The Monitoring Avian Productivity and Survivorship (MAPS) Program in Kings Canyon National Park: 1991 – 2008

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Summary

Since 1989, The Institute for Bird Populations (IBP) has coordinated 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. MAPS provides annual indices of population size and post-fledging productivity and estimates of adult survivorship and recruitment 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 adequately address declines in landbird populations. Here we report data collected at two MAPS stations in Kings Canyon National Park (SEKI), Lion Meadow (1850 masl) and Zumwalt Meadow (1280 masl) between 1991 and 2008 (with a hiatus in monitoring from 1994-2000). Specifically, we: (1) summarize breeding status of all species recorded during the study, (2) summarize capture rates of adult and young birds and productivity (ratio of young to adults caught) from constant-effort capture data, (3) assess long-term trends in capture rates and productivity, (4) estimate and assess trends in adult apparent survivorship during 2001-2008, and (5) assess the role of annual weather variation and climate change in driving trends in avian population sizes and productivity.

We recorded 129 species at the two SEKI MAPS stations. The number of species was higher at Zumwalt (110 species recorded, 81 of which were breeding species) than at Lion (100 species, 65 breeding species) Meadow. Twenty-nine unique species were recorded at Zumwalt, compared with 19 at Lion Meadow. Capture rate of adults was slightly higher at Zumwalt Meadow (145.0 adult birds per 600 net-hours) than at Lion Meadow (137.4 adult birds per 600 net-hours). The most commonly captured species were: MacGillivray's Warbler, Purple Finch, Dark-eyed Junco, Lincoln's Sparrow, and American Robin. In contrast to adult capture rates, young capture rates were higher at Lion (52.3 young birds per 600 net-hours) than at Zumwalt (40.3 young birds per 600 net-hours) Meadow. Consequently, productivity was also higher at Lion (0.39 young/adult) than at Zumwalt (0.28 young/adult) Meadow.

We found little evidence of trends in adult captures, young captures, or productivity for most species; however, adult captures tended to increase and young captures and productivity tended to decline over the study period. Trend in adult capture rates for 23 target species was positive and significant ($P < 0.05$) or nearly significant ($P < 0.10$) for 4 species-station combinations (MacGillivray's Warbler, Song Sparrow, and Lincoln's Sparrow at Lion Meadow; and Pacific-slope Flycatcher at Zumwalt Meadow) and negative for one species-station combination (Wilson's Warbler at Zumwalt Meadow). Spotted Towhee adult capture rate significantly increased when data were pooled across stations. Adult captures for all species pooled significantly increased at Lion Meadow. Young capture rates significantly declined for Mountain Chickadee at both stations and for Brown Creeper at Lion Meadow. Productivity significantly declined for Pacific Slope Flycatcher at Zumwalt Meadow (and nearly significantly declined overall) and for Mountain Chickadee at both stations.

We were able to estimate adult apparent survival rates for 11 species. We found little evidence

of annual variation or trend in survival for most species, although small sample sizes and low precision for most species suggested that trend detection would be difficult. The strongest statistical support for trend in survival was for American Robin for which survival appeared to decline over the study period. Adult survival estimates were high for most species and ranged from a mean (across years) of 0.32 for Black-headed Grosbeak to 0.80 for Yellow Warbler. This suggests that overwintering conditions for many species that breed in SEKI (representing a range of migratory strategies) may have been relatively good over the study period, and that high survival rates at SEKI have been important in explaining observed stable adult capture rates.

To assess effects of weather variation and climate on SEKI landbird trends, we conducted linear regressions of adult capture rates, young capture rates, and productivity on one broad-scale climate metric, the monthly mean El Niño Southern Oscillation (ENSO) Precipitation Index (ESPI) collected during late-winter/spring (January-April). For these analyses, we only considered all species pooled and species-station combinations for which we found evidence of trend in adult captures, young captures, or productivity. Late-winter/spring corresponds to a period spanning maximum precipitation and minimum temperatures in the Sierra Nevada and potentially limiting (e.g., late dry season) conditions on the wintering grounds of migratory species. ESPI reflects broad-scale atmospheric circulation in the tropical Pacific, which can influence wind, temperature, and precipitation across the Americas. ESPI is positive during El Niño-like (ENSO) conditions and such conditions typically yield increased precipitation in the subtropical and tropical eastern Pacific and harsh winters and later springs in the southern Sierra Nevada.

The relationship between ESPI and adult capture rate tended to be negative for all species combined and for the four species that showed evidence of population increases. Fewer adults in years with more El Niño-like conditions could result from harsher winters or later springs in the southern Sierra Nevada during such years or, possibly, (for migrants) poor conditions on wintering grounds. In contrast to adults, capture rates of young tended to be positively related to ESPI. Productivity also tended to be positively related to ESPI. Although it is not entirely clear how conditions favoring late springs would positively affect productivity, such conditions might be more closely matched to food resource (invertebrate) cycles typical of historical conditions. Overall, avian responses to ENSO conditions suggest that bird populations at SEKI, both resident and migrant, respond to weather variation and, given predictions of climate change, will show marked changes in the coming decades. A general warming trend and predicted La Niña-like conditions in the coming decades should continue to suppress productivity at SEKI. If such declines are typical of the larger Sierra Nevada region, we would expect this pattern to eventually lead to adult population declines at SEKI. Clearly, the MAPS program in the Sierra Nevada, including SEKI, provides a unique dataset for understanding avian responses to climate change in the region. Additional years of data collection under a broader range of weather conditions will enable us to better address these questions. Thus, we strongly recommend the sustained operation of the SEKI MAPS stations and the broader Sierra Nevada MAPS network.

Introduction

Birds and Monitoring

Birds can serve as excellent indicators of environmental change in terrestrial ecosystems because of their high body temperature, rapid metabolism, and high ecological position on most food webs. 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. An added benefit is that landbird monitoring is often particularly efficient, in that many species can be monitored simultaneously with the same survey protocol, and costs are relatively low. Finally, landbirds hold high and growing public interest (Cordell et al. 1999; Cordell and Herbert 2002) and are perhaps the most visible faunal component of park ecosystems.

Primary Demographic Parameters

Landbird population trends, while suggesting severe declines in some species, provide no information on primary demographic parameters: productivity and survivorship. Without demographic information, population-trend data alone provide no means for determining at what point(s) in the life cycles problems are occurring, or to what extent population trends are driven by causal factors that affect birth rates, death rates, or both (DeSante 1995). The lack of such information for migratory birds in particular is an obstacle to effective conservation, as it leaves unresolved whether critical problems that drive population declines are occurring primarily on temperate breeding grounds, during migration, or on distant tropical wintering grounds. Lack of data on productivity and survivorship thus impedes the formulation of effective management and conservation strategies to reverse population declines (DeSante 1992).

Environmental factors and management actions affect primary demographic parameters directly and these effects can be observed over a short time period (Temple and Wiens 1989). Because of the buffering effects of floater individuals and density-dependent responses of populations, there may be substantial time lags between changes in primary parameters and resulting changes in population size or density (DeSante and George 1994). Thus, a population could be in trouble well before population trend data reflect severe declines. Perhaps even more importantly, because of the vagility of many bird species, local variation 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). Local abundance can thus sometimes be a poor indicator of reproductive success, particularly in habitats that have been modified substantially by humans (Bock and Jones 2004). For all these reasons, demographic monitoring provides important information that cannot be acquired from population trend monitoring alone.

The MAPS Program

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. The MAPS program has since grown into a continent-wide network comprising hundreds of constant-effort mist-netting and banding stations that provide long-term demographic data on landbirds (DeSante et al. 1995). The design of the MAPS program was patterned after the very successful British Constant Effort Sites (CES) Scheme that has been operated by the British Trust for Ornithology since 1981 (Peach et al. 1996). The MAPS program was endorsed in 1991 by both the Monitoring Working Group of PIF and the USDI Bird Banding Laboratory, and has subsequently has attracted participation from numerous federal agencies, including the National Park Service, Department of Defense, Department of the Navy, Department of the Army, Texas Army National Guard, USDA Forest Service, and US Fish and Wildlife Service.

MAPS data can and are being used to:

- Identify the demographic causes of population declines in landbirds.
- Understand the effects of land management actions on bird populations and provide land managers with management recommendations that will benefit bird populations.
- Monitor the efficacy of those recommendations when they are implemented.
- Elucidate the effects of weather variation on avian demographics and predict and monitor the effects of climate change on bird populations.
- Develop adaptation strategies to mitigate those effects.

The MAPS Program at Kings Canyon National Park

MAPS stations were established in Kings Canyon National Park in 1991, and except for a hiatus from 1994-2000, have been operated through 2008. Elsewhere in the NPS Sierra Nevada Network, MAPS stations have been operated since 1990 in Yosemite National Park (Siegel et al. 2007), and since 2002 in Devils Postpile National Monument (Gates and Heath 2003). Additional stations have been operated on national forests and private lands throughout the Sierra Nevada (Siegel and Kaschube 2007).

The purpose of this report is to an analyze data from the MAPS program at SEKI since the establishment of the two station in 1991 through 2008. Specifically, we:

- Summarize breeding status for all bird species recorded during the monitoring period.
- Evaluate population size and productivity data during all eleven years (1991-1993 and 2001-2008) of station operation at SEKI.
- Assess long-term trends in population sizes and productivity at the SEKI stations.
- Model and estimate adult apparent survivorship at SEKI during the years 2001-2008.
- Assess the role of annual weather variation and climate change in driving observed trends in avian population sizes and productivity.

Methods

Establishment and Operation of Stations

MAPS stations were established at Lion Meadow and Zumwalt Meadow in 1991, and operated in the same locations each year during 1991-1993 and 2001-2008 (Fig. 1). The Lion Meadow station is located at a small montane meadow surrounded by coniferous forest with an area of montane chaparral at 1,853 m elevation; the Zumwalt Meadow station is located along a riparian corridor with open meadows and mixed conifer and oak woodlands at 1,280 m elevation (Table 1).

Through efforts of NPS personnel (particularly Rachel Mazur) and crews trained by IBP, both MAPS stations have been operated in accordance with standardized banding protocols developed for the MAPS Program throughout North America (DeSante et al. 2008). Ten net sites were operated at each station in the same locations in each year of the study. Since 2001 each station was operated for six morning hours per day (beginning at local sunrise) during one day in each of seven or eight consecutive 10-day periods between May 21 and August 8 (Table 1). During 1991-1993, the stations were operated for three days during each 10-day period. With few exceptions, the operation of all stations occurred on schedule during each of the ten-day periods during each year of operation.

Data Collection

With few exceptions, all birds captured were identified to species, age, and sex. If unbanded, the birds were banded with USGS/BRD numbered aluminum bands. Birds were released immediately upon capture and before being banded or processed if situations arose where bird safety was compromised. Such situations could involve 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 collected from all birds captured, including recaptures:

- Capture code (newly banded, recaptured, band changed, unbanded);
- Band number
- Species
- Age and how aged
- Sex (if possible) and how sexed (if applicable)
- Extent of skull pneumaticization
- Breeding condition of adults (i.e., extent of cloacal protuberance or brood patch)
- Extent of juvenal plumage in young birds
- Extent of body and flight-feather molt
- Extent of primary-feather wear
- Presence of molt limits and plumage characteristics
- Wing chord
- Fat class and body mass

- Date and time of capture (net-run time)
- Station and net site where captured
- Any pertinent notes

Effort data (i.e., the number and timing of net-hours on each day of operation) were also collected in a standardized manner. In order to allow constant-effort comparisons of data, 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.

Computer Data Entry and Verification

The computer entry of banding data was completed in some years (including 2008) by John W. Shipman of Zoological Data Processing, Socorro, NM, and in other years by SEKI staff using MAPSPROG, a data input, verification, and error-tracking program developed by The Institute for Bird Populations for MAPS operators (Froehlich et al. 2006). After each year of station operation, 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 data was completed by IBP biologists using custom data entry programs, or by SEKI staff using MAPSPROG. In 2008 the entire banding dataset was run through a series of verification programs by IBP staff as follows:

- Clean-up programs to check the validity of all codes entered and the ranges of all numerical data.
- Cross-check programs to compare station, date, and net fields from the banding data with those from the summary of mist netting effort data.
- 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.
- Screening programs which allow identification of unusual or duplicate band numbers or unusual band sizes for each species.
- 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

<u>Breeding Status</u>

We classified the landbird species captured in mist nets into six groups based upon their breeding status. Each species was classified as one of the following:

- 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.
- 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.
- 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.
- 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.
- Altitudinal disperser (A) if the species breeds only at lower elevation than that of the station but disperses to higher elevations after breeding.
- 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 trend and survivorship analyses only if the species was classified as a regular (B) or usual (U) breeder at the station. Throughout this report we define “target species” for trend and survivorship analyses as those for which an average of 2.5 individual adult birds were captured per year at the two stations combined or at each station for station-specific analysis.

<u>Adult and Young Capture Rate and Productivity</u>

The proofed, verified, and corrected banding data from all eleven years of data collection were run through a series of analysis programs that calculated for each species:

- Numbers of newly banded birds, recaptured birds, and birds released unbanded.
- Numbers and capture rates (birds per 600 net-hours) of first captures (in a given year) of individual adult and young birds. Following the procedures pioneered by the British Trust for Ornithology in their Constant Effort Sites (CES) Scheme (Peach et al. 1996), we consider capture rates to be an index of population size.
- Reproductive index (RI). For each species in each year, we calculated a yearly RI as the number of young divided by the number of adults.

Trends in Capture Rate and Productivity

We estimated trends in adult capture rates of adult and young birds and productivity (RI) with linear regression. Eleven years of data were included in the analysis (1991-1993 and 2001-2008). We conducted separate regressions using the 11-yr data set and the shorter contiguous 8-year (2001-2008) data set and show regression lines of both analyses in figures to provide an impression of how recent short-term trends may differ from long-term trends; however, we report statistics and discuss only the long-term trends in the results. For the long-term trends, we report the slope of the regression (β – for capture rates this is an estimate of the change in numbers of birds per 600 net-hours per year), standard error of β (*SE*), correlation coefficient (*r*), and significance of the correlation (*P*-value). 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 $0.05 \leq P < 0.10$.

Adult Survivorship

We used the computer program MARK (White and Burnham 1999) and modified Cormack-Jolly-Seber CJS mark-recapture models (Pollock et al. 1990) to calculate, for selected target species, maximum-likelihood estimates and standard errors (*SE*s) of annual apparent survival rates (φ) and recapture probabilities (p). Apparent survival rate is defined as the probability of a bird banded at a given station in a given year surviving to the next year and remaining at the same station. Recapture probability is defined as the conditional probability of recapturing a bird at a station in a subsequent year that was banded at the station in a previous year, given that it survived and remained at the station at which it was originally banded. The presence of transient individuals (dispersing, 'floating', and late or early migrating individuals) in the sample of newly captured birds tends to bias apparent survival rates and/or recapture probabilities low, because they are only captured once and never recaptured. We used a version of the CJS model (ad hoc robust design model) that reduces bias and increases precision of adult apparent survival-rate estimates by effectively eliminating these birds from the sample (Nott and DeSante 2002, Hines et al. 2003).

We considered 15 target species for which an average of 2.5 adult birds were captured over the 8 years 2001-2008 (20 year-unique captures) and for which we recorded at least two between-year recaptures. We fit $i = 9$ models representing 3 parameterizations of φ and 3 parameterizations of p. For both φ and p we considered fixed year effects, a time-constant model, and a model with a linear trend (Table 2). Following Burnham and Anderson (1998), we assessed support for these effects from model weights (w_i) based on Akaike's Information Criterion (AIC_c; Burnham and Anderson 1998). To ensure conservative model weighting, we adjusted the 'overdispersion parameter', $\hat{c}$, whenever overdispersion was indicated by the bootstrap goodness-of-fit test in program MARK (Cooch and White 2002). In these cases, we used $QAIC_c$ rather than AIC_c to determine model weights. We report φ and p as model-averaged estimates based on the summed w_i from the full model set. This method of multi-model inference enabled us to use the entire set of candidate models to judge the importance of a parameter to survival rate, rather than basing conclusions on a single best-fit model.

Weather, Climate, and Trends in Captures and Productivity

For all species pooled and for target species and stations for which we detected evidence of trend in capture rates of adults, young, or productivity (i.e., for $P < 0.10$), we conducted linear regressions of response variables (young and adult captures were log+1-transformed) on one broad-scale climate metric, the monthly mean El Niño Southern Oscillation (ENSO) Precipitation Index (ESPI) collected during late-winter/spring (January-April). Late-winter spring corresponds to a period spanning maximum precipitation and minimum temperatures in the Sierra Nevada and a period of potentially limiting (e.g., late dry season) conditions on the wintering grounds of migratory species (Nott et al. 2002, Studds and Marra 2007). ESPI is a satellite-derived measure of large-scale atmospheric circulation in the tropical Pacific (Curtis and Adler 2000, Nott et al. 2002) that influences wind, temperature, and precipitation patterns across North and South America. ESPI is positive during El Niño-like (ENSO) conditions and negative during La Niña-like conditions. El Niño-like conditions typically yield increased precipitation in the subtropical and tropical eastern Pacific and harsh winters and later springs in the southern Sierra Nevada (Stewart et al. 2005). ESPI data were downloaded from the National Oceanic and Atmospheric Administration's Earth System Research Laboratory website (http://www.cdc.noaa.gov/data/correlation/espi.data).

