Trends in Avian Abundance and Diversity in Restored and Remnant Riparian Habitat on the Cosumnes River, 1995 to 2005.

A Report to the California Bay-Delta Authority Ecosystem Restoration Program
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SUMMARY

We studied patterns of bird abundance, diversity, and trends over time in riparian habitat in and adjacent to the Cosumnes River Preserve over an 11-year period, 1995 to 2005. Our objectives were to assess condition of bird populations in mature and restored riparian habitat, characterize the response of birds to restored habitat, and identify linkages between terrestrial bird species and the aquatic/floodplain ecosystem, which is characterized by wintertime and springtime flooding. Breeding season surveys were conducted at 12 sites, including mature riparian habitat, young restored riparian habitat, and older restored riparian habitat, using fixed-radius point counts. Bird species diversity and total number of individuals increased with age of riparian habitat. Differences in these metrics were greater among habitat types than they were among sites within a habitat type. We calculated population trends for 22 landbird species (predominantly songbirds) breeding in riparian habitat within the study area. Species-specific trends were estimated separately for mature and restored riparian habitat, since trends differed markedly with habitat type. Trends in mature riparian habitat were as likely to be decreasing as increasing; six species (Ash-throated Flycatcher, Bewick's Wren, House Wren, Oak Titmouse, Bullock's Oriole, Mourning Dove) demonstrating statistically significant declines, many of them cavity-nesting species. Mechanisms responsible for the decline have not been identified, though studies of nesting songbirds suggest that nest predation rates are high. In restored habitat, trends were generally positive. At specific restoration sites, non-linear responses were demonstrated. For example, for the Spotted Towhee, a ground-nesting species associated with leaf litter from trees, individuals were not commonly observed until year 9 following restoration. In contrast, Common Yellowthroats, a species associated with herbaceous and shrubby plants, were observed to first increase and then decrease in abundance as restoration habitat aged. Tree Swallows demonstrated a positive response to winter flooding: their breeding season abundance increased as a function of the extent of flooding in the immediately preceding winter. Tree Swallows feed on flying insects, which often have an aquatic life stage. In contrast, terrestrial bird species (Song Sparrow, Spotted Towhee, and Common Yellowthroat) demonstrated a negative response to winter flooding, which may reflect changes in associated vegetation. This study demonstrates the value of restored riparian habitat to a broad suite of landbird species and reveals linkages between riparian songbirds and the adjacent floodplain.

INTRODUCTION

Riparian habitat in California is one of the most productive and valuable habitats for all forms of wildlife (Faber 2003). This is one of the most threatened habitats, with only about 5% of the state's original riparian habitat remaining (Katibah 1984, Abell 1989). Due to habitat loss and degradation, management of extant riparian habitat and restoration of riparian habitat have become high management priorities throughout California, by agencies and non-governmental organizations (RHJV 2004).

The most cost-effective method for large scale restoration of floodplain communities is to encourage natural processes to take their course, through levee breaches or levee setbacks that allow natural succession of flood-dependent flora and fauna. However, previous restoration efforts have not necessarily resulted in desired communities of plants and animals, due to factors such as land use history, soil conditions, groundwater supply, predators, timing of flooding, nutrient and detritus supplies, and non-native invasive species.

The Cosumnes River Preserve (CRP) provides the ideal setting to evaluate riparian habitat restoration efforts. Nominated as an Important Bird Area of global significance, the Preserve supports a diverse and abundant avifauna. It is home to many riparian songbird species that are declining or missing from other Central Valley sites (Gaines 1974).

In 1995, in cooperation with The Nature Conservancy (TNC), PRBO began evaluating and monitoring the riparian bird communities within the Cosumnes River Preserve to test the efficacy of restoration activities. PRBO implemented a multi-tiered integrated monitoring program following nationally standardized Partners in Flight protocols (Ralph et al. 1993). To assess the health of the songbird community we collected information on habitat usage, species richness, diversity and demographic parameters (e.g., reproductive success, Howell et al. 2006). The 2005 field season represents the 11th year of data collection by PRBO on the Preserve.

PRBO also began to study bird populations in riparian habitat adjacent to the Preserve, thus adding more sites as the study progressed. Furthermore, in 2002, PRBO began to work with partners in the CALFED-funded Cosumnes Riparian Study, *The influence of flood regimes, vegetative and geomorphic structures on the links between aquatic and terrestrial systems: Applications to CALFED restoration and watershed monitoring strategies.* With funding from the California Bay-Delta Authority, PRBO studied riparian bird populations during 2002-2005, with the specific aim of elucidating the linkages between the terrestrial bird species and the aquatic ecosystem, which is characterized by intermittent flooding during winter and spring.

Objectives

Specific objectives of this study were to:

- Characterize avian species diversity and richness over the study period, for mature riparian and restored riparian habitat.
- Characterize population trends over the study period (1995 to 2005) for a suite of 22 avian study species.
- Compare trends on mature riparian sites with trends on restored riparian habitat for the 22 study species.
- Characterize trajectories for species at individual, restoration sites.
- Identify rain and flooding variables that may be influencing abundance for individual species.

