8 or, for the two higher-elevation stations (White Wolf and Gin Flat East), for one day in each of seven consecutive 10-day periods between May 31 and August 8. With very few exceptions, the operation of all stations occurred on schedule in 2002 during each of the ten-day periods. A brief overview of both the field and analytical techniques applied in 2002 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 and 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 rainfall. The following data were taken on all birds captured, 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 weight;
(13) date and time of capture (net-run time); and
(14) station and net site where captured.

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

For each of the five stations operated, simple habitat maps were prepared on which up to four major habitat types, as well as the locations of all structures, roads, trails, and streams, were identified and delineated; when suitable maps from previous years were available, these were updated. 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 eleven cover categories according to guidelines spelled out in the MAPS Habitat Structure Assessment Protocol, developed by IBP Landscape Ecologist, Philip Nott (Nott et al. 2002b).

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 captured in mist nets 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 within the overall breeding range of the species; an altitudinal disperser (A) if the species breeds only at lower elevation than that of the station but disperses to higher elevations after breeding; 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), transient (T), or altitudinal disperser (A), 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.

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

(1) the numbers of newly banded birds, recaptured birds, and birds released unbanded;

(2) the numbers and capture rates (per 600 net-hours) of first captures (in 2002) of individual adult and young birds; and

(3) the proportion of young in the catch.

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

For all six stations we calculated changes between 2001 and 2002 in the numbers of adult and young birds captured and in the indices of 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. We excluded 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 Yosemite National Park, the significance of park-wide annual changes in the numbers of adult and young birds and in the indices 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 and we use the term "near-significant" or "nearly significant" for differences for which $0.05 \leq P < 0.10$.

B. Analyses of trends in adult population size and productivity. We examined multi-year trends (five-year trends at Gin Flat East Meadow, ten-year trends at the other four stations and for all stations combined, and additional 13-year trends at Hodgdon Meadow) in indices of adult population size and ten-year trends in productivity indices for all stations combined for target species for which an average of at least six individual adult birds were captured per year at each station and at all five stations combined. For trends in adult population size, we first calculated adult population indices for each species for each of the ten years based on an arbitrary starting index of 1.0 in the first year of station operation (1998 at Gin Flat East Meadow, 1993 at the other four stations and for all stations combined and, additionally, 1990 at Hodgdon Meadow). 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 (PT) of these indices over the ten or five year periods. Because the indices for adult population size are based on percentage changes, we further calculated the annual percent change (APC), defined as the average change per year over the ten-year period, to provide an estimate of the population trend for the species; APC was calculated as:

(actual year-one value of *PSI* / predicted year-one value of *PSI* based on the regression) * *PT*.

We present the *APC*, the standard error of the slope (*SE*), the correlation coefficient (*r*), and the significant of the correlation (*P*) to describe each trend. Species for which $r \geq 0.50$ 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 $SE \leq X$ are considered to have a stable trend, and those for which $-0.5 \leq r \geq 0.5$ and $SE > X$ are considered to have widely fluctuating values but no substantial trend; *X* varies by number of years, being 0.140 for five-year trends, 0.035 for ten-year trends, and 0.021 for 13-year trends.

Trends in Productivity, *PrT*, for all stations combined were calculated in an analogous manner by starting with actual productivity values in 1993 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 ten-year productivity trends are considered to be highly fluctuating if the *SE* of the slope > 0.020.

To evaluate the extent to which productivity in one year had an effect on adult population size the following year at all stations combined, we regressed changes in adult population size during one between-year comparison on changes in productivity during the previous between-year comparison. We also compared various demographic variables including population trend among the four long-running stations to see if these variables correlated with elevation.

C. Comparisons of productivity with the Southern Oscillation Index. To assess the degree to which global climate patterns may be affecting landbird productivity, we compared annual productivity indices (mean index over the four stations for all species pooled) with the standardized Southern Oscillation Index (SOI), a measure of global climate based on the strength/weakness of El Niño and La Niña events in the tropical Pacific Ocean. SOI, calculated using pressure differentials between Tahiti and Darwin, Australia, has been used by climatologists as an index of relative global climate throughout the Pacific and North America; low negative SOI's indicate El Niño years and high positive SOI's indicate La Niña years. This SOI index has recently been correlated with productivity and survival in a migratory, eastern North American landbird (Sillett *et al.* 2000), and a similar index the El Niño/Southern Oscillation Precipitation Index (ESPI) has been shown to be correlated with MAPS productivity indices for Neotropical migratory landbird species breeding on national forests in the Pacific Northwest (Nott et al. 2002a). For this report we use the mean of the monthly SOI's for January-December of the year in question.

D. Survivorship analyses. Modified Cormack-Jolly-Seber mark-recapture analyses (Pollock et al. 1990, Lebreton et al. 1992) were conducted using the computer program SURVIV (White 1983) on ten years of banding data (1993-2002) pooled, from all five stations at which each target species was a regular or usual breeder, and for which, on average, at least six individual adults per year were captured.

Using SURVIV, we estimated survivorship parameters for each of the target species using both a between- and within-year transient model which accounts for the presence of transient adults (migrant and floater individuals which are only captured once) in the sample of newly captured adults (Pradel et al. 1997, Nott and DeSante 2002). The transient model permits calculation of maximum-likelihood estimates and standard errors (*SE*) for adult survival probability (φ), adult recapture probability (p), and proportion of residents among newly captured adults (τ). 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. These estimates were derived from the capture histories of all adult birds for each target species captured at all stations at which they were classified as regular (B) or usual (U) breeders (see above).

The ten years of data, 1993-2002, available for assessing 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. We tested the goodness of fit of the models 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 ($\varphi p\tau$) and the model with time-dependent survival but time-constant capture probability and proportion of residents ($\varphi_t p\tau$); thus, $\Delta QAIC_C$ was calculated as $QAIC_C(\varphi_t p\tau)$-$QAIC_C(\varphi p\tau)$, 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 all target species at the four long-running stations combined, 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 at Yosemite was as expected, lower than expected, or higher than expected based on its body mass.

RESULTS

A total of 2245.8 net-hours was accumulated at the five MAPS stations operated in Yosemite National Park in 2002 (Table 1). Data from 2091.2 of these net-hours could be compared directly to the previous year's data in a constant-effort manner.

Indices of Adult Population Size and Post-fledging Productivity - 2002

A. 2002 values. The 2002 capture summary of the numbers of newly-banded, unbanded, and recaptured birds in Yosemite National Park is presented for each species at each of the five stations individually and all stations combined in Table 2. A total of 2503 captures of 65 species was recorded during the summer of 2002. Newly banded birds comprised 76.1% of the total captures. The greatest number of total captures (747) was recorded at the Crane Flat station and the smallest number of total captures (135) was recorded at the White Wolf station. The highest species richness occurred at Hodgdon Meadow (46 species) and the lowest species richness occurred at White Wolf (23 species).

The capture rates (per 600 net-hours) of individual adult and young birds and the proportion of young in the catch are presented for each species and for all species pooled at each station and all stations combined in Table 3. We present capture rates (captures per 600 net-hours) of adults and young in this table so that the data can be compared among stations which, because of the vagaries of weather and accidental net damage, can differ from one another in effort expended (see Table 1). These capture indices suggest that the total adult population size in 2002 was greatest at Crane Flat, followed in descending order by Gin Flat East Meadow, Hodgdon Meadow, Big Meadow, and White Wolf Table 3). The capture rate of young of all species pooled at each station in 2002 was highest by far at Gin Flat East Meadow, followed by Crane Flat, Hodgdon Meadow, and Big Meadow, and was lowest at White Wolf (Table 3). The index of productivity at the five stations in 2002, i.e., the proportion of young in the catch, was greatest at Gin Flat East Meadow (0.76), followed by Crane Flat (0.64), Hodgdon and Big meadows (each 0.56), and was lowest at White Wolf (0.39).