Results

Breeding Status

We recorded 129 species at the two SEKI MAPS stations over the 11 years of monitoring (Appendix I). The number of species recorded was higher at Zumwalt (110 species) than at Lion (100 species) Meadow. The number of unique species recorded at Zumwalt was 29 compared to 19 at Lion Meadow. We recorded evidence of breeding for 81 species at Zumwalt (codes 'B', 'O', or 'U' in Appendix I) compared to 65 species at Lion Meadow.

Mean Indices of Adult Population Size and Productivity

Table 2 presents mean annual numbers (per 600 net-hours) of individual adult and young birds captured, and reproductive index (RI) during the eleven years 1991-1993 and 2001-2008 for each species and all species pooled, at each SEKI station and at both SEKI stations pooled. Pooling all species, the capture rate of adults during the eleven years was slightly higher at Zumwalt Meadow (145.0 adult birds per 600 net-hours) than at Lion Meadow (137.4 adult birds per 600 net-hours). The five most commonly captured species (followed by number of captures per 600 net-hours) at each station and at both stations pooled were:

Lion Meadow	Zumwalt Meadow	Both stations pooled
MacGillivray's War (24.6)	Purple Finch (22.7)	MacGillivray's Warbler (21.6)
Dark-eyed Junco (19.8)	MacGillivray's Warbler (18.0)	Purple Finch (12.7)
Lincoln's Sparrow (16.6)	Warbling Vireo (11.7)	Dark-eyed Junco (12.3)
Yellow-rumped Warbler (13.2)	Song Sparrow (10.8)	Lincoln's Sparrow (9.2)
Pacific-slope Flycatcher (6.7)	American Robin (9.3)	American Robin (6.9)

In contrast to adult capture rates, young capture rates were substantially higher at Lion Meadow (52.3 young birds per 600 net-hours) than at Zumwalt Meadow (40.3 young birds per 600 net-hours). Consequently, productivity was also higher at Lion Meadow (0.39 young/adult) than at Zumwalt Meadow (0.28 young/adult).

Trends in Adult and Young Capture Rate and Productivity

Although highly variable among years (median coefficients of variation [CVs; where CV = (sd/mean)*100] across species for numbers of adults [per 600 net-hours], young, and RI > 100 for each station), we found little evidence of trend in adult population size or productivity (no. young/600 net-hours or RI) for most target species (Figs. 2-4). Furthermore, in many cases trends appeared to differ between the long term data set (1991-2008, with 1993-2001 missing) and the more recent (2001-2008) data set. These differences highlight the importance of continuity in monitoring and the value of long-term data.

Overall, we found a tendency for adult population sizes to increase over the 1991-2008 study period (Fig. 2). Estimates of trend in adult capture rate were positive for 13 of 23 (57%) species (both stations combined) and for 24 of 42 species-station combinations (57%; no adults were captured at 4 species-station combinations). Trend estimates were positive and significant or nearly significant ($P < 0.10$) for 4 species-station combinations (MacGillivray's Warbler, Song Sparrow, and Lincoln's Sparrow at Lion Meadow; and Pacific-slope Flycatcher at Zumwalt Meadow) and negative for just one species-station combination (Wilson's Warbler at Zumwalt Meadow, although this decline was determined almost entirely by exceptionally high capture rate in 1991). Considering data pooled across stations, Spotted Towhee adult capture rate also showed some evidence of increase (+0.10 birds per 600 net-hours per year; $P < 0.10$). Adult captures for all species pooled significantly increased at Lion Meadow (increasing by > 2 birds per 600 net-hour per year; $P < 0.05$) and were relatively stable at Zumwalt Meadow (+ 0.56 birds per 600 net-hours per year; $P = 0.68$).

Trends in capture rates of young were also relatively weak for most species (Fig. 3). In contrast to the pattern for adults, young birds tended to decline over the study period. Trend estimates for young capture rates were negative for 15 of 22 (68%) species (both stations combined; note that no young Hermit Warblers were captured during the study) and for 22 of 38 (58%) species-station combinations. We did not find any significant positive trends in young capture rate, and young capture rate significantly or nearly significantly declined for Mountain Chickadee at both stations and for Brown Creeper at Lion Meadow. Data pooled across species suggested weak declines overall (estimate for both stations combined = - 0.85 birds per 600 net-hours per year; $P = 0.34$).

As would be expected given the tendency for adult captures to increase and young captures to decrease, productivity (RI) tended to decline over the study period (Fig. 4). We found negative trend estimates in RI for 16 of 22 species (73%) and for 24 of 33 species-station combinations. Pacific-slope Flycatcher productivity significantly declined at Zumwalt Meadow (and nearly significantly declined overall) and Mountain Chickadee RI significantly declined at both stations. Although we also found a nearly-significant decline for Song Sparrow at Lion Meadow, RI data were not available for this species during the first 3 years of the study due to no adult birds being captured. For all species combined, trend in RI was slightly negative (-0.01/yr for each station and for both stations combined).

Adult Survivorship

We were able to estimate adult apparent survival rates for 11 of the 15 target species that met minimal sample requirements (see Methods). We found little statistical support for annual variation in survival or capture probability (Table 2), although this undoubtedly reflected (to some extent) insufficient power to detect these effects. In addition, we found little support for temporal trend in either survival or capture probability. The strongest level of model support for a linear trend in survival was for American Robin (summed $wi = 0.557$), for which survival appeared to decline over the study period (Table 3). Statistical support for trend in survival was relatively low for remaining species, although several species with moderate support (summed $w_i > 0.20$) for trend effects showed a slight tendency for declining survival. Adult apparent survival-rate estimates were generally high for most species and ranged from a mean low of 0.32 for Black-headed Grosbeak to a high of 0.80 for Yellow Warbler. In many cases, however, precision on estimates was low (CVs that were typically < 20% for just 3 species: MacGillivray's Warbler, Lincoln's Sparrow, and Dark-eyed Junco).

Weather and Climate Drivers of Trends

Adult captures for all species combined and for each of the four bird species that showed evidence of significant increases at one or both stations over the study period tended to be lower under more El Niño-like conditions (i.e., under higher values of Jan-Apr ESPI; Fig. 5). This relationship was only significant, however, for Spotted Towhee at both stations ($P = 0.01$) and nearly significant for all species pooled at both stations ($P = 0.09$) and for MacGillivray's Warbler at Lion Meadow ($P = 0.06$). Wilson's Warbler, which showed evidence of decline in adult captures at Zumwalt Meadow, showed no notable response to ESPI conditions.

In contrast to adults, capture rates of young tended to be positively related to Jan-Apr ESPI (Fig. 6). This relationship was not significant (or nearly significant), however, when considering all species pooled, and was largely the result of very high numbers of young observed in 1992. Capture rates of young of the two species that showed evidence of significant declines in young over the study period, Brown Creeper and Mountain Chickadee, showed significant positive relationships to Jan-Apr ESPI at the sites where declines were observed (Lion Meadow for Brown Creeper and both sites for Mountain Chickadee). It should be noted however, that the number of young chickadees captured in any year was low (highest in 1992 when 5 individuals were caught at the two stations combined).

As would be expected given negative relationships for adults and positive relationships for young with Jan-Apr ESPI, productivity (RI) tended to be positively related to ESPI (Fig. 7). For all species pooled, this relationship was nearly significant at Zumwalt Meadow ($P = 0.07$) and at both sites combined ($P = 0.10$); as was the case for numbers of young, the El Niño-like conditions and high productivity in 1992 were very important in determining this relationship. Mountain Chickadee productivity was nearly significantly positively related ($P = 0.07$) to ESPI at Lion Meadow and significantly positively related ($P = 0.07$) to ESPI for both stations combined.

Discussion

Population sizes of landbirds at Kings Canyon National Park (SEKI), as indexed by adult capture rates at the two MAPS stations, were slightly low overall compared to the Sierra Nevada as a whole (e.g., 174 birds per 600 net hours for all species combined reported in Siegel and Kaschube 2007 compared to 137 birds per 600 net hours reported at SEKI). Yet several species had capture rates that were exceptionally high for the region, including Pacific-slope Flycatcher, MacGillivray's Warbler, and Purple Finch, suggesting that the areas sampled by the SEKI MAPS stations are providing quality habitat for these species.

As has been noted in earlier reports, productivity indices recorded at the SEKI MAPS stations are generally low compared to MAPS stations in Yosemite National Park or across the larger Sierra Nevada region (DeSante et al. 2005, Siegel and Kaschube 2007). Results reported here are consistent with those findings. For example, compared to productivity indices measured from 1992-2005 at stations across the Sierra (including SEKI stations) only 3 of 22 target species for which we present trend data (Figs. 2-4) had higher productivity in this report (Dusky Flycatcher, Wilson's Warbler, and Fox Sparrow), and the productivity index for all species combined was just 57% of the value reported for the 1992-2005 Sierra data (Siegel and Kaschube 2007). Despite this low productivity, we found little evidence of population declines at SEKI, suggesting that populations at these stations are sustained by a combination of higher than normal survival and/or emigration from outside of the study region.

Although precision of adult apparent survival rate estimates was low for most target species, estimates were generally high. Mean survival rate estimates (from Table 5) for each of the three species for which we could estimate survival with the greatest precision, MacGillivray's Warbler, Lincoln's Sparrow, and Dark-eyed Junco were higher than survival-rate estimates from Yosemite MAPS stations (Siegel et al. 2007) and other Sierra-wide estimates (Siegel and Kaschube 2007, Saracco and DeSante 2008). This pattern extended to 7 of the 8 remaining target species for which we estimated survival with lower precision (all but Song Sparrow). Overall this suggests that overwintering conditions for many species that breed in Kings Canyon (which represent a range of migratory strategies) have been relatively good over the study period and that high survival rates at SEKI are likely important in explaining the stable or increasing trends of adult capture rates. Nevertheless, there is at least some indication that survival may be declining for some species and could limit populations in the future. For example, the one species for which statistical support for temporal trend in survival was greatest, American Robin, showed a decline in survival over the 2001-2008 period and a concurrent decline in adult captures. Slight declines in survival were also suggested for other species, although more years of data will be needed to confirm this pattern.

Our analyses of avian responses to the mean El Niño Southern Oscillation Precipitation Index (ESPI) conditions during late-winter and spring (Jan-Apr) suggest that that bird populations at SEKI, both residents and migrants, are sensitive to weather variation and, given predictions of climate change, will show marked changes in the coming decades. We found a tendency for more El-Niño like conditions to result in fewer adults being captured and higher productivity. Fewer adults in years with more El Niño-like conditions could result from harsher winters or later springs in the southern Sierra Nevada during such years (Stewart et al. 2005) or, possibly, (for migrants) from poor conditions on wintering grounds in such years. Numbers of young and productivity on the other hand, could conceivably be positively influenced by late springs if the timing of initiation of initial broods during such years more closely matches the timing of insect outbreaks during such years (Husby et al. 2009). For example, Dahlsten et al. (1992) report fewer second broods attempted by Mountain Chickadees in years with earlier first laying dates. Nevertheless, small sample sizes and the relatively narrow range of climatic conditions experienced during the study preclude strong inference regarding these patterns at this time. For example, strong El Niño conditions were experienced only during two years spanned by the study period (1992 and 1998 only), and sampling was missed during one of these years (1998). We hope to better address this question with additional years of sampling; however, a general warming trend and Pacific Decadal Oscillation (PDO) conditions that favor La Niña-like conditions may make strong El Niño conditions rare in the near future. Prevailing current conditions and climate trends will likely favor continued declines in productivity at SEKI, and if such declines are typical of the larger Sierra Nevada region, will eventually lead to adult population declines at SEKI.

Clearly, the MAPS program in the Sierra Nevada, including SEKI, provides a unique dataset for understanding avian responses to climate change in the region. Additional years of data collection under a broader range of weather conditions will enable us to better address these questions. Thus, we strongly recommend that the sustained operation of the SEKI MAPS stations and the broader Sierra Nevada MAPS network.

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Table 1. Summary of the 2008 operation of the two MAPS stations in Kings Canyon National Park.

Station						2008 Operation		
Name	Code	No.	Major Habitats	Latitude-Longitude	Elev. (m)	Total Net-hours[1]	No. of Periods	Inclusive Dates
Lion Meadow	LIME	11109	Coniferous forest, montane meadow, montane chaparral	36°44'45"N,-118°58'57"W	1,853	434.0 (400.5)	8	05/29 – 08/07
Zumwalt Meadow	ZUME	11110	Riparian corridor, conifer forest, oak woodland	36°47'57"N,-118°35'58"W	1,280	417.0 (386.8)	8	05/28 – 08/06
ALL STATIONS COMBINED						851.0 (787.3)	8	05/28 – 08/07

[1] Total net-hours in 2008. Net-hours in 2008 that could be compared in a constant-effort manner to 2007 are shown in parentheses.

Table 2. Model parameterization of annual survival (ϕ) and recapture (p) probabilities used in the candidate models for breeding species at the two Kings Canyon National Park stations during 2001-2008. Combinations of these parameterizations provide 16 candidate models for each species[1].

Model Parameterization of ϕ	**Definition**
$\phi_{transient}$	ϕ is constant through time
$\phi_{transient*year}$	ϕ varies independently by year
$\phi_{transient*linear\_year}$	ϕ varies linearly as a function of year

Model Parameterization of p	**Definition**
$p_.$	p is constant through time
p_{year}	p varies independently by year
p_{linear_year}	p varies linearly as a function of year

Table 3. Mean numbers of birds aged as adults or young per 600 net-hours and mean reproductive index (ratio of young to adult birds) at two MAPS stations operated in Kings Canyon National Park over 11 years, 1991-1993 and 2001-2008. Data are presented for all species-station combinations for which the station lies within the breeding range of the species.

	Adults			Young			Reproductive Index[1]		
Species	Lion Meadow	Zumwalt Meadow	Both Stations Pooled	Lion Meadow	Zumwalt Meadow	Both Stations Pooled	Lion Meadow	Zumwalt Meadow	Both Stations Pooled
Sharp-shinned Hawk	0.1		0.1	0.0		0.0	0.00		0.00
Spotted Sandpiper		0.1	0.1		0.0	0.0		0.00	0.00
Red-breasted Sapsucker	1.9		1.1	1.0		0.5	0.50		0.50
Downy Woodpecker		1.5	0.7		0.4	0.2		0.19	0.22
Hairy Woodpecker	0.2	0.5	0.3	0.1	0.4	0.3	0.00	0.00	0.20
White-headed Woodpecker	1.5	0.4	0.8	0.0	0.1	0.1	0.00	0.00	0.13
Northern Flicker	0.4	0.2	0.3	0.0	0.2	0.1	0.00	0.00	0.25
Olive-sided Flycatcher		0.2	0.1		0.0	0.0		0.00	0.00
Western Wood-Pewee	0.2	2.6	1.5	0.0	0.1	0.1	0.00	0.04	0.04
Hammond's Flycatcher	2.3	0.2	1.3	0.7	0.0	0.4	0.32	0.00	0.36
Dusky Flycatcher	5.5	0.3	2.8	1.8	0.0	0.9	0.34	0.00	0.36
Pacific-slope Flycatcher	6.7	4.7	6.1	2.8	1.6	2.1	0.59	0.50	0.37
Black Phoebe	0.1	1.5	0.9	0.0	3.1	1.7	0.00	2.61	2.60
Cassin's Vireo	0.2	3.0	1.8	0.1	0.4	0.3	0.00	0.15	0.20
Hutton's Vireo	0.1	0.0	0.1	0.0	0.1	0.1	0.00	und.	0.00
Warbling Vireo	2.4	11.7	6.8	0.2	0.7	0.4	0.16	0.06	0.05
Steller's Jay	0.4	1.0	0.7	0.0	0.4	0.2	0.00	0.50	0.31
Violet-green Swallow		0.1	0.1		0.0	0.0		0.00	0.00
Mountain Chickadee	3.9	1.1	2.5	1.2	0.3	0.7	0.26	0.50	0.26
Bushtit	0.6		0.3	0.2		0.1	0.20		0.20
Red-breasted Nuthatch	1.6	0.6	1.0	0.5	0.2	0.4	0.25	0.00	0.33
White-breasted Nuthatch	0.0		0.0	0.1		0.1	und.		und.
Brown Creeper	4.8	2.2	3.5	4.6	2.2	3.3	1.20	1.24	1.17
Canyon Wren		0.0	0.0		0.1	0.1		und.	und.
House Wren		0.1	0.1		1.9	1.0		0.00	0.00
Winter Wren	1.1		0.6	0.4		0.2	0.17		0.17
American Dipper		0.1	0.1		0.0	0.0		0.00	0.00
Golden-crowned Kinglet	4.5		2.3	0.7		0.4	0.15		0.17
Townsend's Solitaire	0.1	0.0	0.1	0.0	0.2	0.1	0.00	und.	0.00
Swainson's Thrush		2.4	1.1		0.2	0.1		0.07	0.08
Hermit Thrush	0.6	0.5	0.4	0.0	0.1	0.1	0.00	0.33	0.33
American Robin	4.3	9.3	6.9	0.0	1.6	0.8	0.00	0.18	0.13
Nashville Warbler		4.3	2.1		0.7	0.4		0.19	0.22
Yellow Warbler	0.4	4.3	2.2	0.1	0.9	0.6	0.00	0.25	0.33
Yellow-rumped Warbler	13.2	0.1	6.5	0.2	0.0	0.1	0.01	0.00	0.02
Black-throated Gray Warbler	0.0	2.9	1.4	0.1	0.5	0.3	und.	0.19	0.22
Hermit Warbler	3.1	0.3	1.4	0.0	0.0	0.0	0.00	0.00	0.00

Table 3 continued.

