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AN AVIAN BIOMONITORING PROGRAM FOR THE NATIONAL PARKS AND OTHER NATURAL AREAS TO DETECT LARGE-SCALE, LONG-TERM CHANGES IN THE PRODUCTIVITY AND SURVIVORSHIP OF LAND BIRDS

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Abstract

An avian biomonitoring program was established in 1990 in Yosemite National Park to provide annual estimates of productivity, adult survivorship, and adult population levels of common land birds by means of constant effort mist-netting during the breeding season. The program emphasizes the importance of national parks and other natural areas for the long-term biomonitoring of the effects of large-scale environmental changes such as global climatic change, loss of stratospheric ozone, widespread toxic pollution, and accelerating habitat loss. The program is currently being expanded into other national parks and natural areas as part of the Monitoring Avian Productivity and Survivorship (MAPS) program, a cooperative continentwide network of constant effort mist-netting stations designed to detect large-scale, long-term changes in the productivity and survivorship of land birds. Critical data on avian productivity and survivorship are not currently available from any other avian biomonitoring program in North America, and are crucial for the testing of hypotheses regarding the causes of recent population declines in land birds. Data from the 1990 Yosemite station and limited data from the first two years of the North American MAPS program, along with previous results from a single station on the Point Reyes National Seashore and a network of such stations in Great Britain, provide a positive indication that the method will produce meaningful information on the productivity and survivorship of North American birds.

INTRODUCTION

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

The monitoring of complex terrestrial ecosystems, such as the forests that are protected in national parks and other natural areas, is a difficult task that necessitates monitoring at many levels and at many scales, both spatial and temporal. I suggest that the land bird populations that inhabit our parks

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and other natural areas have a number of characteristics that make them excellent candidates for monitoring the effects of large-scale, long-term environmental changes on upper level consumers. Indeed, because of their high body temperature, rapid metabolism, and high ecological position on most food webs, birds have long been regarded as among the better indicators of the effects of environmental change (Temple and Weins 1989).

First, land birds are present in most terrestrial ecosystems in considerable abundance and with substantial diversity; thus, they can provide solid statistical data upon which changes in their population parameters can be inferred. Second, they are diurnal and have distinctive and persistent vocalizations; thus, they can be relatively easily observed and sampled. Third, they have distinct breeding seasons that produce discrete age classes, thereby making it relatively easy to monitor their productivity. Fourth, they have an intermediate longevity of several but not many years, which facilitates the determination of the age structure and survivorship of their populations. And finally, they enjoy great popularity among humans; the beauty of their plumage, song, and behavior has long made them favorite objects of human attention, study, and love. Truly, the "canary in the mine" analogy can accurately be applied to the biomonitoring of land birds.

It is not surprising, therefore, that a number of large-scale, long-term biomonitoring programs for land birds are already in place in North America. They include the Breeding Bird Survey, the Breeding Bird Census and Winter Bird Population Study, and the Christmas Bird Counts. All of these efforts provide annual estimates of population trends for land birds, and many of these trends are pointing to serious and accelerating declines in many species of North American land birds, particularly forest-inhabiting, neotropical migrant species (Terborgh 1989).

All of these current avian biomonitoring programs, however, suffer from a major shortcoming: they fail to separate the effects of productivity (birth rate effects) from the effects of survivorship (death rate effects). Without these critical data on productivity and survivorship, it is difficult, if not impossible, to test hypotheses to account for observed population changes, or to determine whether the population changes are being driven by causal agents that affect birth rates or death rates or both (Temple and Weins 1989). In particular, the current avian biomonitoring programs have generally been unable to determine to what extent deforestation and forest fragmentation on the temperate breeding grounds and on the tropical wintering grounds are causes for declining populations of neotropical migrant land bird species (Wilcove 1985; Holmes and Sherry 1988; Hutto 1988; Morton and Greenburg 1989; Robbins et al. 1989). An additional sampling method that can provide accurate estimates of changes in land bird productivity and survivorship is a real necessity.