Among individual species in 2002, Orange-crowned Warbler was the most frequently captured, followed by Yellow-rumped Warbler, Dark-eyed Junco, Lincoln's Sparrow, MacGillivray's, Nashville, and Hermit warblers, Anna's Hummingbird, Golden-crowned Kinglet, Song Sparrow, Warbling Vireo, Pine Siskin, Red-breasted Sapsucker, and Wilson's Warbler (Table 2). Overall, the most abundant species at the five Yosemite National Park MAPS stations in 2002 (as determined by the number of adults captured per 600 net-hours), in decreasing order, were Dark-eyed Junco (26.7), Yellow-rumped Warbler (26.4), MacGillivray's Warbler (16.8), Lincoln's Sparrow (15.2), Warbling Vireo (10.4), Song Sparrow (8.0), Hermit Warbler (7.5), Orange-crowned Warbler (7.2), and Western Tanager (7.2). The following is a list of the common breeding species (captured at a rate of at least 6.0 adults per 600 net-hours), in decreasing order, at each station in 2002 (Table 3):

White Wolf
Dark-eyed Junco
Yellow-rumped Warbler
Mountain Chickadee
American Robin

Hodgdon Meadow
MacGillivray's Warbler
Song Sparrow
Warbling Vireo
Lincoln's Sparrow
Dark-eyed Junco
Red-breasted Sapsucker
Yellow-rumped Warbler
Hermit Warbler
Western Tanager

Gin Flat East Meadow
Yellow-rumped Warbler
Dark-eyed Junco
Lincoln's Sparrow
Western Tanager
Red-breasted Sapsucker
MacGillivray's Warbler
Golden-crowned Kinglet
Dusky Flycatcher

Big Meadow
Lazuli Bunting
Lawrence's Goldfinch
Spotted Towhee
Bushtit
Orange-crowned Warbler
Nashville Warbler

Crane Flat
Yellow-rumped Warbler
Dark-eyed Junco
Hermit Warbler
Lincoln's Sparrow
Orange-crowned Warbler
Warbling Vireo
MacGillivray's Warbler
Dusky Flycatcher
Golden-crowned Kinglet
Pine Siskin
Western Tanager
Hammond's Flycatcher
Chipping Sparrow

B. Comparisons between 2001 and 2002. Constant-effort comparisons between 2001 and 2002 were undertaken at all five Yosemite National Park MAPS stations for numbers of adult birds captured (adult population size; Table 4), numbers of young birds captured (Table 5), and proportion of young in the catch (productivity; Table 6).

Adult population size for all species pooled for all five stations combined showed a very slight and non-significant increase between 2001 and 2002, by +2.9% (Table 4). Thirty of 61 species showed increases, a proportion not significantly greater than 0.50. The change in adult population size for all species pooled showed increases at three stations, by amounts ranging from +1.8% at Hodgdon Meadow to +62.5% at Gin Flat East Meadow, and it decreased at two stations, Crane Flat by –7.7% and Big Meadow by –23.1%. The proportion of increasing species at Gin Flat East Meadow was nearly significantly greater than 0.50 (P=0.100). Significant or near-significant decreases in the number of adults captured for all stations combined were recorded for Brown Creeper, Hermit Thrush, Purple Finch, Cassin's Finch, and Lesser Goldfinch, whereas no species showed such increases.

The number of young birds captured of all species pooled at all five stations in Yosemite National Park combined showed a near-significant increase, of +80.7% between 2001 and 2002 (Table 5). Increases were recorded for 21 of 53 species, a proportion not significantly greater than 0.50. Increases were recorded at four stations, by amounts ranging from +41.4% at White Wolf to +181.8% at Crane Flat, while it decreased at Big Meadow by –11.3%. No species showed a significant or near-significant proportion of increasing or decreasing species. Three species (Orange-crowned Warbler, Yellow-rumped Warbler, and Pine Siskin) showed significant or near-significant increases in number of young across all stations, whereas four species (Warbling Vireo, MacGillivray's Warbler, Song Sparrow, and Purple Finch) showed such decreases.

With numbers of adults remaining similar to 2001 and numbers of young increasing, productivity (the proportion of young in the catch) of all species pooled at stations combined in 2002 (0.640) increased over that in 2001 (0.503) by a substantial, but non-significant, +0.137 (Table 6). Twenty-five of 49 species increased, a proportion not non-significantly greater than 0.50. Productivity increased at all five stations, ranging from +0.027 at Gin Flat East Meadow to +0.272 at Crane Flat. No station showed a significant or near-significant proportion of increasing or decreasing species. Four species (Red-breasted Sapsucker, Hermit Thrush, Orange-crowned Warbler, and Cassin's Finch) showed significant or near-significant increases in productivity across stations, and three species (Hammond's Flycatcher, MacGillivray's Warbler, and Song Sparrow) showed significant or near-significant decreases in productivity across stations (Table 6).

Thus, breeding populations remained stable as compared with those of 2001, whereas productivity showed an increase that varied across stations, being larger at Crane Flat and Hodgdon meadow than at the other three stations. These patterns, however, were not very consistent across species. As in past years, we suspect that variations caused by local climate and snowpack, as influenced by station elevation, and their differing effects on various species depending upon their nest location and foraging strategy, may have been a factor causing these mixed results.

Ten-year Mean Adult Population Size and Productivity Indices

Table 7 presents mean annual numbers of individual adults captured (an index of adult population size), numbers of young captured, and proportions of young in the catch (an index of productivity) during the ten-year period (1993-2002) for the White Wolf, Crane Flat, Hodgdon Meadow, and Big Meadow stations and for all stations combined, during the five-year period (1998-2002) for the Gin Flat East Meadow station, and also during the 13-year period (1990-2002) for Hodgdon Meadow. The all-species-pooled values at the bottom of the table indicate that the highest breeding populations at Yosemite occurred at the mid-elevation Crane Flat Meadow station, followed in descending order by Hodgdon Meadow, Big Meadow, Gin Flat East Meadow, and White Wolf. The ten-year mean at Hodgdon Meadow was slightly higher than the 13-year mean there, indicating lower-than-average adult population sizes there during 1990-1992. Numbers of young captured followed a different sequence, being highest at Gin Flat East Meadow, followed by Crane Flat and Hodgdon Meadow, and being lowest at White Wolf and Big Meadow. Productivity followed a generally similar sequence to numbers of young, being highest at Gin Flat East, followed by Crane Flat, White Wolf, and Hodgdon Meadow, and being lowest at Big Meadow. Productivity was quite similar at Hodgdon Meadow during both the ten-year (0.46) and the 13-year (0.45) periods.

Overall, total species richness was 74 species, while the ten-year mean number of adults captured per 600 net-hours was 233.8 and the mean productivity index was 0.49. The most abundant summer species in Yosemite over the ten years, having overall capture rates greater than 6.0 adults per 600 net-hours, were, in descending order: Dark-eyed Junco, MacGillivray's Warbler, Yellow-rumped Warbler, Lincoln's Sparrow, Warbling Vireo, Orange-crowned Warbler, Lazuli Bunting, Dusky Flycatcher, Hermit Warbler, Song Sparrow, Purple Finch, and Black-headed

Grosbeak.