Species	Adults			Young			Reproductive Index[1]		
	Lion Meadow	Zumwalt Meadow	Both Stations Pooled	Lion Meadow	Zumwalt Meadow	Both Stations Pooled	Lion Meadow	Zumwalt Meadow	Both Stations Pooled
MacGillivray's Warbler	24.6	18.0	21.6	12.2	8.6	11.0	0.51	0.48	0.53
Wilson's Warbler	2.3	7.2	3.3	1.3	3.0	2.3	0.80	0.67	0.72
Western Tanager	1.8	5.4	3.3	0.2	0.7	0.5	0.29	0.16	0.21
Spotted Towhee	2.5	0.8	1.6	1.0	0.2	0.7	0.30	0.20	0.32
Fox Sparrow	3.8	0.0	1.8	1.4	0.1	0.7	0.35	und.	0.33
Song Sparrow	1.8	10.8	6.5	1.3	7.4	4.7	0.82	0.69	0.75
Lincoln's Sparrow	16.6	1.4	9.2	8.1	0.1	4.2	0.59	0.06	0.61
Dark-eyed Junco	19.8	4.0	12.3	11.3	1.0	6.5	0.54	0.19	0.52
Black-headed Grosbeak	0.6	8.9	4.5	0.4	0.7	0.6	0.00	0.08	0.17
Lazuli Bunting	0.2	1.2	0.7	0.0	0.3	0.2	0.00	0.29	0.17
Red-winged Blackbird		2.8	1.4		0.3	0.1		0.05	0.05
Brewer's Blackbird		0.2	0.1		0.2	0.1		0.00	0.00
Brown-headed Cowbird	0.1	0.8	0.4	0.1	0.1	0.1	0.00	0.14	0.17
Purple Finch	2.4	22.7	12.7	0.1	0.3	0.3	0.06	0.02	0.02
Cassin's Finch		0.8	0.4		0.1	0.1		0.00	0.00
House Finch		0.0	0.0		0.1	0.1		und.	und.
Pine Siskin	0.7		0.4	0.0		0.0	0.00		0.00
Lesser Goldfinch		2.3	1.3		0.2	0.1		0.17	0.17
Lawrence's Goldfinch		1.1	0.6		0.0	0.0		0.00	0.00
American Goldfinch		0.2	0.1		0.0	0.0		0.00	0.00
Evening Grosbeak	0.3		0.1	0.0		0.0	0.00		0.00
ALL SPECIES POOLED	137.4	145.0	140.3	52.3	40.3	48.4	0.39	0.28	0.35
Number of Species	40	45	55	28	40	48			
Total Number of Species	42	50	58	42	50	58	42	50	58

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

Table 4. QAICc (or AICc) weights for the effects of year and location on survival and recapture probabilities for 15 species breeding at the two Sequoia/Kings Canyon National Park MAPS stations. QAICc (or AICc) weights were obtained from eight years (2001-2008) of mark-recapture data. See Methods for an explanation of model-averaging procedures.

	Effects on Φ		Effects on p	
Species	Year effect	Linear year effect	Year effect	Linear year effect
Pacific-slope Flycatcher	0.000	0.140	0.012	0.323
Warbling Vireo	0.000	0.259	0.025	0.475
American Robin	0.000	0.557	0.022	0.432
Yellow Warbler	0.000	0.070	0.000	0.434
Audubon's Warbler	0.000	0.142	0.001	0.247
MacGillivray's Warbler	0.002	0.213	0.184	0.247
Song Sparrow	0.000	0.135	0.004	0.247
Lincoln's Sparrow	0.000	0.207	0.007	0.261
Dark-eyed Junco	0.000	0.197	0.008	0.303
Black-headed Grosbeak	0.000	0.205	0.003	0.242
Purple Finch	0.000	0.181	0.011	0.360

Table 5. Comparison between model-averaged parameter estimates for annual adult apparent survival and recapture probabilities by year and location for 11 species breeding at the two Kings Canyon National Park MAPS stations. Results were obtained from eight years (2001-2008) of mark-recapture data.

Species	c-hat[1]	Surv. Year[2]	Survival Prob.[3]	CV[4]	Recapture Prob.[5]
Pacific-slope Flycatcher	1.502	2001-2002	0.757 (0.211)	27.9	0.540 (0.268)
		2002-2003	0.753 (0.210)	27.9	0.517 (0.244)
		2003-2004	0.747 (0.207)	27.7	0.480 (0.218)
		2004-2005	0.740 (0.202)	27.4	0.465 (0.202)
		2005-2006	0.730 (0.201)	27.6	0.430 (0.193)
		2006-2007	0.718 (0.214)	29.8	0.408 (0.203)
		2007-2008	0.705 (0.248)	35.2	0.385 (0.220)
Warbling Vireo	1.000	2001-2002	0.533 (0.271)	50.8	0.078 (0.061)
		2002-2003	0.514 (0.241)	46.9	0.085 (0.058)
		2003-2004	0.493 (0.201)	40.9	0.100 (0.056)
		2004-2005	0.469 (0.166)	35.4	0.112 (0.057)
		2005-2006	0.445 (0.157)	35.2	0.145 (0.106)
		2006-2007	0.425 (0.176)	41.4	0.179 (0.185)
		2007-2008	0.407 (0.204)	50.2	0.217 (0.253)
American Robin	1.169	2001-2002	0.905 (0.175)	19.4	0.381 (0.199)
		2002-2003	0.874 (0.191)	21.8	0.348 (0.155)
		2003-2004	0.786 (0.232)	29.5	0.337 (0.195)
		2004-2005	0.622 (0.289)	46.5	0.319 (0.264)
		2005-2006	0.469 (0.388)	82.7	0.315 (0.315)
		2006-2007	0.395 (0.443)	112.2	0.315 (0.334)
		2007-2008	0.370 (17.474)	4719.8	0.317 (0.333)
Yellow Warbler	1.975	2001-2002	0.824 (0.282)	34.2	0.351 (0.379)
		2002-2003	0.822 (0.289)	35.2	0.255 (0.266)
		2003-2004	0.817 (0.299)	36.6	0.184 (0.203)
		2004-2005	0.808 (0.298)	36.9	0.145 (0.197)
		2005-2006	0.796 (0.302)	37.9	0.128 (0.201)
		2006-2007	0.786 (0.324)	41.3	0.120 (0.203)
		2007-2008	0.779 (0.333)	42.8	0.117 (0.204)

Table 5 continued.

Species	c-hat[1]	Surv. Year[2]	Survival Prob.[3]	CV[4]	Recapture Prob.[5]
Audubon's Warbler	1.583	2001-2002	0.737 (0.204)	27.7	0.145 (0.130)
		2002-2003	0.734 (0.205)	27.9	0.144 (0.122)
		2003-2004	0.728 (0.207)	28.5	0.143 (0.118)
		2004-2005	0.716 (0.207)	28.9	0.143 (0.116)
		2005-2006	0.696 (0.201)	28.9	0.142 (0.117)
		2006-2007	0.670 (0.216)	32.2	0.141 (0.121)
		2007-2008	0.644 (0.260)	40.4	0.140 (0.127)
MacGillivray's Warbler	1.066	2001-2002	0.592 (0.072)	12.2	0.823 (0.111)
		2002-2003	0.586 (0.062)	10.5	0.729 (0.139)
		2003-2004	0.581 (0.055)	9.5	0.778 (0.093)
		2004-2005	0.575 (0.054)	9.4	0.747 (0.115)
		2005-2006	0.569 (0.057)	10.1	0.805 (0.116)
		2006-2007	0.564 (0.066)	11.6	0.761 (0.099)
		2007-2008	0.557 (0.076)	13.7	0.736 (0.141)
Song Sparrow	1.392	2001-2002	0.390 (0.146)	37.3	0.468 (0.244)
		2002-2003	0.390 (0.135)	34.8	0.463 (0.227)
		2003-2004	0.389 (0.129)	33.2	0.462 (0.218)
		2004-2005	0.389 (0.128)	32.9	0.460 (0.213)
		2005-2006	0.388 (0.131)	33.8	0.459 (0.216)
		2006-2007	0.388 (0.139)	35.8	0.457 (0.225)
		2007-2008	0.387 (0.150)	38.8	0.456 (0.238)
Lincoln's Sparrow	1.179	2001-2002	0.493 (0.107)	21.6	0.769 (0.134)
		2002-2003	0.483 (0.092)	19.0	0.766 (0.124)
		2003-2004	0.473 (0.081)	17.1	0.767 (0.121)
		2004-2005	0.463 (0.077)	16.7	0.769 (0.126)
		2005-2006	0.453 (0.082)	18.1	0.766 (0.143)
		2006-2007	0.443 (0.093)	20.9	0.766 (0.155)
		2007-2008	0.434 (0.106)	24.4	0.762 (0.177)
Dark-eyed Junco	1.351	2001-2002	0.560 (0.135)	24.1	0.513 (0.160)
		2002-2003	0.549 (0.116)	21.2	0.500 (0.141)
		2003-2004	0.538 (0.101)	18.8	0.490 (0.132)
		2004-2005	0.525 (0.095)	18.1	0.475 (0.129)
		2005-2006	0.513 (0.103)	20.1	0.465 (0.143)
		2006-2007	0.501 (0.121)	24.3	0.449 (0.159)
		2007-2008	0.489 (0.144)	29.3	0.440 (0.180)

Table 5 continued.

Species	c-hat[1]	Surv. Year[2]	Survival Prob.[3]	CV[4]	Recapture Prob.[5]
Black-headed Grosbeak	2.383	2001-2002	0.451 (0.370)	82.2	0.194 (0.296)
		2002-2003	0.404 (0.399)	98.8	0.189 (0.283)
		2003-2004	0.321 (0.323)	100.4	0.189 (1.683)
		2004-2005	0.275 (0.273)	99.3	0.187 (0.299)
		2005-2006	0.263 (0.267)	101.2	0.184 (0.323)
		2006-2007	0.261 (0.267)	102.1	0.186 (0.369)
		2007-2008	0.261 (0.267)	102.4	0.186 (0.408)
Purple Finch	1.222	2001-2002	0.616 (0.190)	30.8	0.233 (0.148)
		2002-2003	0.611 (0.171)	27.9	0.257 (0.140)
		2003-2004	0.606 (0.155)	25.6	0.279 (0.134)
		2004-2005	0.600 (0.147)	24.4	0.312 (0.162)
		2005-2006	0.595 (0.148)	24.8	0.348 (0.220)
		2006-2007	0.589 (0.159)	26.9	0.383 (0.282)
		2007-2008	0.584 (0.178)	30.6	0.410 (0.333)

1 Variance inflation factor (calculated from the global model) as a measure of over-dispersion of the data. C-hat equal to 1 indicates the model fits the data exactly.
2 Years of the survival probability.
3 Survival probability presented as the model averaged maximum likelihood estimate (standard error of the estimate).
4 The coefficient of variation for the model averaged survival probability.
5 Recapture probability is presented as the model averaged maximum likelihood estimate (standard error of the estimate).

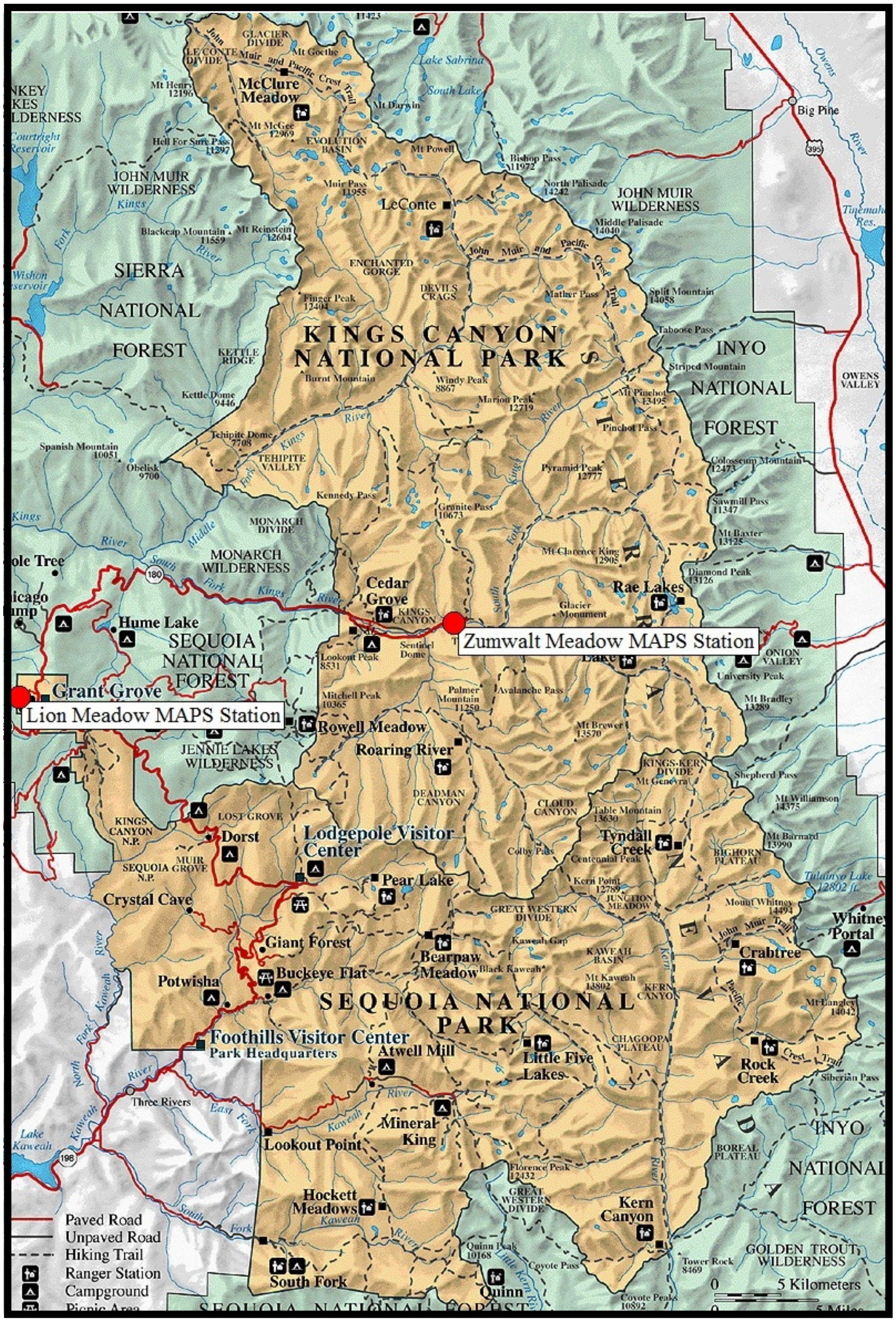


Figure 1. Location (red circles) of Zumwalt Meadow and Lion Meadow MAPS Stations at Kings Canyon National Park.