The purposes of this paper are (1) to describe a new avian biomonitoring program that can provide useful long-term information on the productivity and survivorship of land birds, (2) to provide confirmation of the value and effectiveness of the proposed methodology by reference to studies already completed, and (3) to present the results of the first year of this program at a single location in Yosemite National Park.

THE MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) PROGRAM

The Basic Methodology

The MAPS program is a cooperative effort, established and coordinated by The Institute for Bird Populations, to provide critical, long-term data on select avian population parameters that are crucial for the conservation of avian diversity in North America. In particular, the program is designed to provide annual regional estimates of productivity, adult survivorship, and adult population size for various common land birds, including resident, short-distance migrant, and long-distance neotropical migrant species. The basic methodology employed in the MAPS program is that of a capture-recapture experiment utilizing standardized, constant effort mist-netting and banding during the breeding season at a continentwide network of banding stations. Considerable advances have been made in recent years in both the theory and application of data from capture-recapture experiments (e.g., Clobert et al. 1987; Pollock et al. 1990). A modified Jolly-Seber model for multiple recaptures of adult birds in subsequent years will serve as the basic analytical model from which annual estimates of adult survivorship, adult population size, and recruitment into the adult population can be determined. This model will allow age and/or time dependence to be built into survival and capture rates, permit some parameters to be set equal to fixed *a priori* values, and allow any of the parameters to be related to external variables. Furthermore, by simultaneously banding the young birds that are captured during the breeding season, another measure of post-fledgling productivity, the proportion of young birds captured, can be obtained.

Validation of the Methodology

(1) At a Single Station – The value of constant effort mist-netting, at even a single station, has been confirmed in a 15-year ongoing study by the Point Reyes Bird Observatory at the Palomarin Field Station, located on the Point Reyes National Seashore. Data from this study were used to show the relationship between the productivity of land birds and annual rainfall in central coastal California, and to document a massive and unprecedented reproductive failure of most species of land birds in 1986 (DeSante and Geupel 1987). This study showed that the apparent driving force behind much of the annual variation in the numbers of young birds at Palomarin during the first 10 years (1976-1985) was the amount of annual (winter) rainfall that occurred in this Mediterranean ecosystem. In particular, maximum numbers of young birds were produced in relatively average rainfall years, while low productivity occurred in both very dry years (1976, 1977) and in very wet years (1983, a year characterized by a severe El Niño southern oscillation).

In 1986, however, a relatively normal number of adults produced a very low number of young. In fact, the number of young birds captured in 1986 was only 37.7 percent of (and significantly below) the mean of the previous 10 years, while the number of adults captured in 1986 was 91.7 percent of (and not significantly below) the previous 10 years' mean. Indeed, analysis of the young to adult ratio indicated that productivity in 1986 was highly significantly reduced ($P < .001$) compared to that of the previous 10 years. Although the cause of this 1986 reproductive failure is not yet completely clear, its timing, its geographical extent, and the species most affected, led DeSante and Geupel (1987) to hypothesize that it could have been caused by radioactive fallout of Iodine-131 from the Chernobyl nuclear power plant accident in the U.S.S.R.

(2) At a Network of Stations – The idea of a network of constant effort mist-netting stations to monitor the productivity and survivorship of birds over a large geographical area is not really new. The British have had such a program, the Constant Effort Sites (CES) program, in operation since 1981. In 1986, the CES program was endorsed by the British Trust for Ornithology, which made it one of the cornerstones of the trust's avian biomonitoring strategy (Baillie et al. 1986). By 1989, more than 90 constant effort sites were in operation in Great Britain (Peach and Baillie 1989). Data from the British CES program showed that the proportion of young birds increased between 1986 and 1987 for 18 of the 23 species considered (Baillie and Holden 1988). Moreover, significant changes between 1986 and 1987 were recorded for 10 of the species; 9 of these 10 registered increases. These data thus suggest that productivity was either inordinately low in 1986 or unusually high in 1987. Analysis of additional years of British CES data suggest, in fact, that both phenomena did occur (Peach and Baillie 1989). Thus, some degree of reduced reproductive success in 1986 appeared to extend over large areas of the

Northern Hemisphere. These results illustrate the potential usefulness of a network of standardized constant effort mist-netting and banding stations. Indeed, other constant effort banding projects are currently being established in Finland, France, the Netherlands, and Denmark and are being considered for New Zealand, Australia, Spain, and Israel.