Multi-year Trends in Adult Population Size and Productivity
"Chain" indices of adult population size are presented for target species (those for which at least six adult individuals per year were captured at stations where the species was a breeder or usual breeder) and for all species pooled at each of the five stations individually and for all five stations combined in Figures 1-7. For White Wolf, Crane Flat, Hodgdon Meadow, Big Meadow, and all stations combined we show ten-year trends (1993-2002); for Gin Flat East Meadow we show five-year trends (1998-2002); and for Hodgdon Meadow we also show 13-year trends (1990-2002). We used annual percent change (*APC*) for each species as an estimate of the mean annual population trend for that species. These estimates of *APC*, along with the standard error of the slope (in parentheses), the correlation coefficient (r), and the significance of the correlation (P), are included for each target species and for all species pooled on each graph.

Ten-year (1993-2002) population trends for 24 target species and all species pooled at all five stations combined are shown in Figure 1. Consistent and stable populations (absolute $r < 0.50$ and SE of the slope ≤ 0.035) were shown by only two of the 24 species (Warbling Vireo and Yellow Warbler), both of which had negative trends. The populations of eight species (Cassin's Vireo, Brown Creeper, Golden-crowned Kinglet, American Robin, Lincoln's Sparrow, Purple Finch, Cassin's Finch, and Pine Siskin) showed wide interannual fluctuation (SE of the slope > 0.035) but no substantial linear trend (absolute $r < 0.5$), although the trends for all but American Robin, Cassin's Finch and Pine Siskin were negative. Populations of five species (Mountain Chickadee, Yellow-rumped Warbler, MacGillivray's Warbler, Western Tanager, and Song Sparrow) showed substantially increasing trends ($r \geq 0.5$), which were highly significant for Yellow-rumped Warbler and Western Tanager and significant for MacGillivray's Warbler. Populations of the remaining nine species (Red-breasted Sapsucker, Western Wood-Pewee, Dusky Flycatcher, Hermit Warbler, Chipping Sparrow, Dark-eyed Junco, Black-headed Grosbeak, Lazuli Bunting, and Lesser Goldfinch), as well as all species pooled, showed substantially declining trends ($r \leq -0.5$). The declines for Dusky Flycatcher, Chipping Sparrow, Black-headed Grosbeak, and Lazuli Bunting were highly significant, that for Lesser Goldfinch was significant, and those for Western Wood-Pewee, Hermit Warbler, and all species pooled were nearly significant. Overall, seven of ten significant or near-significant trends plus that of all species pooled were negative and 16 of the 24 species showed negative trends. The ten-year trend for all species pooled was a decrease of -1.5% per year, producing a decrease of nearly 15% over the ten years.

Ten-year (White Wolf, Crane Flat, Hodgdon Meadow, and Big Meadow), five-year (Gin Flat East Meadow), and 13-year (Hodgdon Meadow) population trends for target species and all species pooled at each station are shown in Figures 2-7. At White Wolf (Fig. 2), the population of Dark-eyed Junco was stable over the ten-years, while trends for Yellow-rumped Warbler, Cassin's Finch, and all species pooled showed wide interannual fluctuation but no substantial linear trend. Overall, trends for two of the three target species were positive, while the trend for all species pooled was very slightly negative.

At Gin Flat East Meadow (Fig. 3) the five-year trend for Yellow-rumped Warbler was stable and those for Western Tanager, Lincoln's Sparrow, Dark-eyed Junco, and all species pooled were substantially positive, with the trend for Western Tanager being nearly significant. Overall, trends for all four target species were positive, with the trend for all species pooled also being an increase of 9.2% per year.

At Crane Flat (Fig. 4), ten-year populations for Warbling Vireo, MacGillivray's Warbler, Dark-eyed Junco, and all species pooled were stable without substantial trends, although trends for all four were negative. Trends for Dusky Flycatcher and Lincoln's Sparrow showed wide interannual fluctuation but no substantial linear trend, although again both were negative; the trend for Yellow-rumped Warbler was highly significantly positive; and those for Golden-crowned Kinglet and Hermit Warbler were near-significantly negative. Overall, the trends for seven of the eight target species were negative, while all species pooled also was a decrease of 0.9% per year.

At Hodgdon Meadow (Fig. 5), 10-year populations for Warbling Vireo, MacGillivray's Warbler, and all species pooled were stable with no substantial linear trend, although trends for Warbling Vireo and all species pooled were negative. Populations of Lincoln's Sparrow, Dark-eyed Junco, and Black-headed Grosbeak were highly fluctuating with no linear trend, although trends for Lincoln's Sparrow and Black-headed Grosbeak were negative. The trend for Song Sparrow was highly significantly positive; and those for Red-breasted Sapsucker, Dusky Flycatcher, Hermit Warbler, and Purple Finch were substantially negative, with that for Dusky Flycatcher being highly significant and those for Red-breasted Sapsucker and Purple Finch being near-significant. Overall, trends for seven of the ten target species were negative while the trend for all species pooled was a decrease of 1.0% per year. Thirteen-year trends at Hodgdon Meadow (Fig. 6) were similar in direction to 10-year trends for all species except MacGillivray's Warbler, Lincoln's Sparrow, Dark-eyed Junco, and all species pooled (each of which changed from negative to positive). Whereas seven of ten species plus all species pooled showed negative ten-year trends, only four of ten species showed negative 13-year trends; indeed, 13-year trends for nine of ten species (all but Purple Finch) and all species pooled were less negative (or more positive) than 10-year trends, indicating lower-than-average populations at Hodgdon for these species during 1990-1992.

At Big Meadow (Fig. 7), no species showed a stable population; Warbling Vireo showed a highly fluctuating population but no substantial linear trend, although its trend was positive. Purple Finch showed a substantial but non-significant positive trend, while Chipping Sparrow, Black-headed Grosbeak, Lazuli Bunting, Lesser Goldfinch, and all species pooled showed substantial and significant negative trends, with those for Lazuli Bunting and all species pooled being highly significant. Overall, four of the six target species showed negative trends and the trend for all species pooled was a decrease of 6.3% per year. Among 27 target species at the four longer-running stations, only eight 10-year trends were positive, whereas 19 were negative.

"Chain" indices of productivity for each of the ten years (1993-2002) are shown in Figure 8 for the 24 target species and all species pooled at all five stations combined. Only one species, Lesser Goldfinch, showed a substantially declining productivity trend ($r \leq -0.50$), which was highly significant. In contrast, ten species (Red-breasted Sapsucker, Mountain Chickadee, Brown Creeper, American Robin, Yellow Warbler, Hermit Warbler, Black-headed Grosbeak, Lazuli Bunting, Purple Finch, and Pine Siskin) showed substantially increasing productivity trends ($r \geq 0.50$), which were highly significant for Yellow Warbler and Pine Siskin, significant for Red-breasted Sapsucker and Mountain Chickadee, and nearly significant for Black-headed Grosbeak and Purple Finch. The remaining 13 species showed stable (absolute $r < 0.50$ and SE ≤ 0.20; nine species) or fluctuating (absolute $r < 0.50$ and SE > 0.20; four species) productivity trends with no substantial linear trend, with six being positive and seven negative. Thus, overall, 16 of the 24 target species had positive productivity trends whereas only eight had negative trends. The productivity trend for all species pooled was almost substantially positive ($r = 0.494$) with an average increase of 0.017 per year.