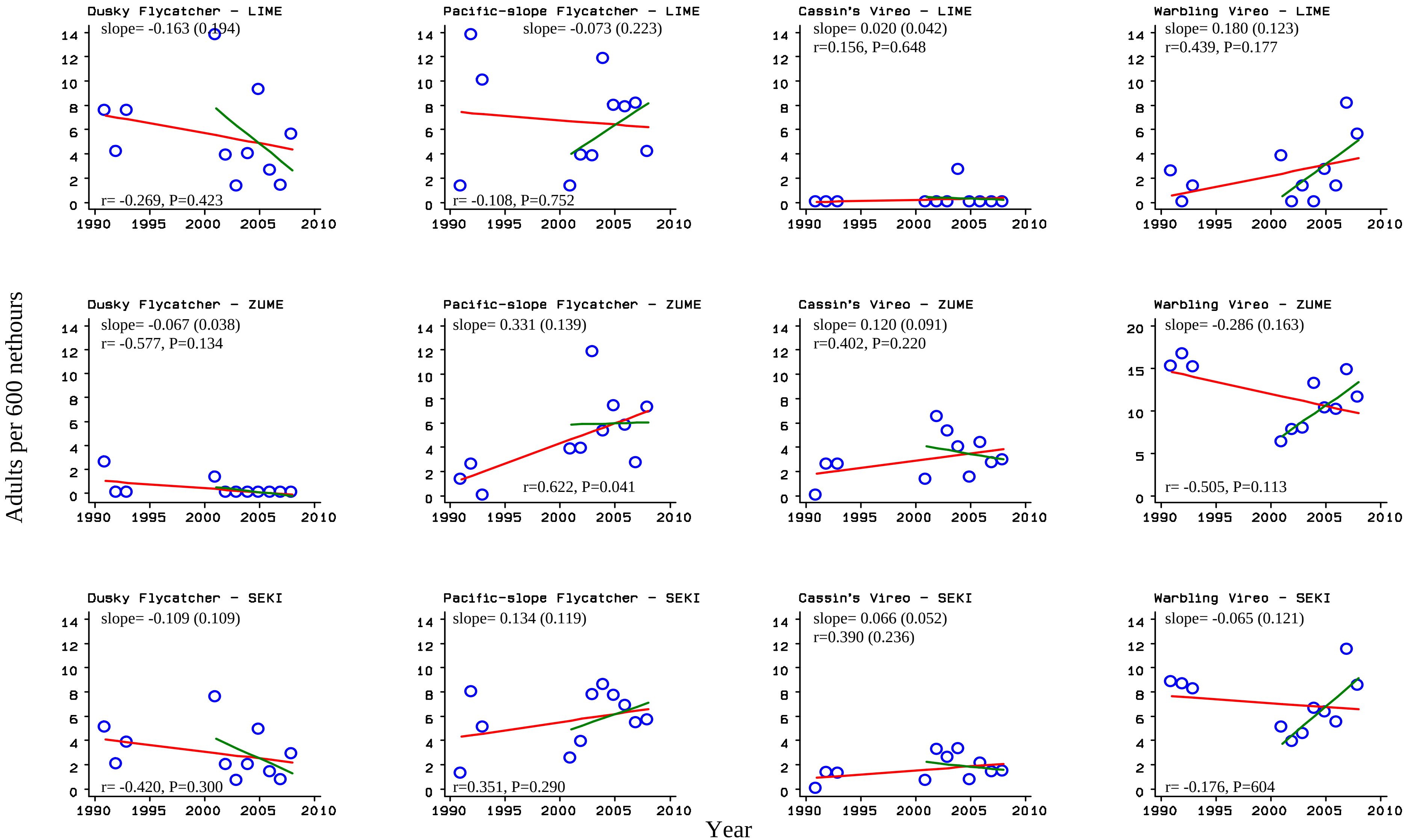


Figure 2. Population trends for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. Number of adult individuals captured per 600 nethours was used as the measure of population size. The slope of the linear regression line was used as the measure of the population trend. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.

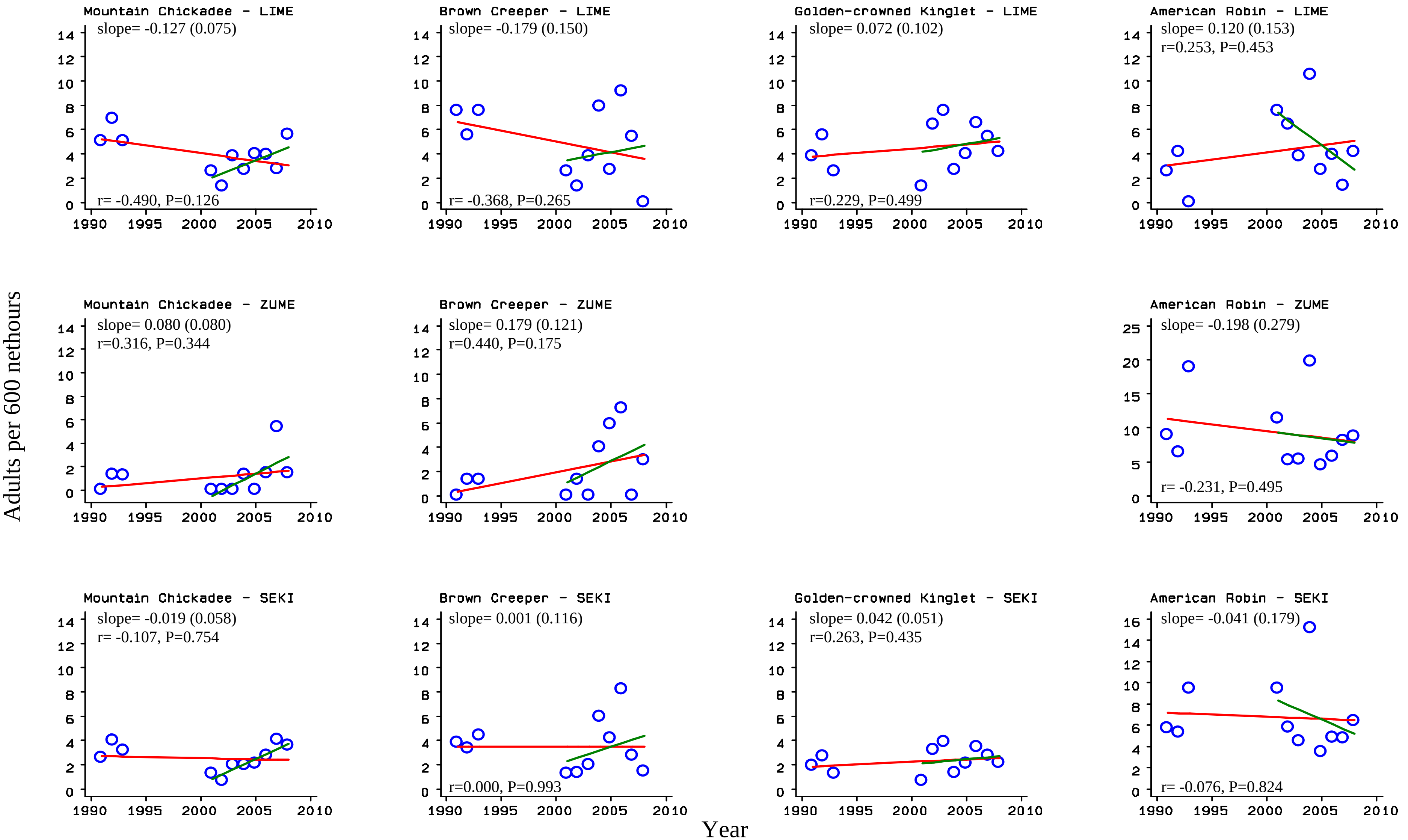
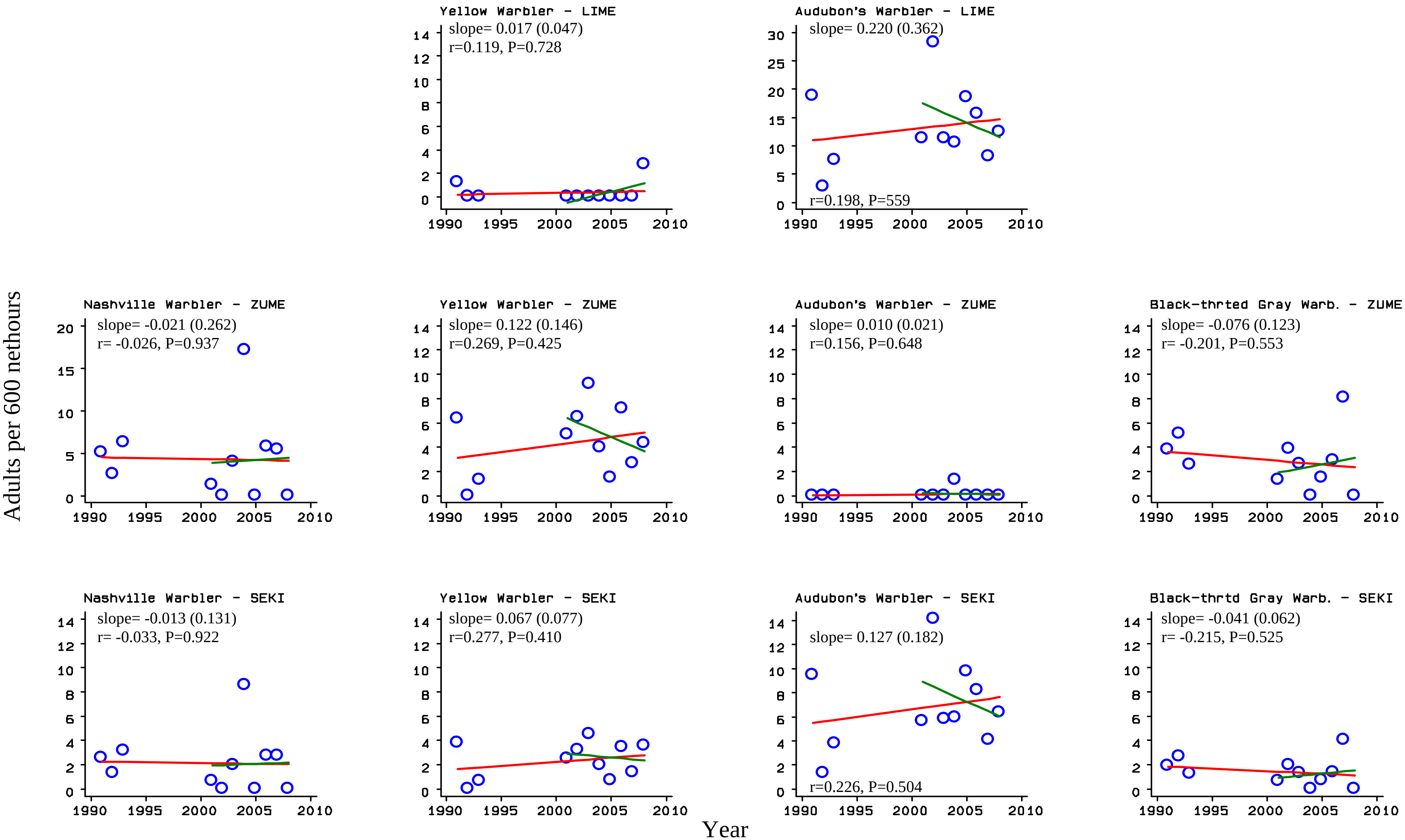


Figure 2. (cont.) Population trends for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. Number of adult individuals captured per 600 nethours was used as the measure of population size. The slope of the linear regression line was used as the measure of the population trend. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.



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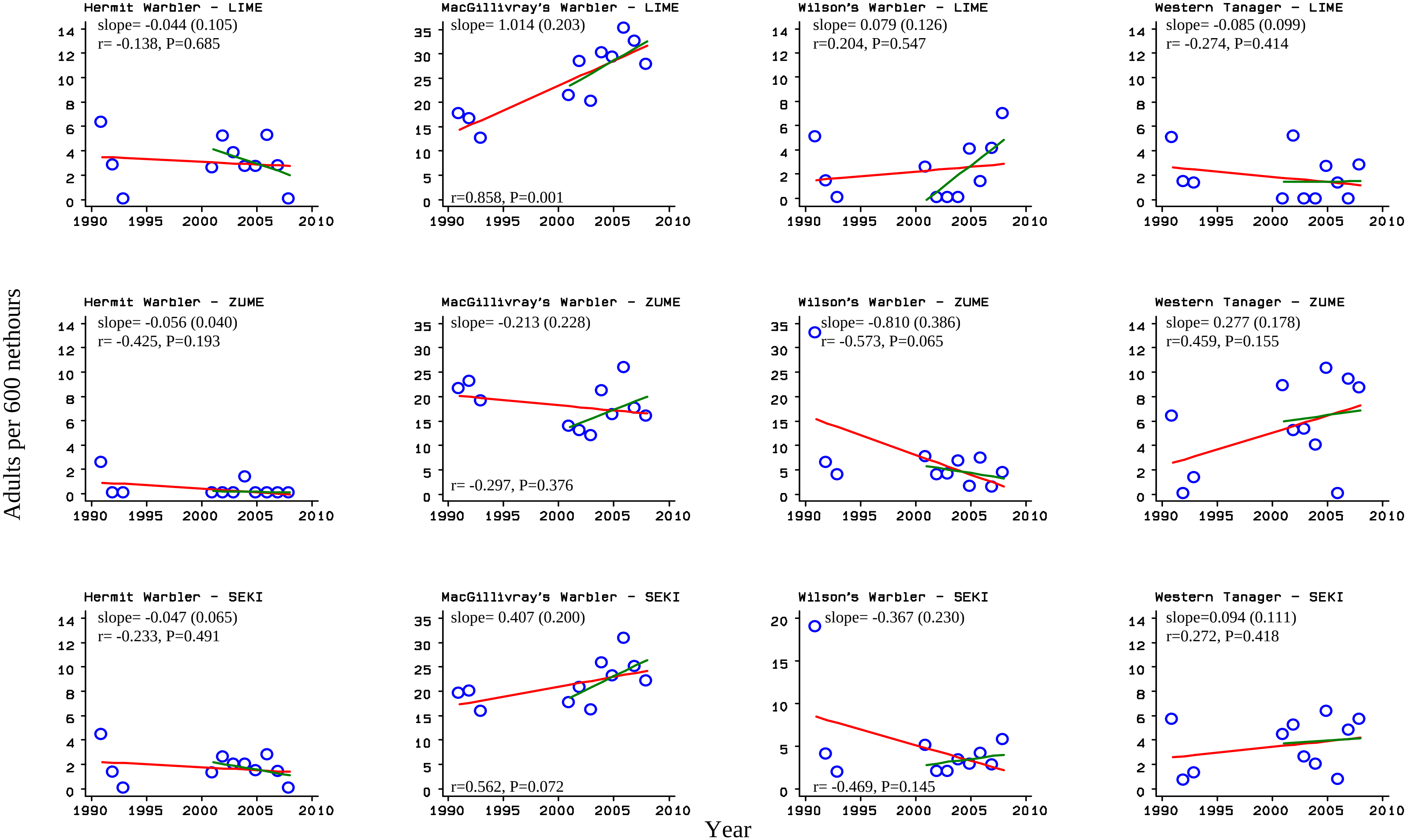


Figure 2. (cont.) Population trends for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. Number of adult individuals captured per 600 nethours was used as the measure of population size. The slope of the linear regression line was used as the measure of the population trend. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.