The Proposed Network of Stations in North America

A constant effort mist-netting and banding program has now been established in North America, the MAPS program. The program has existed on a very limited basis since the summer of 1989, when 14 stations were established and operated. At least 35 stations were operated during the summer of 1990. The long-term goal for the program is the operation of about 180 stations, about 30 in each of six major regions of the continent: northeast, southeast, north-central, south-central, northwest, and southwest. The delineation of these regions was based upon the average location and apparent east-west periodicity of the jet stream. Seasonal weather in a given year generally tends to be similar at points within one of these regions, but often tends to vary considerably from region to region.

The basic assumption of the proposed MAPS methodology is that significant changes in population parameters (productivity, adult survivorship, and adult population levels) between a given pair of years or over a longer time period will tend to be similar for a given species at several banding stations within a region. Thus, data on a given species can be combined from all of the banding stations in a region, thereby greatly increasing the resulting sample sizes and the precision of the population parameter estimates. By this method, local changes in the population parameters will tend to be ignored, while large-scale changes will tend to be emphasized. This is in accord with the basic objective of the proposed program. Inferences regarding local changes in population parameters can be obtained by combining the data on a number of species at one or a few nearby stations into an appropriate species group (e.g., arboreal insectivorous species, neotropical migrant species, ground-nesting species), and testing for the significance of annual changes or long-term trends.

The strategy for the development of the MAPS program in North America calls for the establishment of a four-year pilot project (1991-1994) to test and evaluate the ability of the methodology to produce useful (precise) data. Indeed, one of the purposes of the pilot project is to determine empirically the capture probabilities that actually can be obtained. Analyses of data from the limited 1989 and 1990 field seasons suggest that capture probabilities in excess of 0.33 can be obtained. If this is indeed the case, samples from 30 stations in each of the six regions are expected to generate enough data for some 15 to 20 common land bird species so that the resulting estimates of survivorship will have adequate precision, and the statistical tests based on these estimates will have sufficient power, to be biologically meaningful and useful.

I suggest that the national parks, the Research Natural Areas of the national forests, and other protected natural areas can provide ideal locations for a network of MAPS stations, because they provide large areas of diverse and relatively pristine ecosystems that promise to be maintained in an undisturbed manner indefinitely into the future. I further suggest that such a network of stations can help forge a partnership among the federal agencies responsible for the stewardship of protected public lands (i.e., National Park Service, U.S. Forest Service, Bureau of Land Management) and those responsible for the conservation of avian diversity in North America (U.S. Fish & Wildlife Service), and the bird banders of North America.

The Operation of a MAPS Station

The establishment and operation of a MAPS station is straightforward. First, a study area is established in an appropriate habitat and location that will allow for the operation of the station indefinitely into the future, or at least for five to ten years, and that will permit the mist-netting of substantial numbers of many of the common land bird species present in the area. Stations can be sited in scrub habitats, in riparian and lowland woodland and forest habitats, or in upland woodland and forest habitats, but should be sited in relatively mature habitats so that the effects of successional change upon the population parameters of the species studied will tend to be minimized.

Next, mist nets are to be erected at 5 to 20 sites (preferably about 10) in the study area. Because a primary aim of the project is to capture and recapture in subsequent years a relatively high proportion of the breeding populations, nets should generally be placed reasonably close together over a medium-sized study area rather than spread widely over a very large study area. A density of about two 12-meter nets per hectare of study area may be ideal.

The operation of the nets should be standardized, if possible, for about six hours per day, for 1 to 10 days per 10-day period, and for up to 12 consecutive 10-day periods from May 1 to August 28. A minimum of one day of operation within each 10-day period is required, although three to six days of operation per 10-day period is suggested. We recommend opening the nets about 15 minutes after sunrise and running the nets for about six hours during each day of operation. While we recommend standardizing the netting operation each day, rigid standardization within the year is not required. The total effort and timing, however, must be kept essentially constant for all years at each station.