Thus, in summary, populations of adults of all species pooled at all stations combined at Yosemite National Park have shown a substantial and nearly significant ten-year decline of -1.5% per year, whereas productivity of all species pooled has shown a nearly substantial ten-year increase of +0.017 per year. Similarly, adult populations of 16 of 24 target species at all stations combined have shown declining 10-year trends, while productivity at all stations combined for 16 of 24 target species have shown increasing 10-year trends.

To investigate the relationships among population trend, productivity, and elevation, we modeled, for all species pooled at each of the four long-running stations: (**A**) the annual percentage change in adult population (APC), (**B**) the direction and strength of the correlation between adult population size and year (*r*), and (**C**) the mean productivity index as functions of elevation; and (**D**) APC and (**E**) *r* as functions of mean productivity. The five graphs in Figure 9 indicate that population trends for all species pooled (Figs. 9**A** and 9**B**) generally became increasingly negative as elevation decreased, from White Wolf to Big Meadow. Mean productivity generally showed the same relationship (Fig. 9**C**), which in turn resulted in population trends correlating positively with productivity (Figs. 9**D** and 9**E**). Although none of these correlations were significant (undoubtedly because of the small *n* of just four stations), these correlations suggest that the decreasing population trends at Yosemite, that became stronger decreases at lower elevations, were, in general, driven by low productivity, which also became lower at lower elevations.

Productivity-Population Correlations

To see if productivity in a given year has had a direct effect on breeding population size the following year, we regressed the proportional change in the number of adults between year i+2 and year i+1 on the absolute change in productivity between year i+1 and year i for 24 species and all species pooled in Yosemite National Park over the ten years 1993-2002 (Fig. 10). The slopes and r-values in Figure 10, hereafter termed “productivity-population correlations”, are used as indicators of the strength of this relationship. The productivity-population correlation was positive for 14 of 24 species and all species pooled. Both of the correlations that were significant ($P < 0.05$; Yellow-rumped Warbler and Hermit Warbler) were also positive. These results support the concept that changes in productivity one year tend to correspond to changes in population size the next year, at least for some species, but suggest that other factors besides productivity must be involved to bring about the observed annual changes in population size.

Productivity as a Function of the El Niño/Southern Oscillation Index

To assess the degree to which global climate patterns may be affecting landbird productivity in Yosemite, we regressed annual productivity values on the standardized El Niño/Southern Oscillation Index (SOI), a measure of global climate based on the strength/weakness of El Niño and La Niña events in the tropical Pacific Ocean. Figure 11 shows the relationship between SOI and productivity for all species pooled at all five stations combined, the relationship between SOI and year during the course of the study, the expected trend in productivity given the relationships between productivity and SOI and between SOI and year, and the actual productivity trend for all species pooled (from Fig. 8). The relationship between SOI and productivity (Fig. 11**A**) was slightly, but not significantly, negative, indicating little if any relationship between productivity and SOI. Because SOI tended to increase between 1993 and 2002 (Fig. 11**B**), we predicted that the productivity index, given the effects of SOI, should have decreased slightly at Yosemite (by -0.004 per year) between 1993 and 2002 (Fig. 11**C**). In fact, productivity for all species pooled tended to increase at Yosemite during this period by +0.017 (Fig. 11**D**). Thus, other aspects of global or local climate, in addition to the El Niño/Southern Oscillation, appear to affect productivity in Yosemite National Park.

Estimates of Adult Survivorship

Using ten years of data (1993-2002), estimates of adult survival and recapture probability were obtained for 19 of the 24 target species breeding in Yosemite National Park (Tables 8-9). The remaining five species (Cassin's Vireo, Western Tanager, Cassin's Finch, Pine Siskin, and Lesser Goldfinch) had too few between-year recaptures, due, at least for the three Cardueline finch species (finch, siskin, and goldfinch), to low intrinsic site fidelity, for mark-recapture models to provide estimates of between-year survival.

Because of the existence of floaters, failed breeders, and dispersing adults in bird populations, the transient model, which permits estimation of the proportion of residents in the population and allows survival estimates to be based on the resident population, will always produce less biased survivorship estimates than non-transient models. Thus, we only present results of the transient model. Table 13 indicates that the fully time-constant model ($\varphi p \tau$) was selected over all time-dependent models for 15 of the 19 species by having an Akaike Information Criterion ($QAIC_c$) value that was at least 2.0 QAIC's lower than any other. For the other four species, the time-constant model was equivalent to (within 2.0 QAIC's of) all other selected models. An equivalent model for time-dependence in survival was detected for Dark-eyed Junco; an equivalent model for time-dependence in recapture probability was detected for Lincoln's Sparrow and Dark-eyed Junco; and an equivalent model for time-dependence in proportion of residents was detected for Warbling Vireo and Black-headed Grosbeak. The relatively high positive $\Delta QAIC_c$ values for 18 of the 19 species suggest that relatively little interannual variation in survival exists for those species; indeed, the mean $\Delta QAIC_c$ was +9.24. Only for Dark-eyed Junco did the $\Delta QAIC_c$ (+2.0) indicate substantial time-dependence in survival.

In Table 9, we present the maximum-likelihood time-constant estimates of annual adult apparent survival probability, recapture probability, and proportion of residents, as well as the maximum-likelihood estimates for these parameters from the equivalent time-dependent models identified in Table 8. Estimates of annual adult survival rate for the 19 species, using the time-constant model, ranged from a low of 0.166 for Purple Finch (indicating very low site-fidelty for this species) to a high of 0.658 for American Robin, and displayed a mean of 0.478. Recapture probability varied from a low of 0.115 for Western Wood-Pewee (reflecting the inherent difficulty of capturing this species that typically forages above net-level) to a high of 0.649 for MacGillivray's Warbler, with a mean of 0.326. Proportion of residents varied from a low of 0.101 for Golden-crowned Kinglet to a high of 1.000 for Mountain Chickadee, American Robin, and Chipping Sparrow, and averaged 0.578. Both the very low and very high values of proportion of residents are probably confounded, to some extent, with recapture probability.

For Dark-eyed Junco, survival was relatively high (> 0.50) during the winters of 1995-1996, 1996-1997, 1999-2000, and 2001-2002, and relatively low (< 0.35) during the winters of 1994-1995 and 2000-2001. We suspect that this reflects the weather and food availability along the Pacific slope of California, where this species winters. The two species showing time dependence in capture probability, Lincoln's Sparrow and Dark-eyed Junco, showed different patterns. Recapture probability for Lincoln's Sparrow was relatively high (>0.60) in 1994, 2000, and 2001, and relatively low (< 0.35) in 1996 and 1998; whereas in Dark-eyed Junco it was relatively high in 1994, 1996, and 1997 and relatively low in 1995 and 2001. The two species showing time-dependence in proportion of residents, Warbling Vireo and Black-headed Grosbeak, likewise showed some small differences in interannual variation. Proportion of residents for Warbling Vireo was relatively high (> 0.70) in 1994 and 1998 and relatively low (< 0.20) in 1996, 1999, and 2000; whereas for Black-headed Grosbeak it was relatively high in 1993, 1995, and 1997 and relatively low in 1996, 1999, and 2001. We have no explanation for the causes of time dependence in recapture probability or proportion of residents at this time.