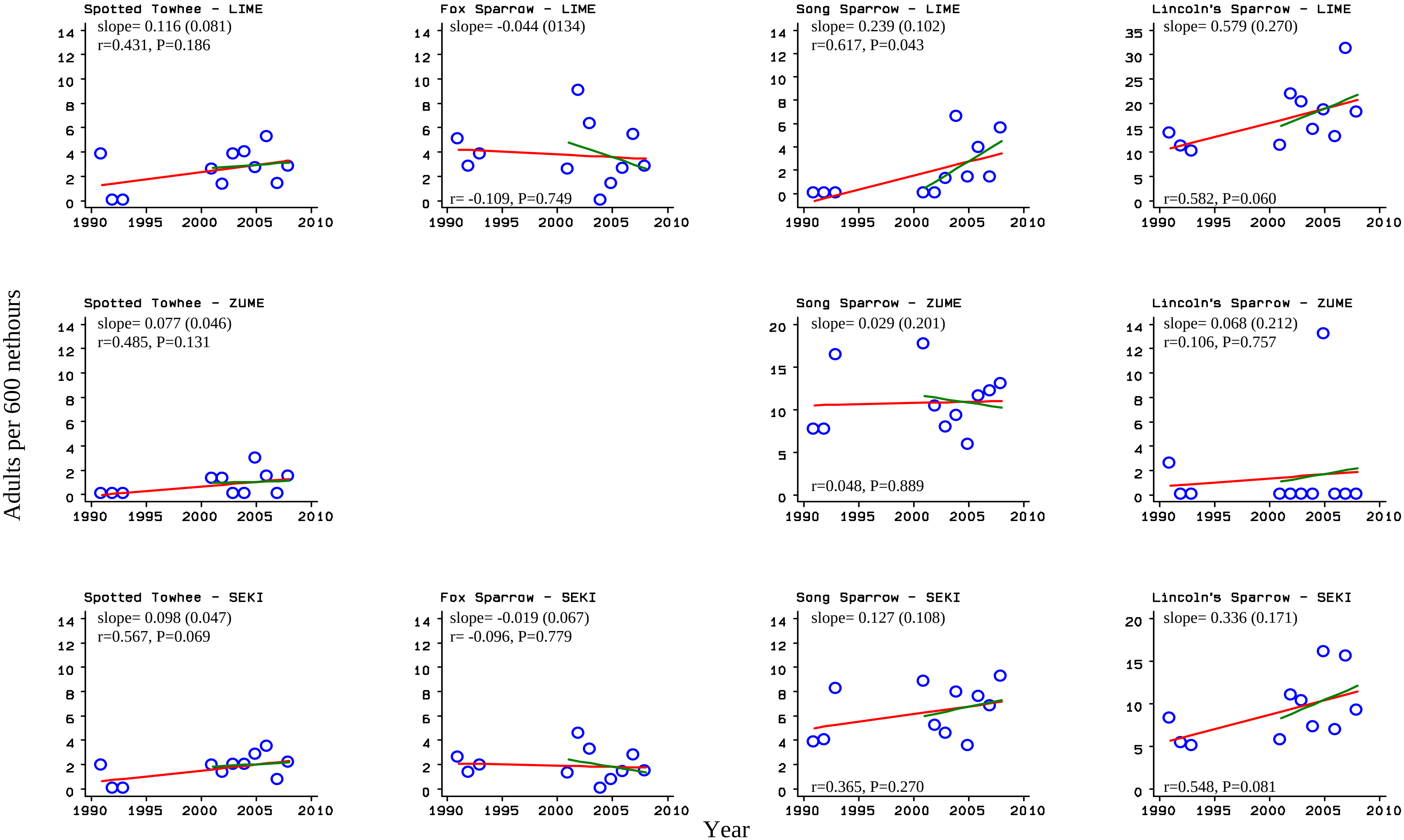
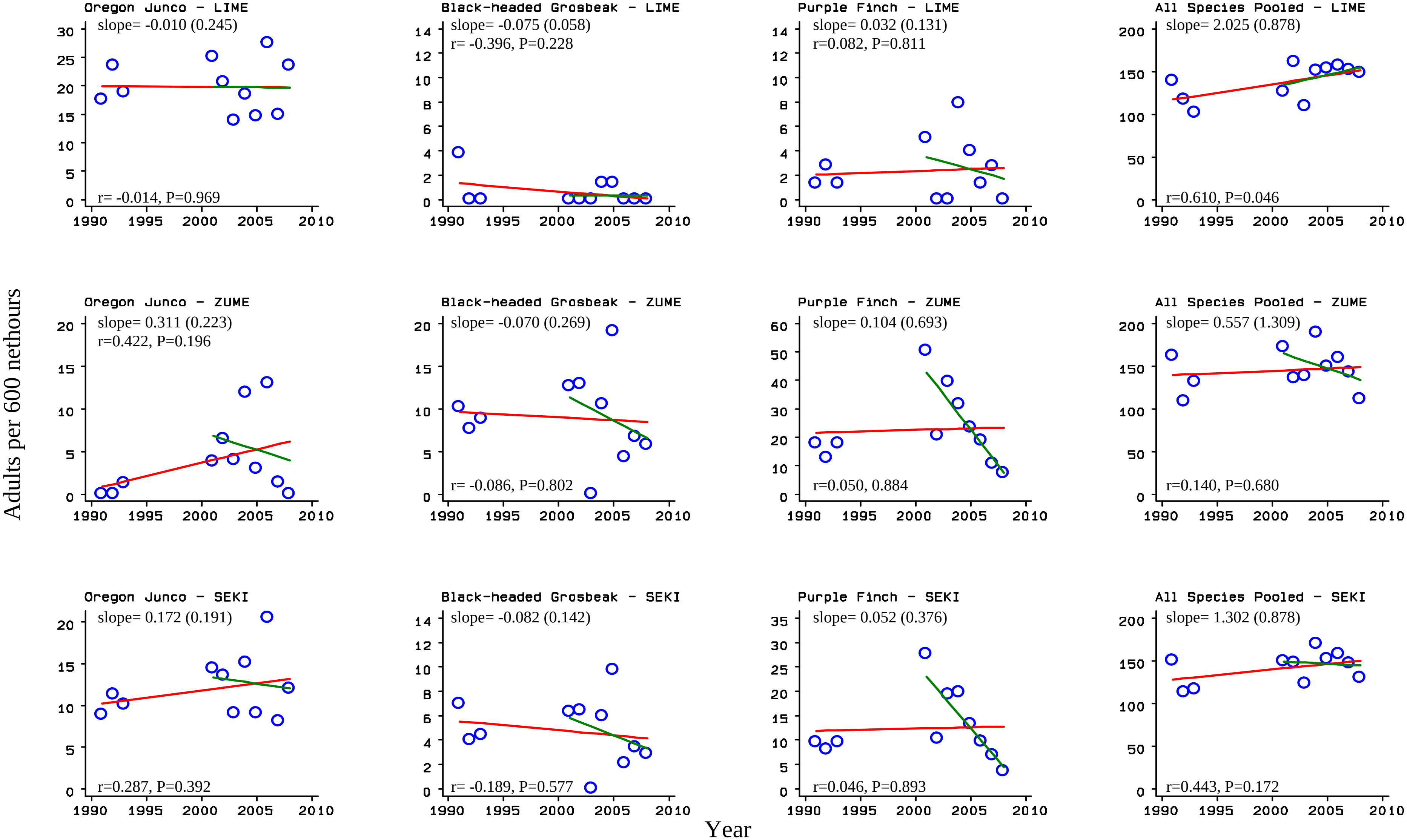


Figure 2. (cont.) Population trends for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. Number of adult individuals captured per 600 nethours was used as the measure of population size. The slope of the linear regression line was used as the measure of the population trend. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.



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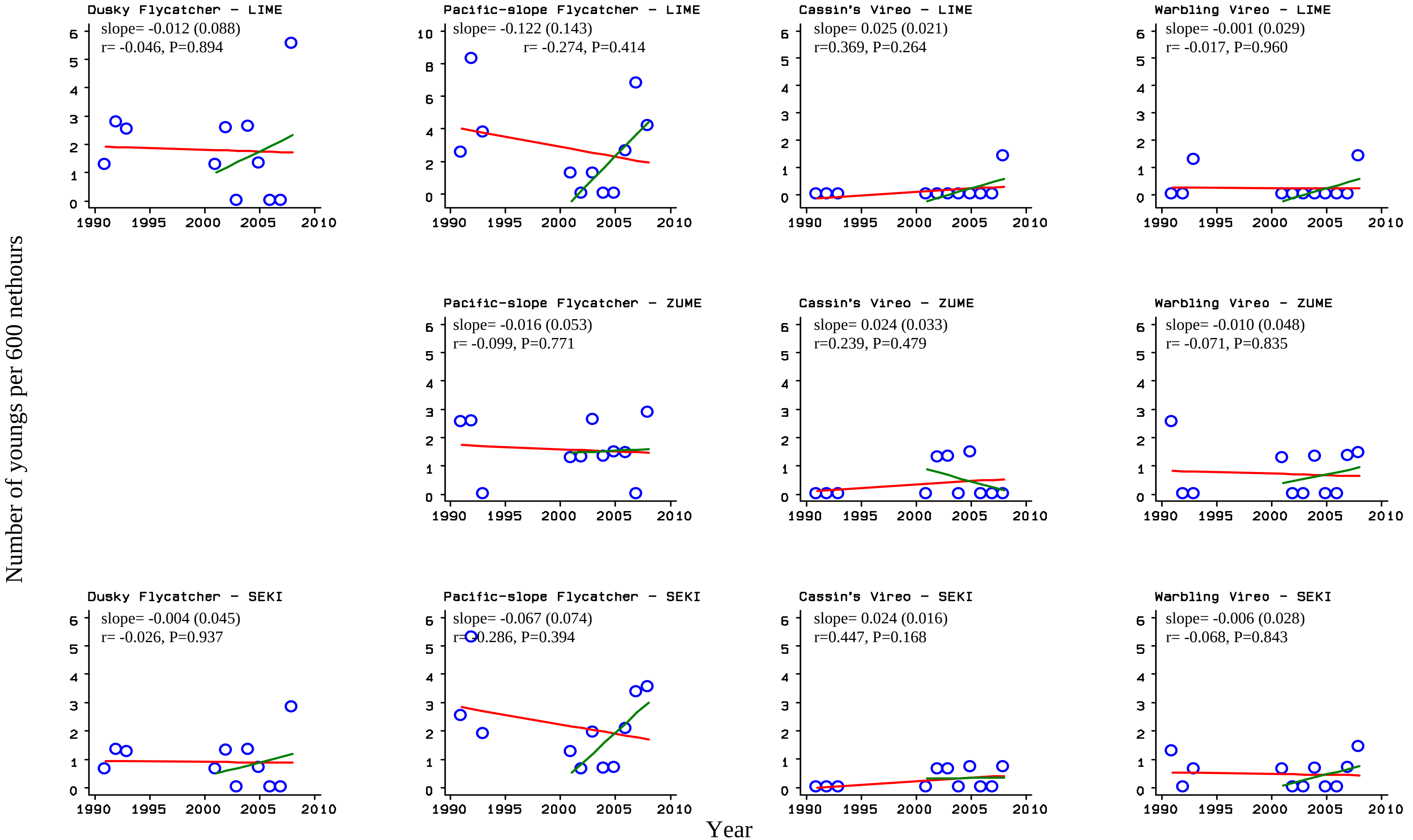


Figure 3. Trend in the number of young birds per 600 nethours for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. The slope of the linear regression line was used as the measure of the trend in numbers of young. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.

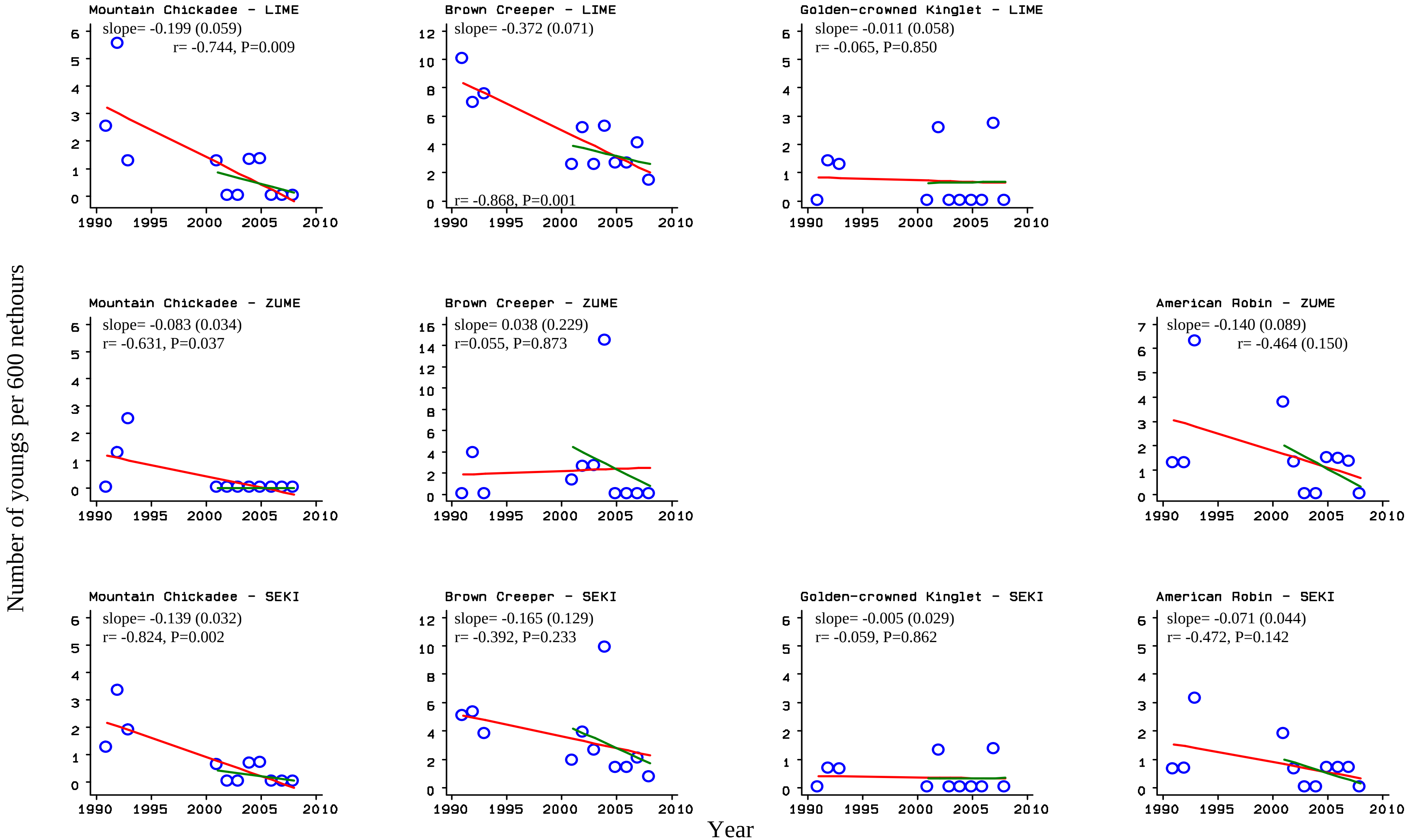
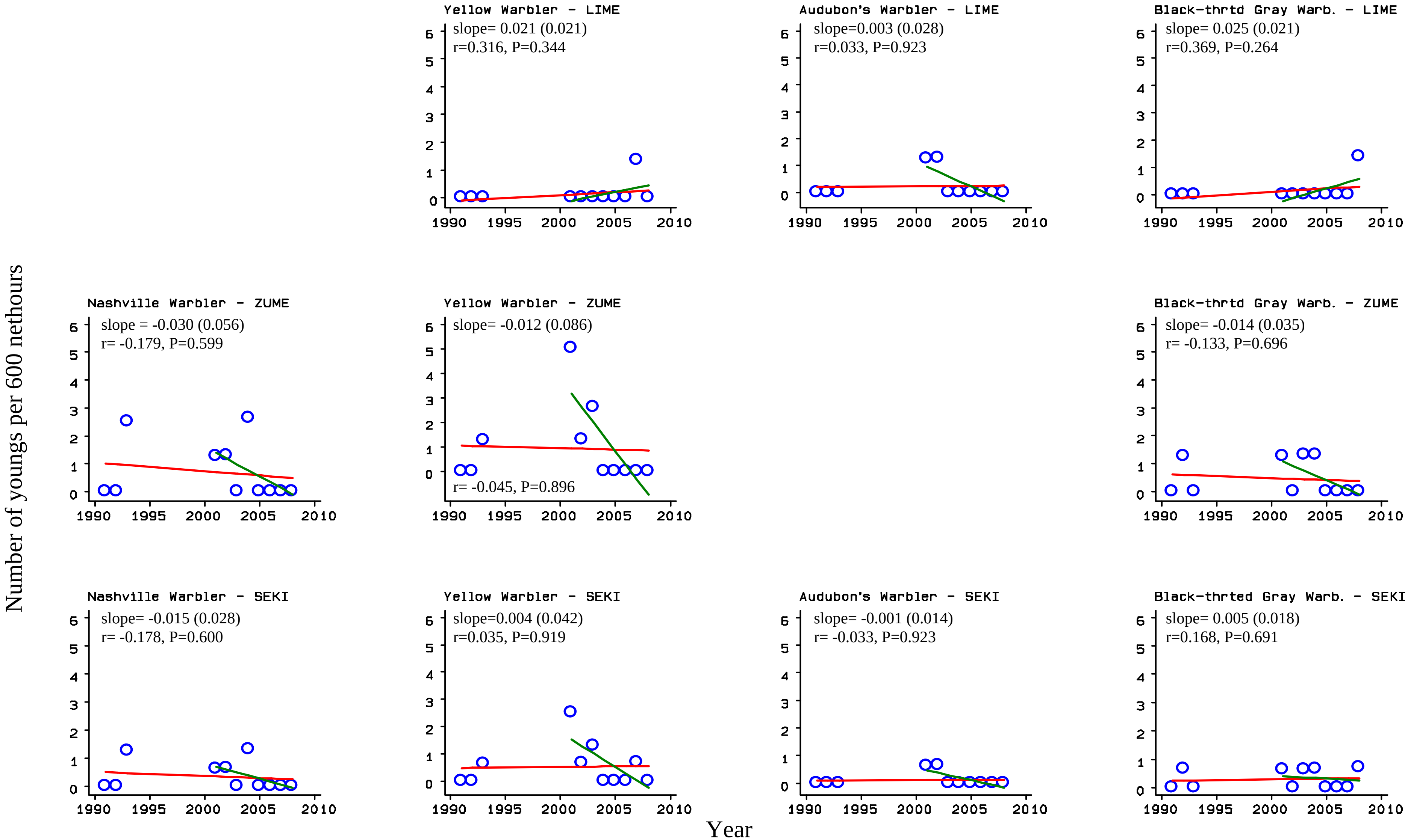


Figure 3. (cont.) Trend in the number of young birds per 600 nethours for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. The slope of the linear regression line was used as the measure of the trend in numbers of young. Both the slopes for the long term trend, 1991-2008 (red line), and short term trend, 2001-2008 (green line), are displayed on the graph. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.