All birds captured throughout the season (including recaptures) must be identified to species, banded with U.S. Fish and Wildlife Service numbered aluminum bands, and correctly aged, if possible, by the extent of skull pneumatization and/or other appropriate plumage, mensural, or molt characters (Pyle et al. 1987). If possible, the sex, breeding condition of adults (presence or absence of a cloacal protuberance or brood patch), and extent of juvenile plumage in young birds should also be recorded.

To provide additional information on the population levels of birds at each station, and to sample species that are not captured efficiently by mist nets, a series of from 4 to 12 standardized eight-minute point counts, 60 to 200 meters apart, should be conducted along a route through the habitat at each station. This series of point counts should be conducted three times during the early part of the breeding season when the amount of singing is near its peak.

Finally, because changes in the type and structure of the vegetation at a given station can affect both the number of breeding birds present and their productivity and survivorship, as well as the efficiency with which they can be monitored by mist nets, standardized habitat maps and descriptions must be prepared each year. These maps and descriptions will identify, locate, and characterize the major habitat types present in an area that extends at least 100 meters beyond the outermost net locations.

A MAPS STATION IN YOSEMITE NATIONAL PARK

A MAPS station was established in 1990 in Yosemite National Park for a three-year pilot study. The station was located at Hodgdon Meadow, elevation 1,414 meters, at the ecotone between a wet meadow and a mixed coniferous forest/black oak woodland (fig. 1). Ten permanent nest sites were established at Hodgdon Meadow, three in willows in the meadow itself, three along the meadow edge, and four some 10-30 meters inside the adjoining forest and woodland. One 12-meter long, 30-mm mesh, four-tier nylon mist net was erected at each of the 10 sites. The station was then operated for

Figure 1. A view of Hodgdon Meadow, Yosemite National Park.

ten 10-day periods, from May 21 through August 28, for a total of 56 days of netting and banding. Because of the extremely high density of birds at Hodgdon Meadow, only five nets could be operated on any given day. Thus, we alternated days, operating the five eastern nets one day and the five western nets the next day. Nets were opened each day at about 0630 AM, and were operated from four to six hours per day depending upon the weather conditions; several weeks of extremely hot weather necessitated the closing of nets by 1030 or 1100 AM rather than at the scheduled time of about 1230 PM. A total of 1,279 net-hours were thus accumulated during the season. A summary of the timing, effort, and results of the 1990 MAPS station at Hodgdon Meadow is presented in table 1.

A total of 989 individuals of 49 species were captured during the season, and various individuals of these were recaptured a total of 173 times. Thus, 1,162 captures were recorded. The number of newly captured birds increased from about 60 birds per 100 net-hours early in the season to over 100 birds per 100 net-hours late in the season, and averaged 77.3 birds per 100 net-hours. This was nearly six times the average summer capture rate at the Palomarin Field Station and speaks to the extremely high density of birds along the edges of Sierran montane meadows during the summer months.

As expected, the number of newly banded adult birds decreased from a high of 63.5 birds per 100 net-hours at the start of the season to a low of only 6.8 birds per 100 net-hours in early August, and then increased in mid- to late August to 19.3 birds per 100 net-hours, possibly a result of fall migration (fig. 2). Young birds, in contrast, increased throughout the season from none in late May to 88.8 birds per 100 net-hours in late August (fig. 2). A peak in the number of young birds in late July could represent a synchronous burst of dispersal of young from first brood nests, while a second peak in mid- to late August could again represent fall migration. The proportion of young birds in the catch thus increased from none in late May to a peak of 0.900 in early August and then declined slightly to 0.821 in late August (fig. 3). The overall seasonal mean proportion of young was 0.567.