Productivity and Survival as a Function of Body Mass

It has previously 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, in order to assess whether or not productivity or survival in a given species is higher or lower than expected, body mass needs to be accounted for. Figure 12 shows mean productivity indices and time-constant annual adult apparent survival rate estimates recorded at Yosemite National Park as a function of mean body mass (log transformed) for 18 target species for which survival could be estimated using data from all five stations combined (Purple Finch was not included as its very low survival estimate likely reflects the typically low site-fidelity that is characteristic of Cardueline finches). The purpose of this analysis was to determine which species at Yosemite 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 18 target species using data from Yosemite National Park, 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. For both productivity and survival, the regression lines based on data from the 18 species at Yosemite were similar to those based on data from North America as a whole, although productivity of smaller species and, perhaps, survival of larger species each tended to have been higher at Yosemite than in North America as a whole.

Eight of the 18 species shown in Figure 12 (species alpha codes in bold uppercase letters) showed substantial population declines (r of the population trend $\leq$ -0.50; Figure 1). Four of these species, Western Wood-Pewee (WEWP), Dusky Flycatcher (DUFL), Chipping Sparrow (CHSP), and Lazuli Bunting (LAZB), each showed lower-than-expected productivity. Dusky Flycatcher also showed slightly lower-than-expected adult survival, while survival for Chipping Sparrow was as expected and that of Western Wood-Pewee and Lazuli Bunting was higher than expected. Three species, Hermit Warbler, Dark-eyed Junco, and, possibly, Red-breasted Sapsucker, had higher-than-expected productivity; the warbler also had higher-than-expected survival whereas the junco and sapsucker had as-expected survival. The remaining species, Black-headed Grosbeak, had as-expected survival and productivity.

Four of the 18 species (shown in Figure 12 in regular uppercase letters) showed substantial population increases (r of the population trend $\geq$ 0.50; Figure 1). Two of these species, Yellow-rumped Warbler (YRWA) and Song Sparrow (SOSP), showed higher-than-expected productivity and as-expected survival. The other two species, Mountain Chickadee (MOCH) and MacGillivray's Warbler (MGWA), also showed relatively high productivity (at least compared to North America as a whole) and as-expected or, in the case of the chickadee, lower-than-expected survival. Thus, it appears that productivity, more often than survival, accounts for the population decreases and increases in Yosemite birds.

The remaining six species (shown in Figure 11 in regular lowercase letters) had generally stable or widely fluctuating population trends over the ten years at Yosemite (see Fig. 1). Most of these species showed as-expected or counterbalanced productivity indices and survival estimates, although productivity of Brown Creeper (BRCR) was higher than expected without correspondingly low survival, and both productivity and survival of Warbling Vireo (WAVI) was lower than expected, given its stable population trend.

Causes of Population Declines and Increases Based on Demographic Data

Based on all of the above demographic data, we made assessments as to whether Yosemite population declines were due to poor productivity on the breeding grounds, low survival presumably during migration and/or on the winter grounds, both, or neither (Table 10). Assessments for each species were based on a synthesis of actual productivity indices, productivity trends, productivity-population correlations, actual survival estimates, $\Delta QAIC_C$ values, and productivity and survival values relative to Yosemite-wide and continent-wide relationships for productivity and survivorship as a function of body mass. As an example, for Yellow-rumped Warbler, productivity was high (0.46; based on the ten-year mean for all stations pooled from Table 7), the productivity trend was positive (+0.025; Fig. 8) but widely fluctuating, the productivity-population correlation was significantly positive (Fig. 10), survival was about average (0.425; Table 9), $\Delta QAIC_C$ was high (+7.4; Table 8), and productivity was higher than expected while survival was about as expected relative to body mass (Fig. 12). In this case, most or all evidence suggests that high productivity rather than high survival has been driving the population increase for Yellow-rumped Warbler at Yosemite.

Using this approach, we suggest that lower-than-expected or decreasing productivity may be driving the population declines of five of the nine declining species, Western Wood-Pewee, Dusky Flycatcher, Chipping Sparrow, Lazuli Bunting, and Lesser Goldfinch, including four of the five significantly declining species. In addition, lower-than-expected survival may also be contributing to the significant decline in Dusky Flycatcher. Red-breasted Sapsucker presents a unique situation in which the very low productivity during the first four years (1993-1996) corresponded to the strongly declining population during the first six years (1993-1998), and the much higher productivity during the last six years (1997-2002) corresponds well to an increasing population size during the past five years (1998-2002). Indeed, the nine-year (1993-2001) population decline for this species was significant, while the ten-year (1993-2002) decline was not. Thus, a dramatically changing productivity regime for this species seems to be dramatically changing its population trajectory. On the other hand, both productivity and survivorship were as expected or higher than expected for Hermit Warbler, Dark-eyed Junco, and Black-headed Grosbeak. We can only surmise that other factors not currently measured by MAPS (e.g., low intrinsic recruitment or low first year survival rates) are causing the declines in these species.

Among the increasing species, it appears that higher than expected or increasing productivity may be driving the population increases of four of the five species: Mountain Chickadee, Yellow-rumped Warbler, MacGillivray's Warbler, and Song Sparrow. Survival for these four species was as expected or, in the case of Mountain Chickadee, lower tan expected. In contrast, productivity for Western Tanager was about as expected while its survival could not be estimated. Thus, overall, it appears that productivity at Yosemite is driving the population dynamics of ten of the 14 species showing substantial trends, whereas survival away from Yosemite is only driving the population dynamics of one species.

DISCUSSION AND CONCLUSIONS

Annual Changes in Adult Population Size and Productivity

Previous reports documented that populations of adult birds in Yosemite National Park increased substantially and significantly between 1999 and 2000 by +17.6% for all species pooled, and then decreased substantially and nearly significantly between 2000 and 2001 by -19.3% for all species pooled. Productivity showed the opposite pattern, decreasing substantially between 1999 and 2000 by -0.110 for all species pooled, and then increasing substantially between 2000 and 2001 by +0.111 for all species pooled. This alternating cycle of population increases and decreases, with increases and decreases in productivity exactly out of phase with those of population size, has frequently been seen at many MAPS locations across the continent. This alternating, two-year population dynamic was observed at Yosemite between about 1996 and 2001, but was not observed during 1993-1996. Nor was it observed in 2002 when adult population sizes increased slightly by +2.9%, while productivity rose dramatically by +0.137 for the second year in a row to reach the highest value (0.640) recorded at Yosemite during the entire ten years of this study.

We believe that the alternating out-of-phase pattern between increases and decreases in productivity and population size relates to density-dependent effects on productivity and recruitment along with lower productivity of first-time breeders. This model suggests that populations that have shown an increase in a given year, typically show reduced productivity that year, apparently due to stronger intra- and, possibly, inter-specific competition and a greater proportion of inexperienced first-time breeders. This poor productivity then results in decreased recruitment and fewer breeding birds the following year, which in turn have higher productivity due to weaker competition and a higher proportion of experienced (two-year-old or older) breeders. Populations that show this alternating two-year dynamic often also show a strong "productivity-population correlation," whereby changes in productivity in a given year are followed by corresponding changes in adult population size the following year.

The productivity-population correlation was positive at Yosemite for 14 of 24 species and for all species pooled, and both significant correlations were positive, thus generally supporting the idea that changes in productivity one year bring about corresponding changes in population size the next year, at least for certain species. However, the productivity-population correlations at Yosemite were weaker than those at other national parks, including both Denali and Shenandoah. Indeed, this dynamic appears to be less strongly manifest in regions, such as Yosemite, that are characterized by high annual variation in weather and snowpack, than in regions where weather is more predictable year-round. It is possible that the relatively unstable (El Niño dominated) weather in Yosemite in the early to mid 1990's gave way to more consistent (La Niña dominated) weather late in the 1990's through 2001, but returned to El Niño dominated weather in 2002 which, for reasons we do not yet understand, was associated with excellent productivity.