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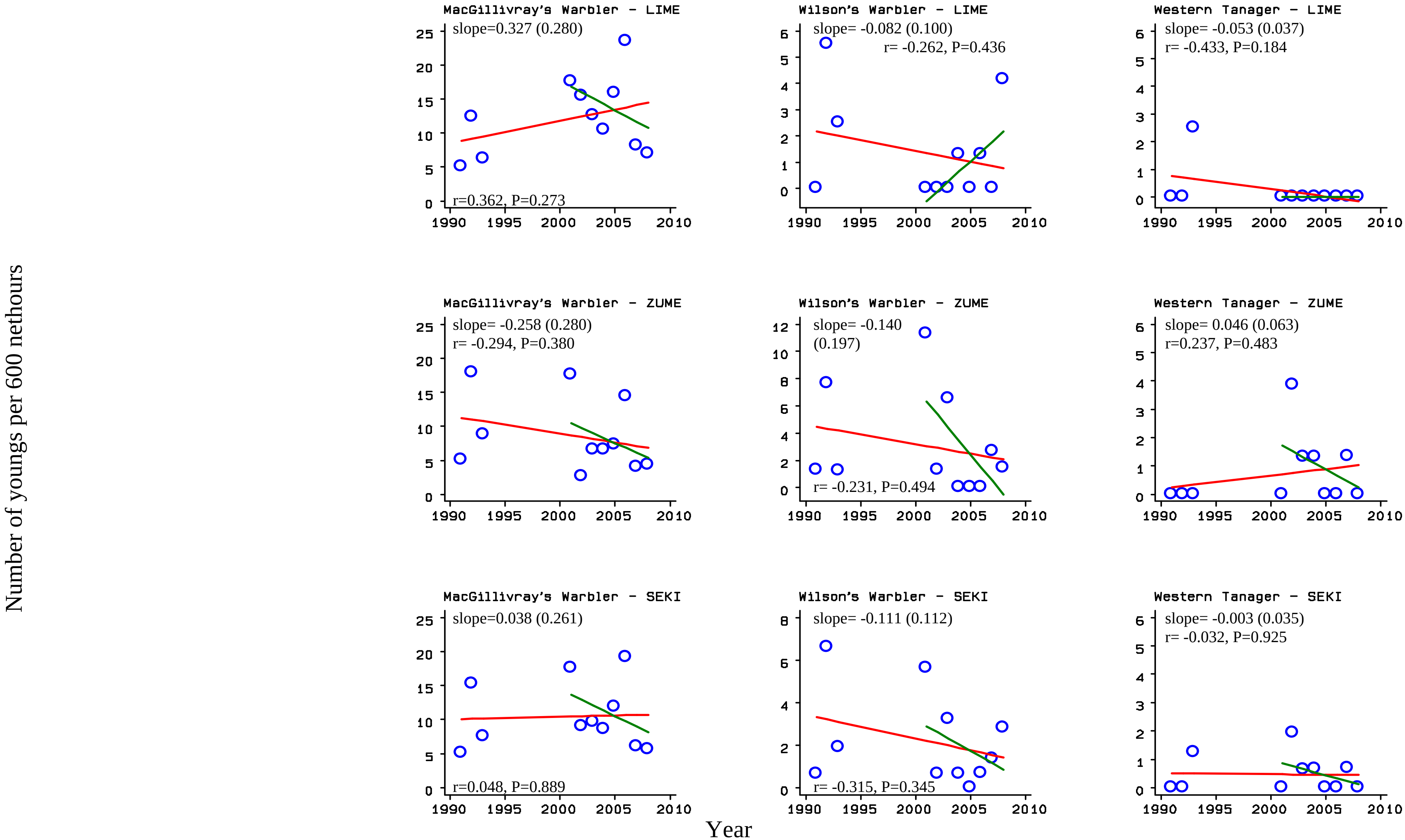

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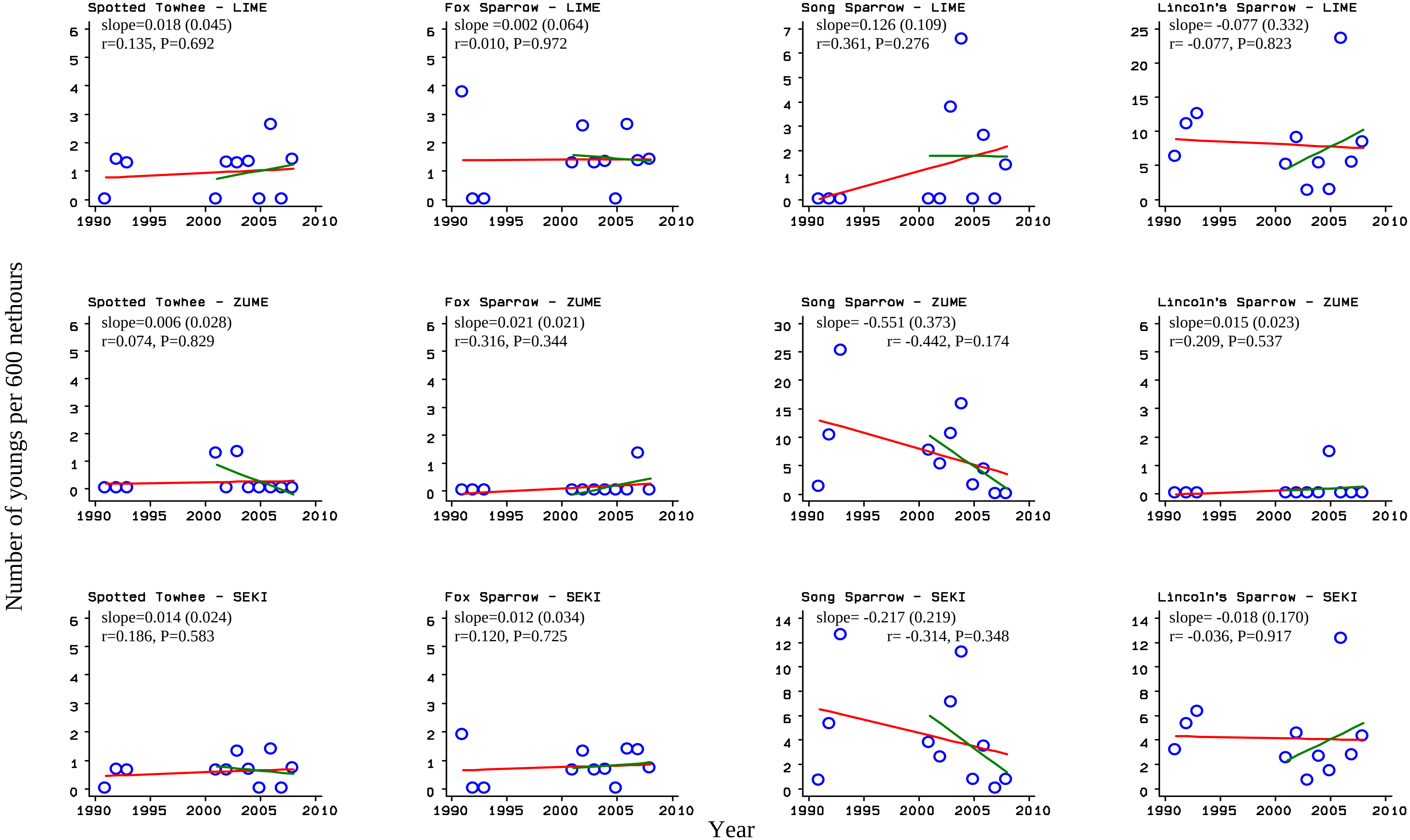

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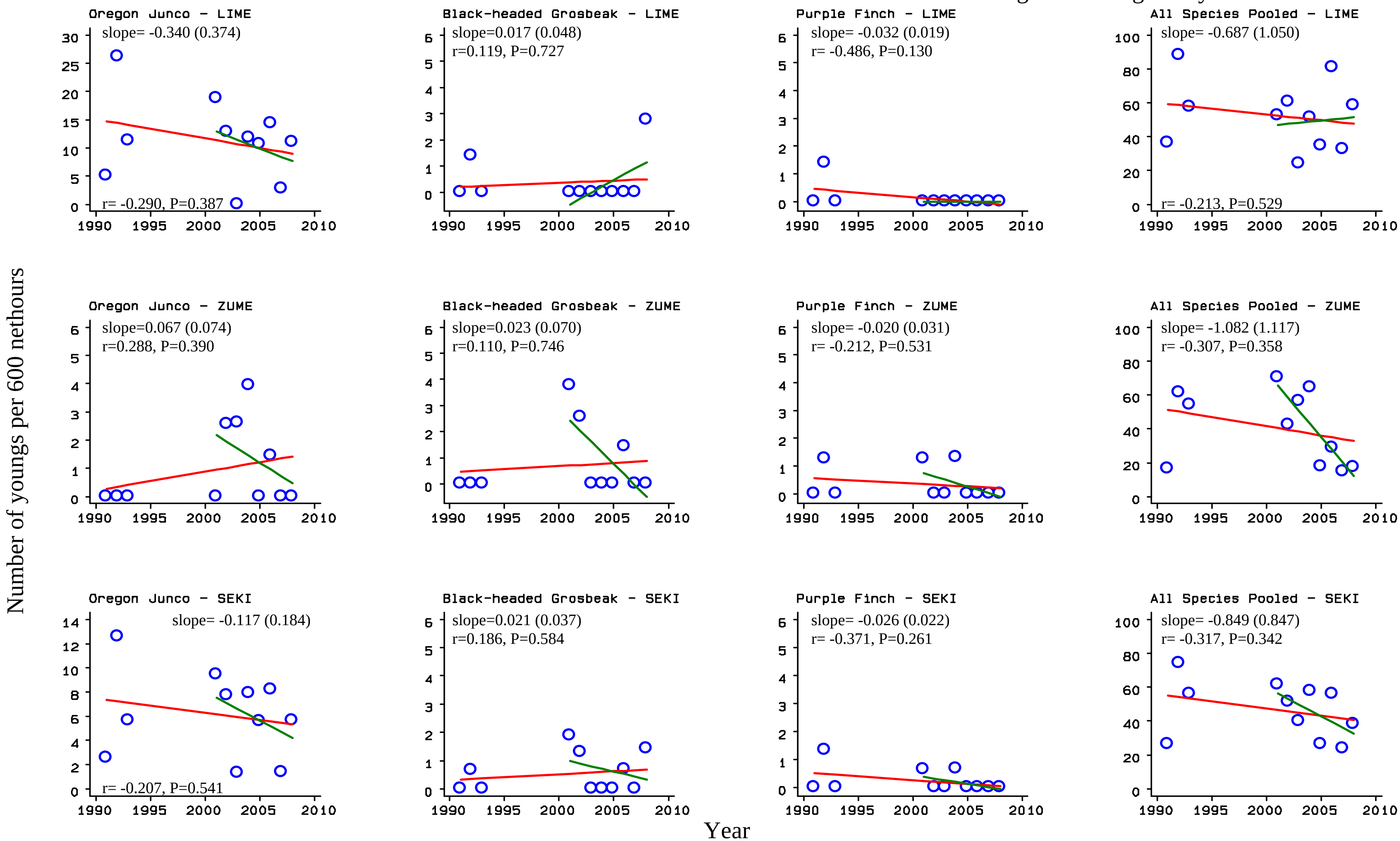

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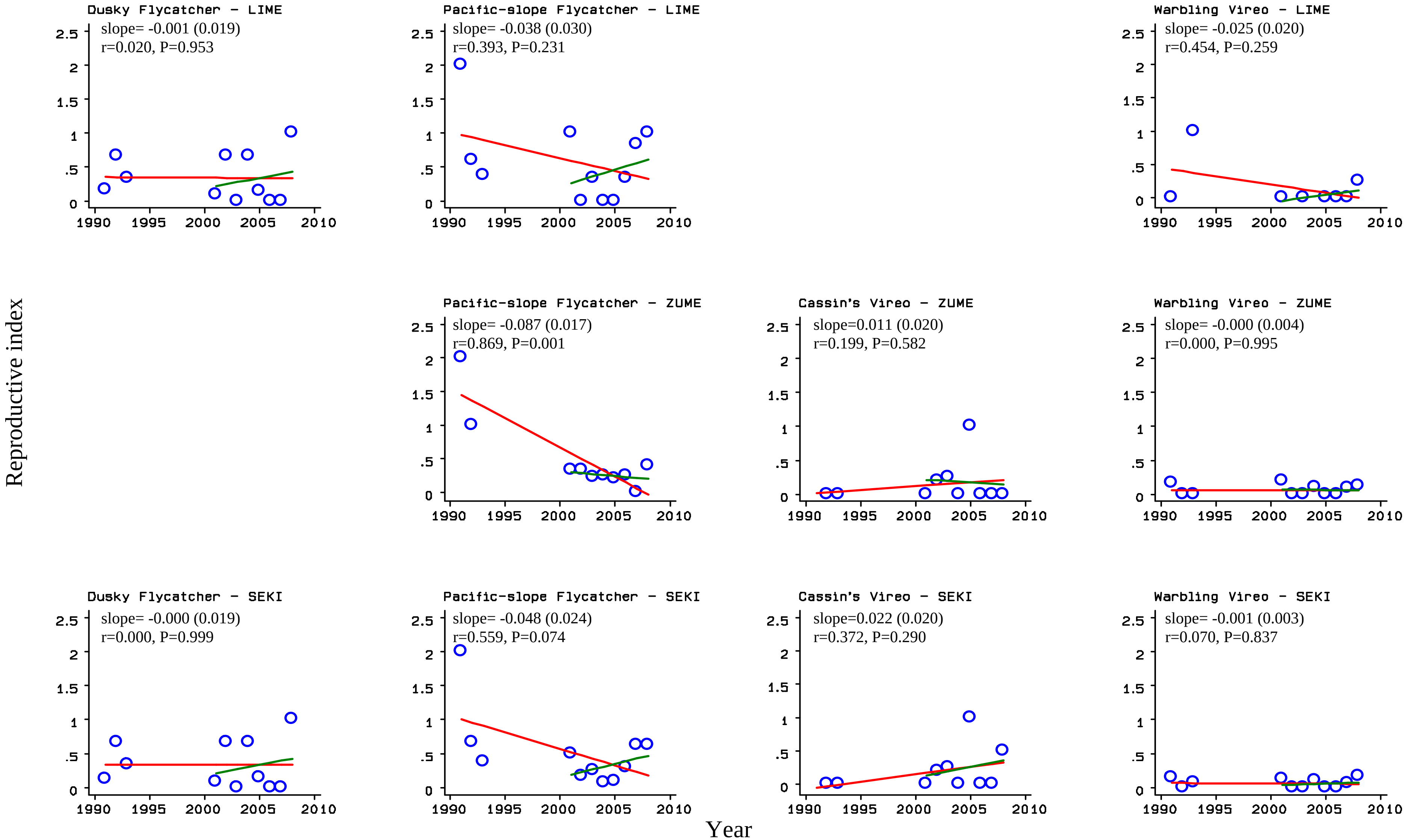
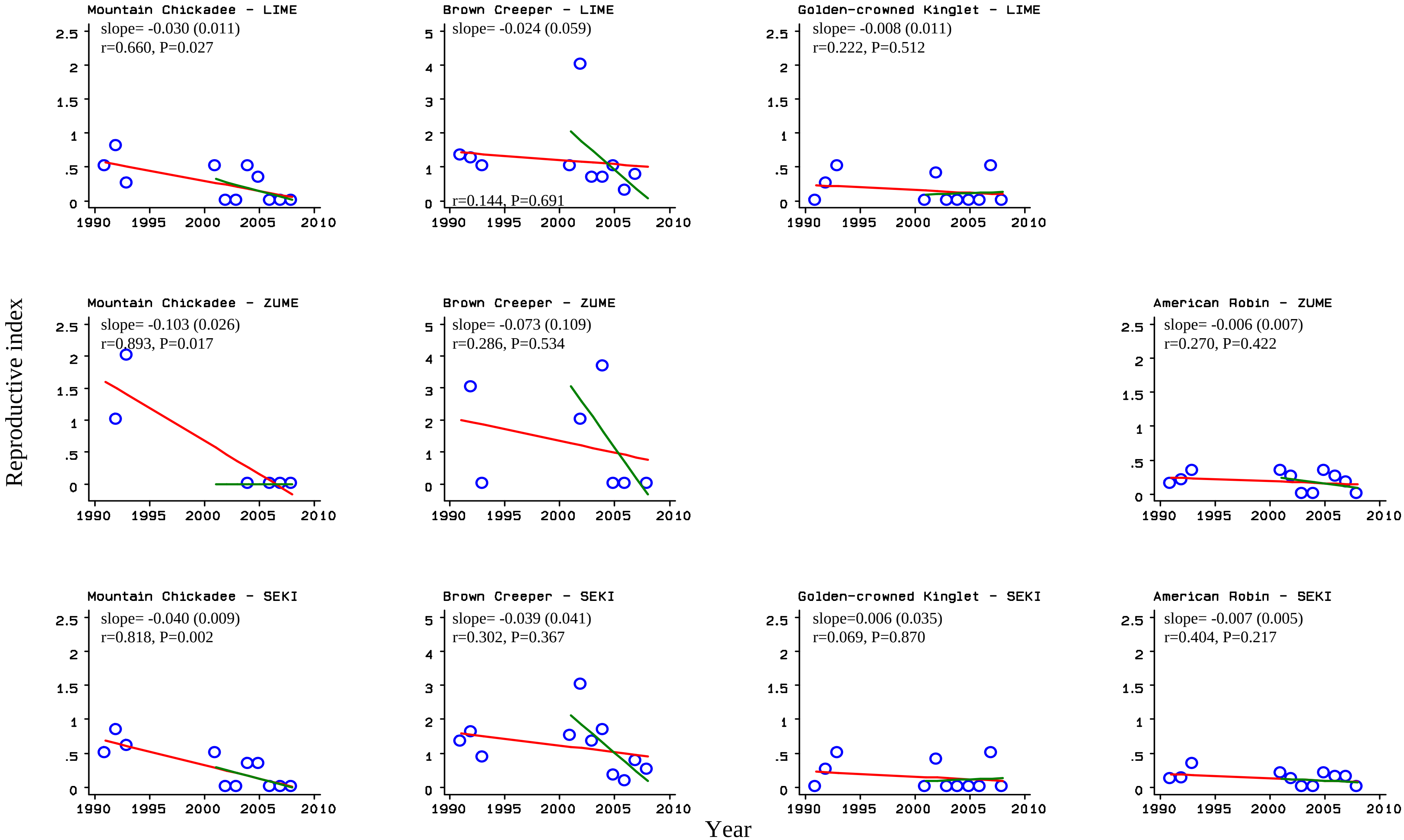


Figure 4. Trend in productivity for 23 species and all species pooled at each of the MAPS stations in Sequoia and Kings Canyon National Parks, and both stations combined, over the years 1991-1993 and 2001-2008. The productivity index was defined as the number of young per adult in each year and the slope of the regression line was used as the measure of the productivity trend. The slope, the standard error of the slope (in parentheses), the correlation coefficient (*r*) and significance of the correlation coefficient (*P*) for only the long term trend are shown on each graph. LIME = Lion Meadow; ZUME = Zumwalt Meadow; SEKI = Both Sequoia/Kings Canyon stations combined.