The proportion of young birds captured, however, varied greatly among individual species (table 2), from as high as 90 percent for orange-crowned warblers that breed only at elevations lower than Hodgdon Meadow and disperse up-mountain after the nesting season, to as low as 6 percent for hermit warblers that breed in the forest at Hodgdon Meadow but stay primarily high in the trees. The proportion of young for most species was about 35-60 percent. These data illustrate the fact that the proportion of young cannot be used directly to compare productivity between species, but can be used to provide indications of year-to-year (or longer) changes in productivity for each species, and can permit accurate comparisons of changes in productivity between species. The 14 species for which more than 15 individuals were captured (table 2) will provide key information on changes in productivity (the proportion of young in the catch) and survivorship (from capture-recapture analyses) in subsequent years.

Of additional interest was the fact that several major fires burned considerable areas of Yosemite National Park to within one mile of the Hodgdon Meadow banding station during mid-August. Our data, however, indicate that these fires had no obvious effect on either the capture rates of birds at Hodgdon Meadow or the proportion of young birds captured.

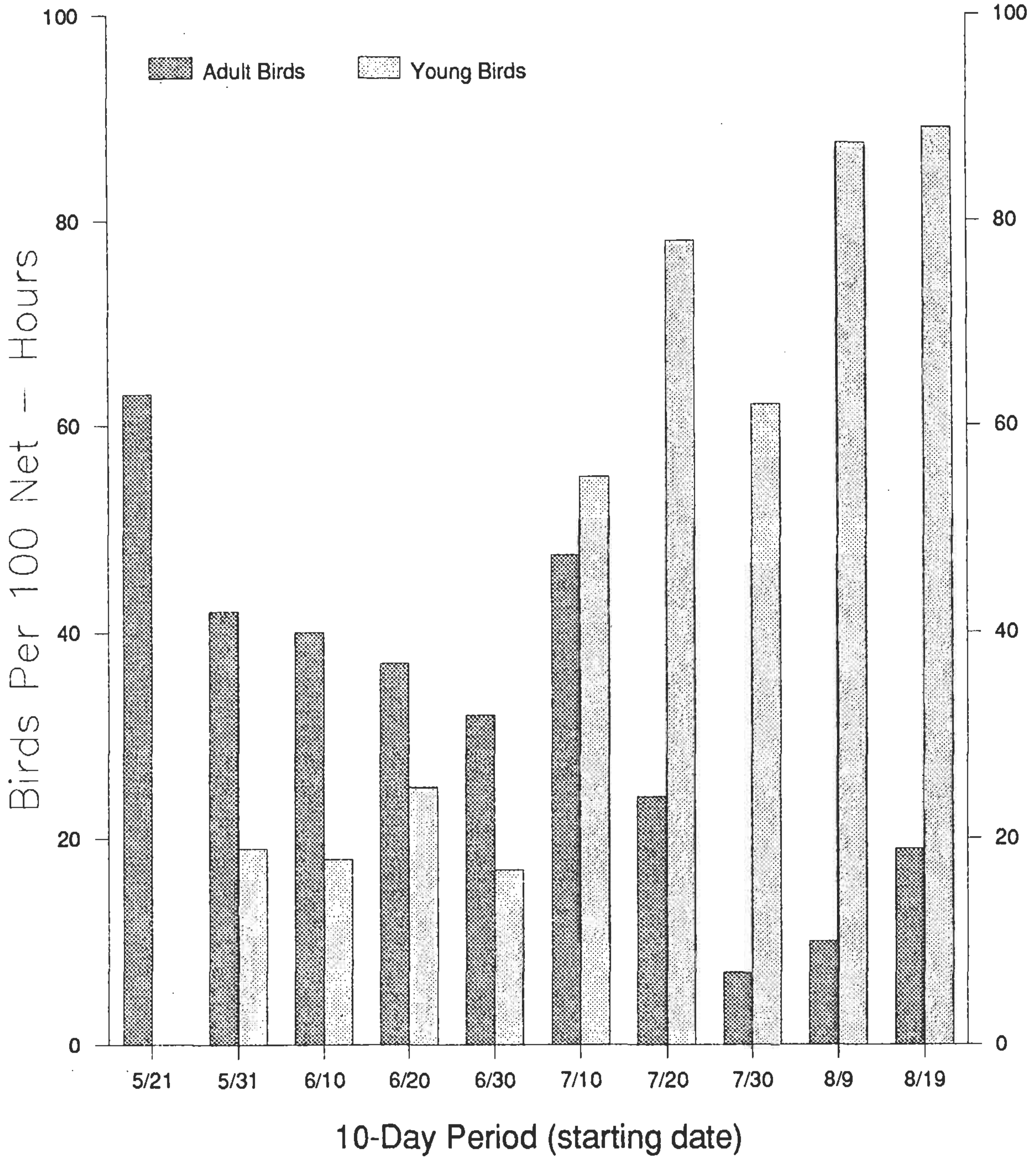

Figure 2. Numbers of newly captured birds per 100 net-hours (excluding hummingbirds) at Hodgdon Meadow during the summer of 1990.