Population Trends of Yosemite's Birds

Based on data presented in this report, populations of adult birds of all species pooled in Yosemite National Park have shown a substantial and near-significant decrease of -1.5% per year over the ten years 1993-2002. While this may not seem to be large annual decline, it suggests that Yosemite's landbird populations have declined by over 14% during the past decade. Moreover, substantial ten-year declines were observed in nine species (Red-breasted Sapsucker, Western Wood-Pewee, Dusky Flycatcher, Hermit Warbler, Chipping Sparrow, Dark-eyed Junco, Black-headed Grosbeak, Lazuli Bunting, and Lesser Goldfinch), with the declines of all except the sapsucker and junco being significant or nearly significant. In contrast, substantial ten-year increases were observed in only five species (Mountain Chickadee, Yellow-rumped Warbler, MacGillivray's Warbler, Western Tanager, and Song Sparrow), of which three, those for the two warblers and the tanager, were significant.

The ten-year trend in adult population size for all species pooled at Hodgdon Meadow (-1.0% per year, r = -0.311) was fairly similar to the ten-year trend for all species pooled for all stations combined (-1.5% per year, r = -0.570), suggesting that population trends at Hodgdon Meadow may tend to be somewhat representative of population trends in Yosemite National Park as a whole. It is of interest, therefore, that the 13-year trend in adult population size for all species pooled at Hodgdon Meadow was non-substantially positive (+0.9% per year, r = 0.264). The difference between the ten- and 13-year trends at Hodgdon Meadow was that populations during the three years, 1990-1992, tended to be lower than the subsequent ten-year mean. This suggests that populations in Yosemite National Park may be relatively stable and undergo small and perhaps cyclical increases and decreases over decade-long periods. Nevertheless, three of the five species that occurred as target species at Hodgdon Meadow and showed substantial ten-year decreases over all Yosemite stations combined (Red-breasted Sapsucker, Dusky Flycatcher, and Hermit Warbler), also showed substantial 13-year decreases (which were highly significant for the sapsucker and flycatcher) at Hodgdon Meadow. These decreases, thus, do not appear to be part of a short-term cycle and are cause both for concern and for management action (although the population trend for the sapsucker seems very recently to be increasing). The same is likely true for Lazuli Bunting and Chipping Sparrow, which showed highly significant declines in Yosemite overall and substantial (sparrow) or significant (bunting) declines at Big Meadow, the only station at which they were target species. In contrast, Dark-eyed Junco and Black-headed Grosbeak populations showed 13-year increases but ten-year decreases (or were stable over ten years) at Hodgdon Meadow, suggesting that these populations may indeed be cyclical.

Comparison of long-term (1966-2002) and more recent (1980-2002) BBS population trends for the entire Sierra Nevada physiographic strata for the 24 target species whose ten-year population trends are available from MAPS data for Yosemite National Park reveals a number of interesting observations. Five (Western Wood-Pewee, Hermit Warbler, Chipping Sparrow, Dark-eyed Junco, and Black-headed Grosbeak) of the nine species with substantial ten-year declines in Yosemite National Park also showed both long-term and more recent Sierra-wide BBS population declines; these five species, along with Dusky Flycatcher, which showed more recent Sierra-wide and Yosemite declines, are clearly in need of active management and conservation measures. Two (Red-breasted Sapsucker and Lesser Goldfinch) of the nine species showed substantial ten-year declines in Yosemite National Park and long-term, but not more recent, Sierra-wide BBS population declines. As mentioned above, Yosemite MAPS data suggest that the population decline for the sapsucker may be abating, while the goldfinch continues to decline in Yosemite. Finally, Lazuli Bunting showed substantial declines in Yosemite National Park but increasing populations Sierra-wide, both long-term and recent. All three of these latter species should continue to be monitored closely, both in Yosemite and Sierra-wide.

Six (Warbling Vireo, Brown Creeper, Golden-crowned Kinglet, Yellow Warbler, Lincoln's Sparrow, Purple Finch) of the seven species that showed non-substantial (generally highly fluctuating) decreasing trends in Yosemite National Park from MAPS data also showed both long-term and more recent decreasing Sierra-wide BBS trends. We suspect that the declines of these species noted in Yosemite are real and reflect widespread Sierra declines, and suggest that they also need to be closely monitored. Only one species that showed a non-substantial decreasing trend from Yosemite MAPS data (Cassin's Vireo) showed both a long-term and more recent increasing Sierra-wide trend. This and the Lazuli Bunting are the only species that appear to be declining in Yosemite but increasing in the Sierra as a whole.

In contrast, six species that showed ten-year increasing population trends from Yosemite MAPS data, including three species with substantial increases (Mountain Chickadee, MacGillivray's Warbler, and Western Tanager) and three species with non-substantial increases (American Robin, Cassin's Finch, and Pine Siskin), showed both long-term and more recent Sierra-wide BBS declines. It seems likely that the relatively pristine habitat conditions in Yosemite National Park may allow populations of these species to experience higher productivity and, for permanent resident species, higher survival as well, that has led to increasing populations in Yosemite despite decreasing populations Sierra-wide. This hypothesis can be tested when several more years of MAPS data are available from stations both inside and outside of Yosemite National Park. Finally, we mention two species that showed substantial ten-year increasing population trends from Yosemite MAPS data (Yellow-rumped Warbler and Song Sparrow) and appear to be increasing throughout the entire Sierra according to both long-term and more recent BBS data.

Trends in Productivity in Yosemite National Park

In contrast to population trends, only one species, Lesser Goldfinch, showed a substantial ten-year (1993-2002) declining productivity trend, which was highly significant, while ten species (Red-breasted Sapsucker, Mountain Chickadee, Brown Creeper, American Robin, Yellow Warbler, Hermit Warbler, Black-headed Grosbeak, Lazuli Bunting, Purple Finch, and Pine Siskin) showed substantial increasing productivity trends, which were significant or nearly significant for Red-breasted Sapsucker, Mountain Chickadee, Yellow Warbler, Black-headed Grosbeak, Purple Finch, and Pine Siskin. The productivity trend for all species pooled was almost substantially positive, with an average absolute increase of +0.017 per year. In part, this increasing trend in productivity was driven by high productivity during the two most recent years of the study; indeed productivity in 2002 was the highest recorded for all ten years of the study.

Although 16 of 24 species showed increases in productivity while 16 of 24 species showed decreases in adult population trends, there was not an inverse relationship between trends in productivity and adult population size. For example, both productivity and population size decreased significantly for Lesser Goldfinch. Of the four species with significantly increasing productivity (Red-breasted Sapsucker, Mountain Chickadee, Yellow Warbler, Pine Siskin), two (sapsucker and warbler) had decreasing and two (chickadee and siskin) had increasing population trends. Of the total of 16 species with increasing productivity trends, five had increasing and 11 had decreasing population trends. Similarly, of the eight species with decreasing productivity trends, three had increasing and five had decreasing population trends.