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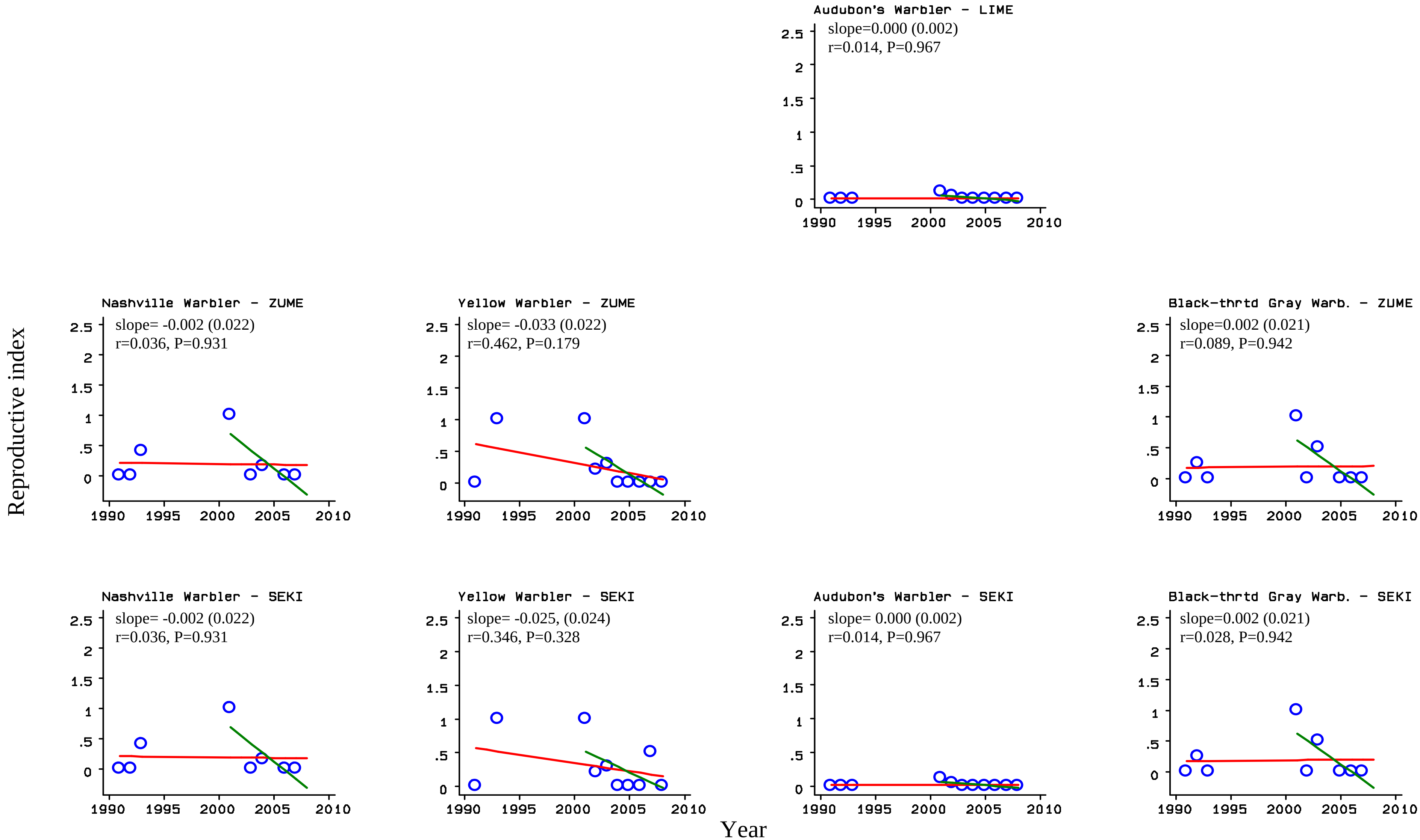

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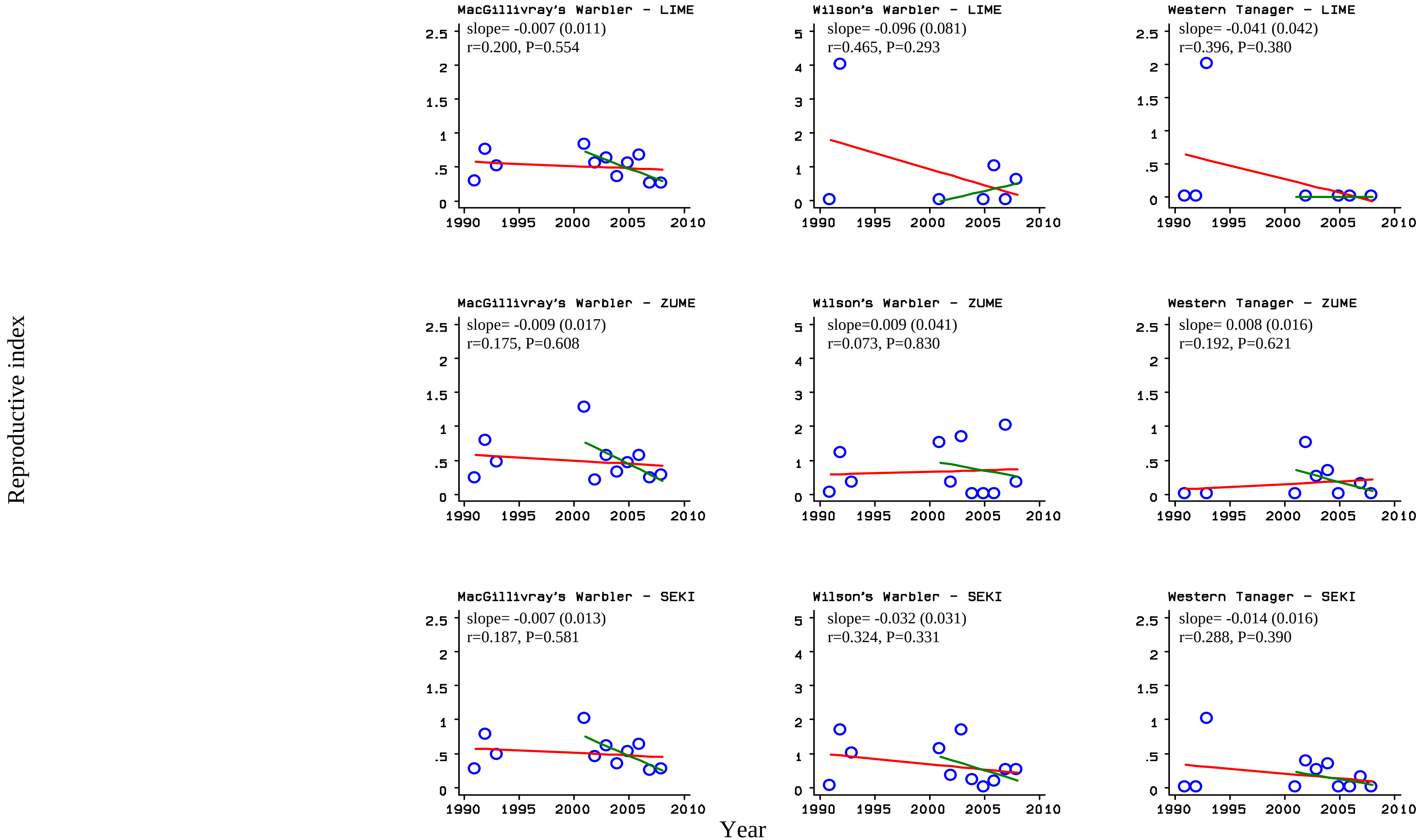

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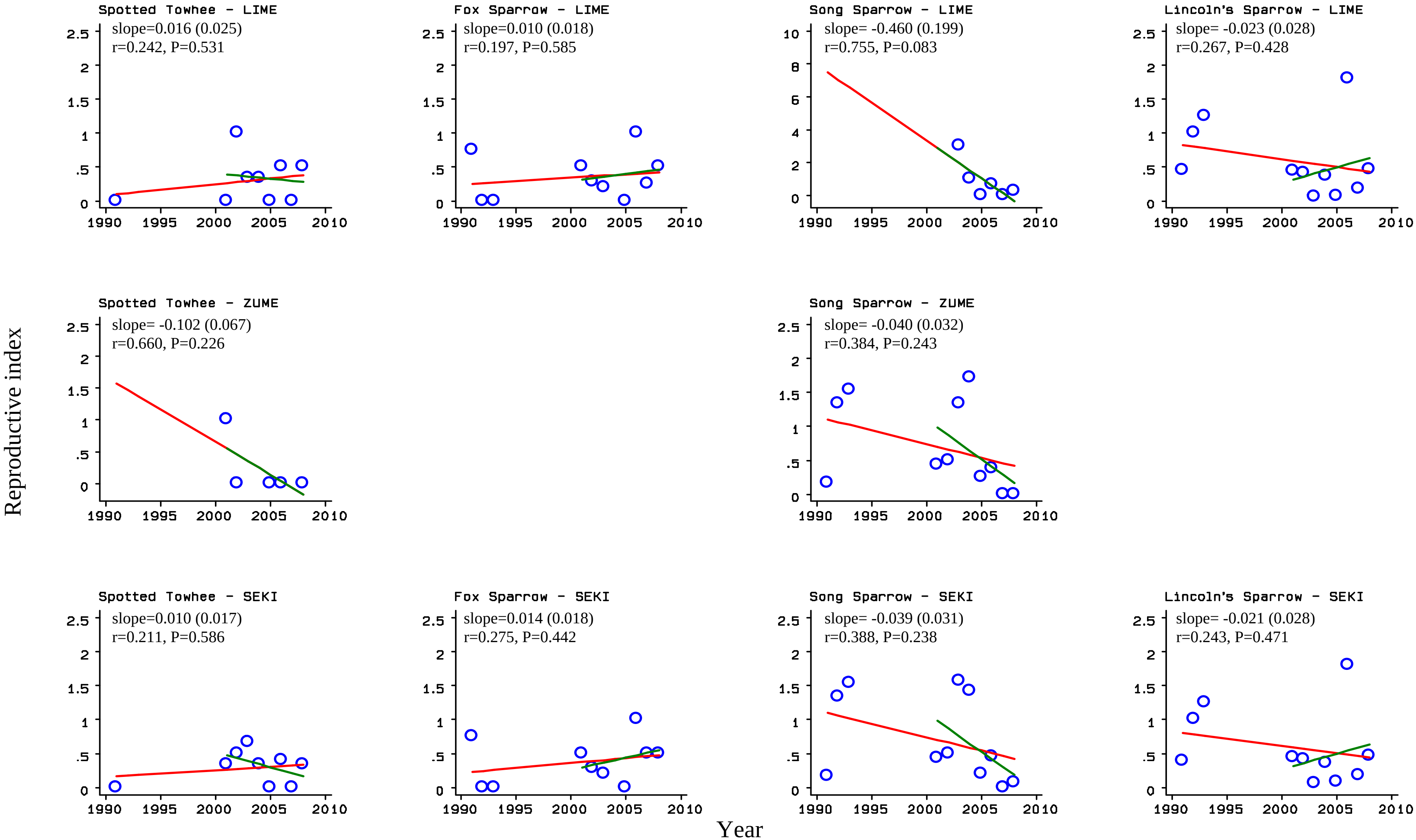

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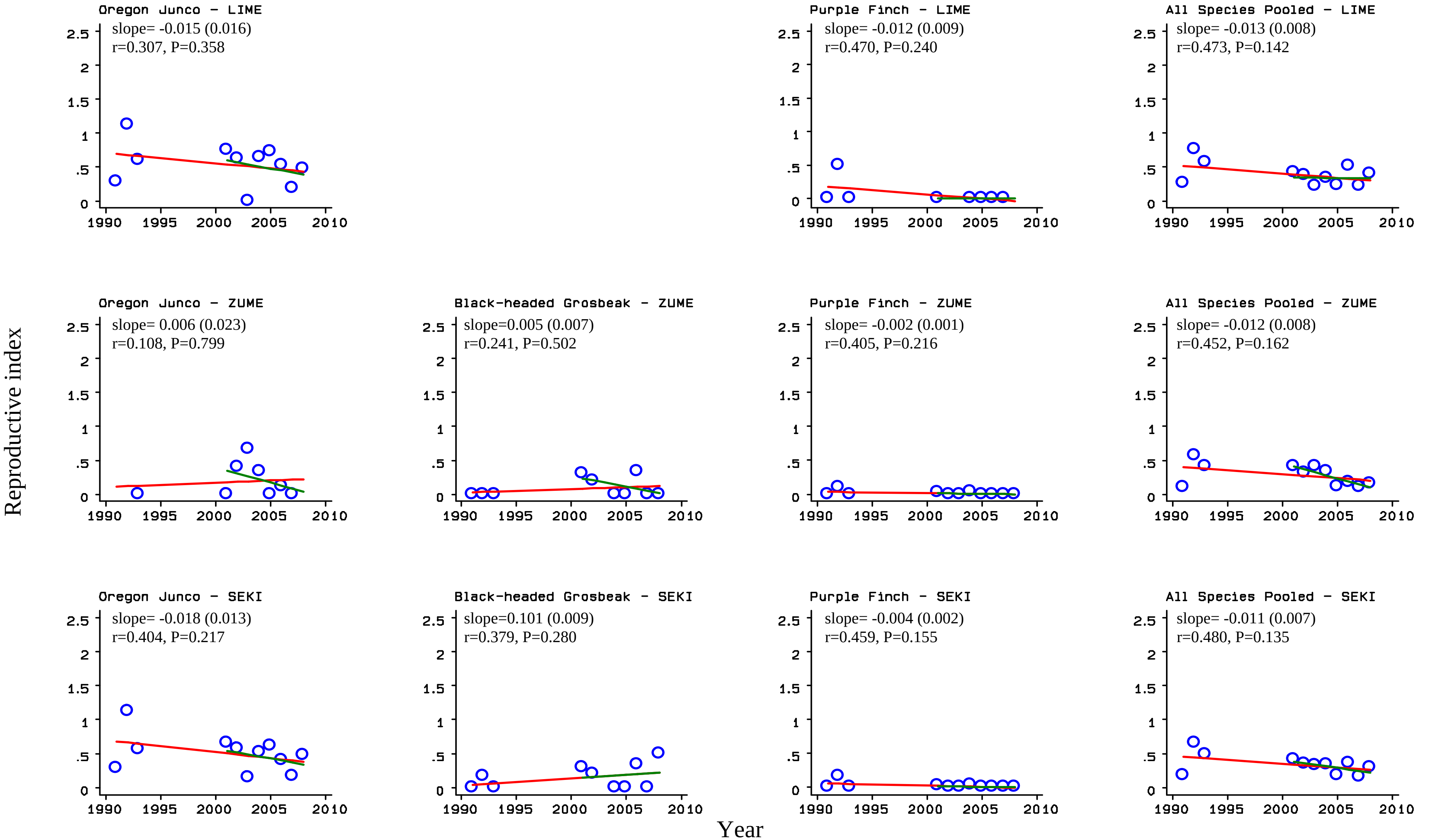