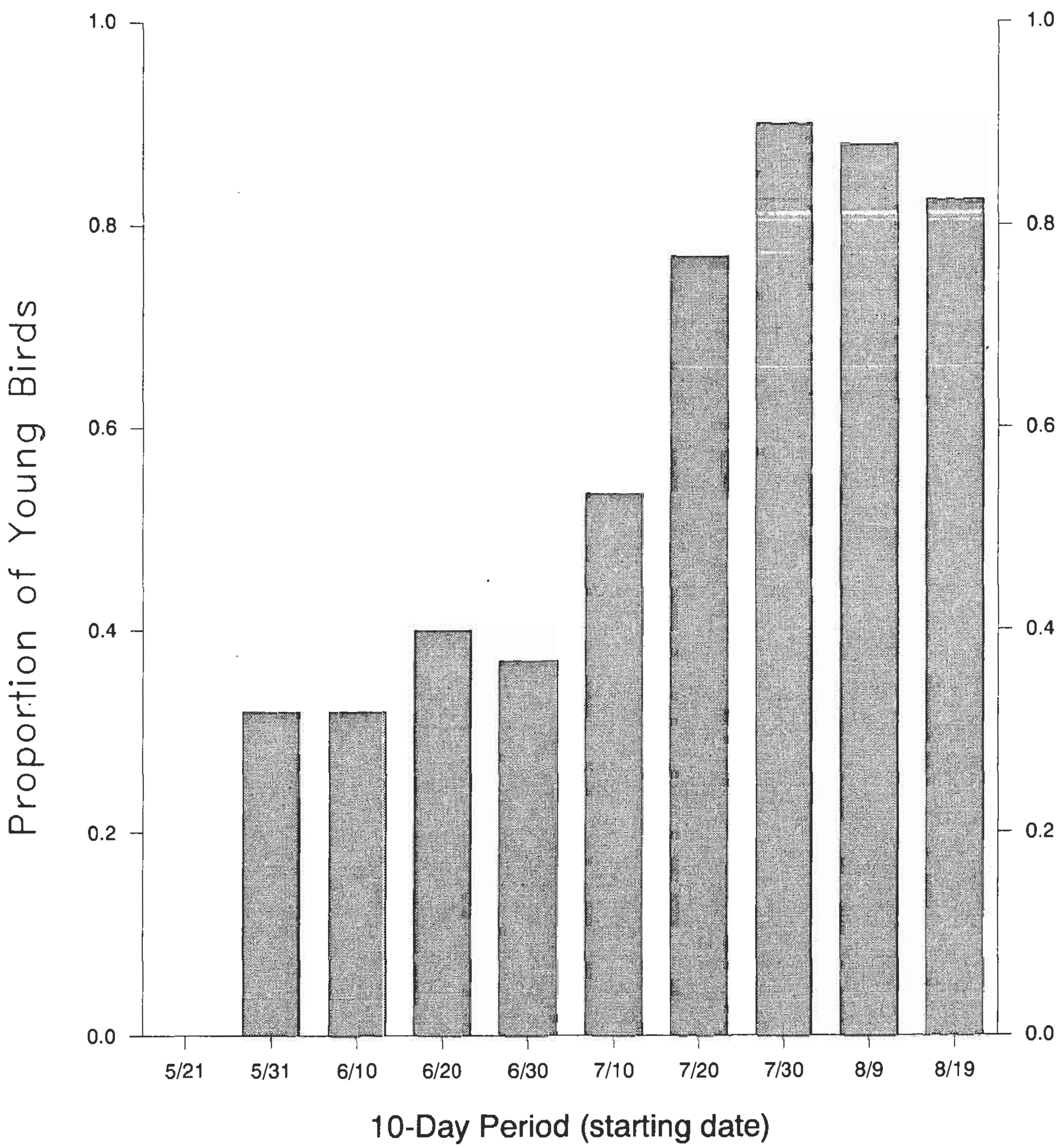

Figure 3. Proportion of young among all newly captured birds (excluding hummingbirds) at Hodgdon Meadow during the summer of 1990.

Table 1. Summary of the effort and results of the 1990 Yosemite National Park MAPS station located at Hodgdon Meadow

Period	No. of banding days	Total net-hrs	No. of species	Number of individuals: Newly captured	Number of individuals: Recaptured	Newly captured birds per 100 net-hrs
3: May 21-30	4	72.4	19	46	1	63.5
4: May 31-Jun 9	6	198.5	33	124	24	62.5
5: Jun 10-19	5	140.0	23	82	27	58.6
6: Jun 20-29	5	160.0	28	99	24	61.9
7: Jun 30-Jul 9	7	135.0	25	72	20	53.3
8: Jul 10-19	5	103.3	25	114	21	110.3
9: Jul 20-29	9	186.4	27	191	27	102.5
10: Jul 30-Aug 8	7	132.8	20	93	15	70.0
11: Aug 9-18	2	36.7	17	40	4	109.1
12: Aug 19-28	6	113.8	17	128	10	112.5
Total	**56**	**1,278.9**	**49**	**989**	**173**	**77.3**

Table 2. The fourteen most commonly captured species at the Yosemite National Park MAPS station located at Hodgdon Meadow

Species	Number newly captured: Total	Adults	Young	% young
Orange-crowned warbler *(Vermivora celata)*	226	22	204	90.3
Purple finch *(Carpodacus purpureus)*	142	71	71	50.0
MacGillivray's warbler *(Oporornis tolmiei)*	82	41	41	50.0
Dusky flycatcher *(Empidonax oberholseri)*	69	43	26	37.7
Warbling vireo *(Vireo gilvus)*	63	47	16	25.4
Nashville warbler *(Vermivora ruficapilla)*	52	11	41	78.8
Dark-eyed junco *(Junco hyemalis)*	31	9	22	71.0
Song sparrow *(Melospiza melodia)*	28	11	17	60.7
Lincoln's sparrow *(Melospiza lincolnii)*	26	16	10	38.5