A very weak relationship was found between annual productivity for all species pooled and the El Niño/Southern Oscillation Index, such that productivity tended to be higher during El Niño years. A similar but much stronger relationship was found, at least for Neotropical migratory species, at 36 MAPS stations on six national forests in the Pacific Northwest (Nott et al. 2002a). Considering that the early years of this study tended to include more El Niño years, while the latter years saw a strong La Niña, we would expect productivity at Yosemite to have declined slightly over the ten years. In fact, however, there was a slight tendency for productivity of all species pooled at Yosemite to have increased. Clearly other factors than the El Niño/Southern Oscillation (ENSO) are affecting productivity of Yosemite's birds. One of these factors seems to be timing of melting of the snowpack (which, surprisingly, is not always correlated with ENSO), with a tendency toward lower productivity associated with earlier melting snowpacks at lower elevations and higher productivity associated with such earlier melting snowpacks at the highest elevations. Another factor could be the North Atlantic Oscillation which has been shown to effect productivity of landbirds, especially temperate-wintering species, in the Pacific Northwest (Nott et al. 2002a). Additional analyses utilizing substantially more years of data will be necessary to unravel the relationships among productivity of Yosemite's birds, elevation, weather conditions, and climate cycles. As an indication of how complex these relations might be, Nott et al. (2002a) found that it was late winter weather on the wintering grounds, as effected by ENSO and that presumably acts through physical condition of the birds prior to migration and with wind conditions during migration, that had the strongest effect on productivity of Neotropical migratory species in Pacific Northwest. This contradicts the general thrust of conventional wisdom that has held that weather on the breeding grounds is the primary determinant of annual variations in productivity.

Demographics of Yosemite's Birds Along an Elevation Gradient

Ten years (1993-2002) of data from four MAPS stations (and five years from a fifth) along an elevation gradient on the west slope of the Sierra Nevada in Yosemite National Park have shown that species richness (number of species), total adult population size, productivity, and adult population trend each varied with elevation in unique ways. Total species richness of breeding species was highest at the lowest elevation (Big Meadow – 60 species), lowest at the highest elevation (White Wolf Meadow – 34 species), and clearly decreased with increasing elevation. In marked contrast to total species richness, mean annual number of adults of all species pooled (essentially an index of total bird density) was highest at intermediate elevations (Crane Flat – 302.8 birds per 600 net-hours) and decreased progressively both at lower (Hodgdon – 264.0; Big Meadow – 208.2) and higher (Gin Flat East – 171.1; White Wolf – 140.0) elevations.

In further contrast, mean annual productivity for all species pooled was highest at still higher elevations (Gin Flat East – 0.63) and, again, decreased progressively both at lower (Crane Flat – 0.49; Hodgdon – 0.46; Big Meadow – 0.43) and higher (White Wolf – 0.48) elevations.

Excluding Gin Flat East, which has only been operated for five years, productivity showed a positive correlation with elevation. Station-specific ten-year population trends for all species pooled also correlated positively with elevation, being nearly flat (-0.1% per year) at White Wolf, where two of three target species increased, and substantially and highly significantly negative (-6.3% per year) at Big Meadow, where four of six target species decreased significantly. As expected from these two results, station-specific ten-year population trends for all species pooled for the four long-running stations also correlated positively with mean annual productivity for all species pooled for those stations. Although none of these correlations were significant (due to the small number of stations), they suggest that the increasingly negative population trends at lower elevation stations may have been driven by the increasingly lower productivity at those same stations, especially in drought years with meager snowpacks. Predictions from global climate models and recent weather data suggest that the Sierra is becoming increasingly arid and that this drying tendency may be accelerating. Data from MAPS suggest that, in general, avian populations in the Sierra will be adversely affected by such climate change. This hypothesis underscores the importance of long-term avian demographic monitoring data in Yosemite National Park, where avian population and demographic changes are affected heavily by concurrent land-use changes.

Survival Rates of Yosemite's Birds

It is important to note that productivity alone is not necessarily the driving force for long-term population trends, even when annual changes in productivity can be shown to drive annual changes in population size. This is because it is the overall relation between average productivity and average mortality that determines overall population trends. Indeed, an alternating cycle of out-of-phase changes in productivity and population size, such as that described earlier, could operate in species showing any particular population trend, increasing, stable, or decreasing. In order to fully investigate the effects of productivity on long-term population trends and determine the causes of population change, we must also consider annual adult survival rates.

We were able to obtain estimates of annual adult apparent survival rates for 19 target species at Yosemite using ten years data from all five stations combined. As mentioned in previous reports, increased years of data have resulted in increased numbers of species for which survival estimates could be obtained. In addition, the mean precision of these survival rate estimates has increased substantially with each additional year of data. For example, the mean CV(φ) for 16 species whose adult survival rates could be estimated from seven (1993-1999), nine (1993-2001), and ten (1993-2002) years of data decreased from 23.9% for seven years of data, to 16.7% for nine years of data, and to 15.4% for ten years of data. Similarly, the mean CV(φ) for the 14 species that each had CVs less than 30% in both datasets decreased from 19.4% for seven years of data, to 14.6% for nine years of data, and to 13.5% for ten years of data. These results suggest that maximum precision may not be obtained until 12 or more years of data are available, a result in agreement with predictions by Rosenberg et al. (1996, 1999). Despite the relatively good precision obtained for most species with CV(φ)<30% (mean CV(φ)=13.5%), $\Delta QAIC_C$ values were relatively high (>2.0) in all but one (Dark-eyed Junco) of these 14 species. This suggests that there is relatively little interannual variation in survival for most Yosemite species.

Causes of Population Changes in Yosemite's Birds

In order to help determine the causes of changes in landbird populations at Yosemite, one of the primary goals of MAPS, we have examined patterns of productivity and survival as a function of body mass for 18 target species to evaluate which of the two factors may be unexpectedly low or high and, thus, which factor is likely to be more influential in driving population trends. For both productivity and survival, the regression lines based on data from the 18 species at Yosemite were quite similar to those based on data from North America as a whole, although productivity for the smaller species (thus for most species), and, perhaps, survival for the few larger species appeared to be substantially higher at Yosemite than for North America as a whole. This might be expected considering the protected nearly pristine nature of the park. Among nine species showing substantial population declines, six showed lower than expected productivity or low productivity that corresponded to the major part of their decline. Moreover, four of the five species that showed substantial population increases showed higher than expected productivity. In contrast only one declining species (Dusky Flycatcher) showed lower-than expected survival and no increasing species showed higher-than-expected survival. Thus it appears that productivity at Yosemite accounts for the population decreases and increases in ten of the 14 species showing substantial trends, whereas survival, presumably away from Yosemite, accounts for the population decrease of only one species.

Based on all demographic data available from all stations combined for each of the 18 target species, including a synthesis of actual productivity indices, productivity trends, productivity-population correlations, actual survival estimates, $\Delta QAIC_C$ values, and productivity and survival values relative to continent-wide relationships for productivity and survivorship as a function of body mass, we made assessments as to whether population declines were due to low productivity on the breeding grounds, low survival (probably during migration and/or on the winter grounds), both, or neither. Results of our analysis suggest that decreasing or lower-than-expected productivity (at least during the time that corresponded to the major portion of the decline) likely drove the population declines of six of the nine declining species, Red-breasted Sapsucker, Western Wood-Pewee, Dusky Flycatcher, Chipping Sparrow, Lazuli Bunting, and Lesser Goldfinch, and that lower than expected survival may also be contributing to the decline in Dusky Flycatcher. For Hermit Warbler, Dark-eyed Junco, and Black-headed Grosbeak, both productivity and survivorship were as expected or higher than expected. We can only surmise that other factors not currently measured by MAPS (e.g., low intrinsic recruitment or low first year survival rates) are causing the declines in these species. Among the increasing species, it appears that higher than expected or increasing productivity was driving the population increases for four of the five species: Mountain Chickadee, Yellow-rumped Warbler, MacGillivray's Warbler, and Song Sparrow. For Western Tanager, productivity was as expected but survival could not be estimated. Either high adult survival or some other factor that we are not currently estimating (i.e., low intrinsic recruitment or low first year survival rates) is apparently causing the increase in this species.