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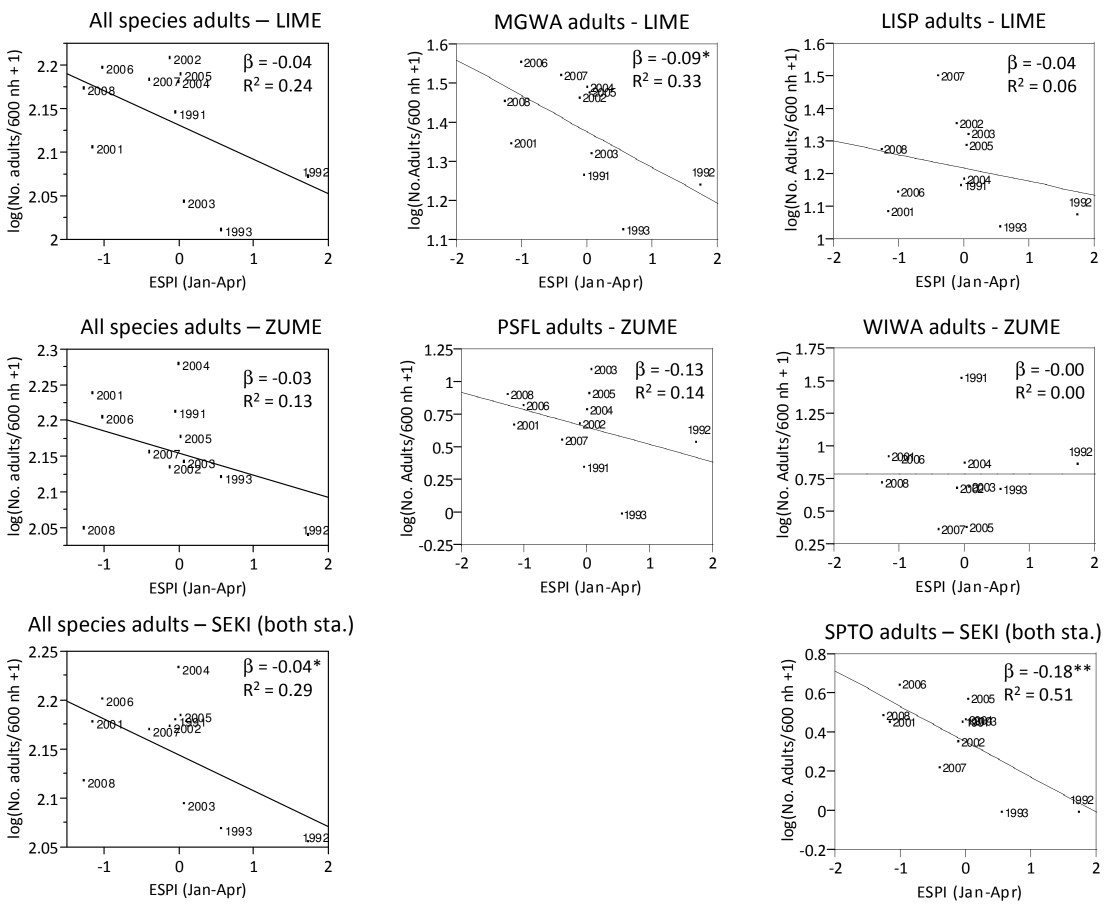

Figure 5. Relationships between the El Niño Southern Precipitation Index (ESPI) during January through April and the (log +1-transformed) number of unique adult captures per 600 net-hours for all species pooled (left panels) and for species-station combinations for which we found significant ($P < 0.05$) or nearly significant ($P < 0.10$) trends in adult captures (see Fig. 2). Points are labeled with years to facilitate comparison with trend data. Regression slopes (β), significance levels (* = $P < 0.10$; ** = $P < 0.05$; *** = $P < 0.01$), and % variation explained (R^2) are indicated on each panel.

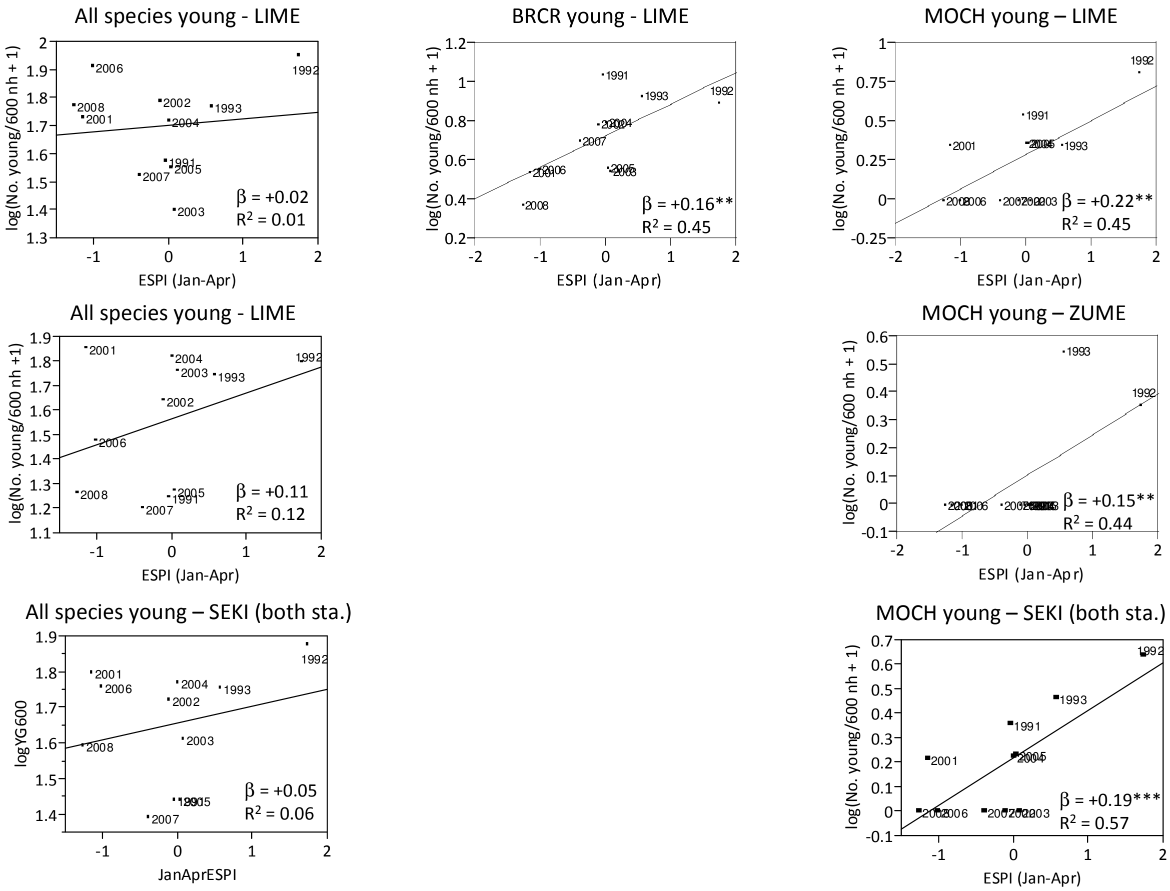

Figure 6. Relationships between the El Niño Southern Precipitation Index (ESPI) during January through April and the (log +1-transformed) number of unique young captures per 600 net-hours for all species pooled (left panels) and for species-station combinations for which we found significant ($P < 0.05$) or nearly significant ($P < 0.10$) trends in young captures (see Fig. 3). Points are labeled with years to facilitate comparison with trend data. Regression slopes (β), significance levels (* = $P < 0.10$; ** = $P < 0.05$; *** = $P < 0.01$), and % variation explained (R^2) are indicated on each panel.

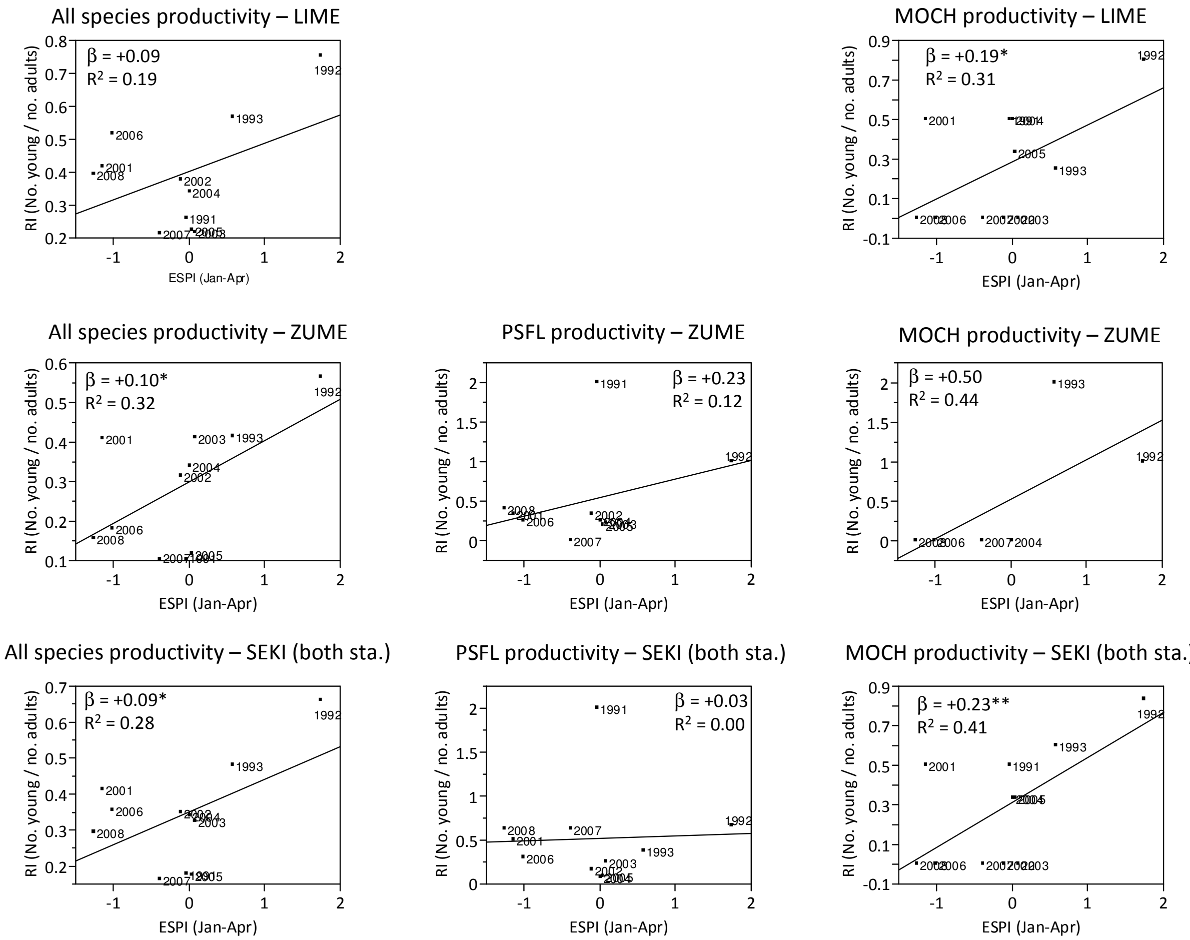

Figure 7. Relationships between the El Niño Southern Precipitation Index (ESPI) during January through April and the number of unique adult captures per 600 net-hours for all specie pooled (left panels) and for species-station combinations for which we found significant ($P < 0.05$) or nearly significant ($P < 0.10$) trends in adult captures (see Fig. 4). Points are labeled with years to facilitate comparison with trend data. Regression slopes (β), significance levels (* = $P < 0.10$; ** = $P < 0.05$; *** = $P < 0.01$), and % variation explained (R^2) are indicated on each panel.

Appendix I. Listing (in AOU checklist order) of species sequence numbers, alpha codes, and names for all species banded or encountered during the eleven years, 1991-1993 plus 2001-2008, of the MAPS Program at the two stations operated in Sequoia and Kings Canyon National Parks.

Cumulative breeding status for all years in which each station was operated are also included (B = Regular Breeder (all years); U = Usual Breeder (>½, not all, years); O = Occasional Breeder (<½ years); T = Transient; M = Migrant; A= Altitudinal Disperser; ? = Uncertain Species ID

NUMB	SPEC	SPECIES NAME	Lion Meadow (LIME)	Zumwalt Meadow (ZUME)
01300	TUVU	Turkey Vulture	T	T
01630	MALL	Mallard	O	O
02200	SSHA	Sharp-shinned Hawk	T	T
02210	COHA	Cooper's Hawk		O
02240	NOGO	Northern Goshawk	O	
02460	RTHA	Red-tailed Hawk	T	T
02630	AMKE	American Kestrel		T
02700	PEFA	Peregrine Falcon		T
03100	MOUQ	Mountain Quail	O	
04020	SPSA	Spotted Sandpiper		T
05440	BTPI	Band-tailed Pigeon	T	O
05570	MODO	Mourning Dove		O
06670	WESO	Western Screech-Owl		T
06800	GHOW	Great Horned Owl	T	
06830	NOPO	Northern Pygmy-Owl	T	
06940	SPOW	Spotted Owl	T	
07530	WTSW	White-throated Swift	T	O
08670	ANHU	Anna's Hummingbird	O	B
08690	CAHU	Calliope Hummingbird	T	O
08730	RUHU	Rufous Hummingbird	T	T
08740	ALHU	Allen's Hummingbird	M	M
09110	BEKI	Belted Kingfisher		O
09430	ACWO	Acorn Woodpecker	T	U
09600	RBSA	Red-breasted Sapsucker	U	O
09650	DOWO	Downy Woodpecker	T	U
09660	HAWO	Hairy Woodpecker	U	U
09690	WHWO	White-headed Woodpecker	U	U
09800	RSFL	Red-shafted Flicker	U	U

Appendix I. Continued

NUMB	SPEC	SPECIES NAME	LIME	ZUME
09860	PIWO	Pileated Woodpecker	O	
11340	OSFL	Olive-sided Flycatcher	O	O
11380	WEWP	Western Wood-Pewee	U	B
11475	TRFL	Traill's Flycatcher	M	
11475	WIFL	Willow Flycatcher	M	
11510	HAFL	Hammond's Flycatcher	B	O
11520	GRFL	Gray Flycatcher	M	M
11530	DUFL	Dusky Flycatcher	U	O
11555	PSFL	Pacific-slope Flycatcher	B	U
11555	WEFL	Western Flycatcher	B	U
11600	BLPH	Black Phoebe	T	U
12710	CAVI	Cassin's Vireo	O	B
12740	HUVI	Hutton's Vireo	T	O
12760	WAVI	Warbling Vireo	U	B
12920	STJA	Steller's Jay	B	B
13110	WESJ	Western Scrub-Jay	O	
13150	CLNU	Clark's Nutcracker		T
13300	CORA	Common Raven	B	O
13440	VGSW	Violet-green Swallow		O
13490	NRWS	Northern Rough-winged Swallow		O
13580	MOCH	Mountain Chickadee	B	U
13680	BUSH	Bushtit	T	T
13690	RBNU	Red-breasted Nuthatch	B	U
13700	WBNU	White-breasted Nuthatch	O	
13710	PYNU	Pygmy Nuthatch	T	
13730	BRCR	Brown Creeper	B	U
13850	CANW	Canyon Wren		O
14070	HOWR	House Wren	A	O
14110	WIWR	Winter Wren	U	
14210	AMDI	American Dipper		O
14240	GCKI	Golden-crowned Kinglet	B	T
14250	RCKI	Ruby-crowned Kinglet	M	
14570	WEBL	Western Bluebird	T	
14590	TOSO	Townsend's Solitaire	O	T
14810	SWTH	Swainson's Thrush		U
14820	HETH	Hermit Thrush	O	O
15000	AMRO	American Robin	B	B
15110	WREN	Wrentit	T	O
15150	NOMO	Northern Mockingbird	T	
15660	OCWA	Orange-crowned Warbler	A	A
15670	NAWA	Nashville Warbler	A	U

Appendix I. Continued

NUMB	SPEC	SPECIES NAME	LIME	ZUME
15750	YWAR	Yellow Warbler	O	B
15800	AUWA	Audubon's Warbler	B	O
15810	BTYW	Black-throated Gray Warbler	O	U
15840	TOWA	Townsend's Warbler	M	
15850	HEWA	Hermit Warbler	U	U
16140	MGWA	MacGillivray's Warbler	B	B
16290	WIWA	Wilson's Warbler	U	U
16840	WETA	Western Tanager	U	B
17790	GTTO	Green-tailed Towhee	O	O
17810	SPTO	Spotted Towhee	U	U
18130	SAVS	Savannah Sparrow		M
18220	FOSP	Fox Sparrow	B	T
18230	SOSP	Song Sparrow	B	B
18240	LISP	Lincoln's Sparrow	B	O
18320	ORJU	Oregon Junco	B	B
18600	RBGR	Rose-breasted Grosbeak		M
18610	BHGR	Black-headed Grosbeak	U	B
18660	LAZB	Lazuli Bunting	T	O
18730	RWBL	Red-winged Blackbird		B
18860	BRBL	Brewer's Blackbird		U
18960	BHCO	Brown-headed Cowbird	O	U
19105	BUOR	Bullock's Oriole		O
19350	PUFI	Purple Finch	U	B
19360	CAFI	Cassin's Finch	T	T
19370	HOFI	House Finch		T
19430	PISI	Pine Siskin	O	T
19490	LEGO	Lesser Goldfinch	T	O
19500	LAGO	Lawrence's Goldfinch		T
19510	AMGO	American Goldfinch		O
19580	EVGR	Evening Grosbeak	O	