Red-breasted sapsucker *(Sphyrapicus ruber)*	24	14	10	41.7
Yellow warbler *(Dendroica petechia)*	21	15	6	28.6
Solitary vireo *(Vireo solitarius)*	17	10	7	41.2
Yellow-rumped warbler *(Dendroica coronata)*	16	9	7	43.7
Hermit warbler *(Dendroica occidentalis)*	16	15	1	6.3
All species (except hummingbirds)	954	413	541	56.7

CONCLUSIONS

(1) Current avian biomonitoring programs have failed to provide the critical annual estimates of productivity and survivorship of land birds that are crucial for testing hypotheses regarding the causes of the recent declines in North American land bird populations.

(2) The MAPS program, a cooperative network of constant effort mist-netting and banding stations operated during the breeding season and located primarily on protected public lands, has been designed to provide these critical estimates through modified Jolly-Seber analyses of capture-recapture data.

(3) Previous results from a single constant effort banding station on the Point Reyes National Seashore, and a network of constant effort banding stations in Great Britain have provided validation of the effectiveness of the methodology for the long-term monitoring of land bird productivity.

(4) Data from the first year of a three-year pilot study in Yosemite National Park and from the first two years of the North American MAPS program have provided a positive indication that the method will produce meaningful information on the productivity and survivorship of North American birds.

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