Future Analyses

We cannot estimate first year survival with current MAPS analyses. This is because young birds typically disperse substantial distances from their natal site to their site of first breeding, resulting in very few or no recaptures of birds banded as juveniles. In future analyses we hope to be able to index first year survival by using data on species for which we can identify both one-year-old (second-year; SY) and older (after-second-year; ASY) birds in spring, by using CJS mark-recapture models to estimate annual recruitment of both SY and ASY birds. Then, by comparing spatial and temporal patterns of productivity and recruitment of SY and ASY birds, we will be able to make inferences regarding first year survival rates as well as amounts of immigration and emigration in the populations. Once these analyses have been performed, we will be able to examine patterns in adult and first year survival rates according to geographic location, climate, and habitat considerations, and to identify species (e.g., Hermit Warbler at Yosemite) for which declines may be driven by low first year survival.

In five or six more years, when we will have accumulated 14 or 15 consecutive years of data from each of the four long-running stations, we hope to perform many of these park-wide analyses at the spatial scale of the four individual stations. This may yield especially important results at Yosemite, where the stations span such a significant elevation range and the population dynamics appear to be influenced by elevation. Once these analyses have been completed we will be able not only to identify the effects of elevation on various demographic processes, but to identify species that are declining based on poor productivity at each station (or within each of the parks elevation regimes), and make recommendations for management of these species accordingly.

We have recently initiated two additional broad-scale analyses to help us further understand the population dynamics of landbirds and potential management actions to assist bird populations. First, by modeling spatial variation in vital rates as a function of spatial variation in population trends we are beginning to determine the proximate demographic causes of population trends within a species on multiple spatial scales (DeSante et al. 2001). Among Gray Catbird populations on a continental scale, for example, we found that adult survival-rate estimates varied appropriately between areas of increasing vs. decreasing population trends while productivity indices were independent of area, suggesting that low survivorship was driving population trends in this species at that scale. At a smaller spatial scale, we modeled productivity indices and time-constant annual adult survival-rate estimates with MAPS data from DoD installations for target species for which trends in adult captures were substantially negative on installations in one subregion and positive on installations in another subregion. We found that differences in productivity were evident in and correctly predicted differences in population trends for all five target species, while difference in survival were evident in only two species but also correctly predicted population trends for both (DeSante et al. 2001). Analyses of spatial variation in productivity and survival as a function of spatial variation in population trends, therefore, appear to be very effective in understanding causes of population declines. We hope to undertake such analyses (e.g., between Sierra stations within and outside of Yosemite) sometime in the future, when we will have accumulated about 14 or 15 years of data.

Second, we have found that patterns of landscape structure detected within a two- to four-kilometer radius area of each station are good predictors not only of the numbers of birds of each species captured but, more importantly, of their productivity levels as well (Nott 2000). For four forest interior species in the eastern U.S., for example, this study revealed the existence of threshold values of woodland/forest patch size above which productivity levels were high and below which productivity dropped off rapidly. As another example, for Wilson's Warblers in Pacific Northwest national forests, we found that the amount of deciduous forest cover in otherwise coniferous forest matrices within two km of the stations correlated positively and highly significantly with breeding population size, but non-significantly with productivity, indicating that increasing the deciduous component of these forests can increase adult population size without compromising productivity. These types of analyses provide extremely powerful tools to identify and formulate management actions aimed at reversing declining populations and maintaining stable or increasing populations of landbirds, because they can address the particular vital rate responsible for the decline. We plan to conduct similar analyses for the target species in the Sierra, by modeling productivity as a function of various landscape characteristics that vary along a gradient from the pristine landscapes found in Yosemite National Park to the much more heavily managed landscapes on Sierran national forests where we also have MAPS stations. Again, we plan to conduct such analyses after we have accumulated some 14 or 15 years of data.

Because of the pronounced elevation factor at Yosemite, and the complex effects of weather on population size and productivity, we will need to incorporate elevation-specific habitat analyses and account for weather on an annual basis. For example, as discussed in a previous year's report (DeSante et al. 2000), elevation effects on adult population size also reflect the effects of dry years (greater population sizes at higher elevations due to lack of snow pack and warmer temperatures) vs. wet years (greater population sizes at lower elevations due to higher food productivity and cooler temperatures). Thus, landscape-level analyses at Yosemite will necessarily involve interactions between elevation and weather as well as habitat characteristics. It is the complexity of these interactions that create the need for long-term (at least 15 years) data.

Conclusions

Analyses of ten years of MAPS data from four stations along an elevation gradient in Yosemite National Park, plus five years of data from a fifth station, have shown that bird populations in Yosemite have decreased over the ten years with substantially more species decreasing than increasing. These data have also shown that species richness, total bird density, productivity, and population trends all vary with elevation in generally different ways. We have also demonstrated how MAPS data can be used to measure and assess the effects of productivity and survivorship as driving forces for the varying avian population trends documented in Yosemite National Park, both overall and at the individual species level. In future analyses, we hope to include estimates of first-year recruitment and indices of first-year survival in order to more fully understand what parameters are most affecting population changes in each target species.

This report demonstrates that the indices and estimates of primary demographic parameters provided by the Yosemite MAPS Program are providing critical information that will be extremely useful for the management and conservation of landbirds in Yosemite and, in combination with similar data from other areas, throughout the Sierra Nevada and across the whole of North America. The results highlighted above have also revealed that the population dynamics of the breeding birds of Yosemite National Park are complex, as are the likely causes of the dynamics and, for those trends deemed problematic, their solutions. This complexity, in turn, underscores the importance of standardized, long-term data. Once about 14 or 15 years of data have accumulated and the precision of our estimates improves further, time-dependence in estimates is more readily apparent, and long-term trends are more clearly established, we will be able to incorporate weather and climate data as well as landscape-level habitat data as additional co-variates in logistic regression analyses of productivity and in survivorship models. We are confident that, with these additional years of data, we will be able to further our understanding of the population dynamics of Yosemite's birds and shed more light on the complex paths leading from stressors to population responses.

Results from the first ten years of the MAPS Program in Yosemite National Park (13 years at the Hodgdon Meadow station), as documented in this report, indicate that meaningful station-specific indices of adult population size and post-fledging productivity, reasonably precise park-wide estimates of annual survival rates of adults, and important information on annual changes, longer-term trends, and elevation differences in these indices and estimates are being obtained for at least 24 target species. We conclude that the MAPS protocol is very well-suited to provide a critical component of the Park Service's Long-Term Ecological Monitoring program in Yosemite National Park. Based on the above information, we recommended that the operation of the five MAPS stations currently active in Yosemite National Park be sustained indefinitely into the future, and a comprehensive analysis of all Sierran MAPS data (including Yosemite's) be conducted after about 14 or 15 years of data have been accumulated, that is, depending on the availability of additional funding for these analyses, after the 2006 or 2007 field season.

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