METHODS

Study Sites

Data on avian abundance were collected and analyzed from 95 survey stations in 12 sites during the study period, using nationally-standardized protocols for point count surveys (Ralph et al. 1993; Table 1). Each point count survey station was at least 200 m from the nearest station and at least 50 m from the edge of a habitat patch.

Table 1. Study sites. Sample size (number of point count station-years analyzed is shown), habitat and years analyzed. PB = Process-based. “Rest’d” = Restored

Site Name/Abbrev		sample size	Habitat	Years Analyzed
Cottonwood Grove	CWGR	8	PB Restored	2002-2005
DWR East	DWRE	95	Mature Riparian	1995-2002
Fallow Field	FAFI	70	PB Restored	1995-2005
Green Field	GRFI	6	PB Restored	2002-2004
Middle Breach	MIBR	12	PB Restored	2002-2005
Tall Forest	TAFO	137	Mature Riparian	1995-2005
Tall Forest West	TFWE	26	Planted, Restoration	2002-2005
Triangle Plot	TRPL	19	PB Restored	2002-2005
Valensin	VALE	102	Mature Riparian	1995-2001, 2005
Wendel’s Levee	WELE	83	Levee scrub + Rest’d	1995-2005
Wendel’s Road	WERO	92	Levee scrub + Rest’d	1995-2005
Willow Slough	WISL	142	Mature Riparian	1995-2005

Two sites could not be easily classified as either remnant (i.e., mature) riparian habitat or restoration habitat: Wendell’s Levee and Wendell’s Road. These two sites were not included in analyses that specifically compared mature riparian and restoration sites.

The point-count survey method was used because it is a proven, cost-effective method for estimating avian species diversity, species richness and relative abundance (Howell et al. 2004, Nur et al. 1999). Five-minute point counts were used in which the distance from the observer to each individual detected (including raptors and swallows foraging over the plot) was estimated. Detection distances were estimated in bands of 10 m outward to 50 m and then from 50 to 75 m, 75 m to 100 m, and beyond 100 m. Only detections within 50 m were analyzed here. The type of detection (song, visual or call) and any observed breeding behaviors (e.g., copulation, nest-material carry and food carry) were recorded. Birds flying over the station and not actively using the habitat were recorded separately and not included in analyses. Surveys began at local sunrise and were completed within four hours; surveys were not conducted during rain or high winds. All bird surveys were conducted April through June which corresponds to the songbird breeding season.

Two or three visits were conducted at each point count station in each year. For analysis, detections were summed over the two visits each year corresponding to mid-May and mid-June.

Species Selected

We selected 22 focal species for analysis. Criteria for selection of species included the following: 1) known or presumed to breed in riparian habitat in the Central Valley and 2) adequate sample size (at least 100 detections over all study sites during the study period). Most of the species studied have been analyzed in other Central Valley riparian studies (Gardali et al. 2005, Nur et al. 2005). Names of species are listed in Appendix 1.

Flooding and Weather Variables Analyzed

We examined patterns of abundance and change in abundance from one year to the next for our study species in relation to 13 variables that reflected flooding, local weather, and large-scale weather patterns. Daily accumulated precipitation data were acquired from two weather stations within 30 km of the Cosumnes River Preserve. River flow data were recorded at the USGS Michigan bar sensor on the Cosumnes River which is approximately 50 km upstream from the Cosumnes River Preserve and known to accurately predict flood conditions on the floodplain (Hammersmark et al. 2005). Data were obtained from the U.S. Geological Survey's National Water Information System (USGS 2005).

Daily accumulated precipitation was used to determine rainfall during the winter (October of previous year through February of current year; "winter rain"), early breeding season (March through May; "early rain"), and late breeding season (June-July; "late rain"). Mean daily discharge was used to calculate the total volume of water in the early (March-April) breeding season, the late breeding season (May-June), and the entire breeding season. Flood days included the number of days in which the water discharge volume exceeded flood stage for the river; the variables examined were winter flood days (October of previous year through February of current year), spring flood days (March-June), early breeding season flood days (March-April), and late breeding season flood days (May-June).

The Southern Oscillation Index (SOI) was used as a measure of El Niño Southern Oscillation (ENSO) strength, based on monthly, standardized values obtained from the National Center for Atmospheric Research (Boulder, CO), **www.cgd.ucar.edu/cas/catalog/climind/soi.html**. El Niño events have negative SOI values and La Niña events have positive SOI values. Because there may be a delay in the effect of ENSO events on bird populations, we considered SOI over 3 time periods: the first four months of the current year (i.e., the shortest lag), the last four months of previous year (Sept-Dec) , and an annual SOI, i.e., the previous 12 months (first 4 months of current plus last 8 months of the previous).

We analyzed variation in abundance and the change in abundance from the previous year to the current year in relation to 13 flood, rain, and SOI variables for the "current year" (as defined above) and we also analyzed the same dependent variables in relation to the 13 flood, rain, and SOI variables from the previous year.

Analysis.

For each species, we analyzed the number of detections per point-count station in each year, summed over two visits (all years had at least 2 visits per point count station). Statistical analysis was conducted with negative binomial regression using the program STATA 8 (Stata Corp. 2003). Negative binomial regression (nbreg) is the most suitable method for analyzing count data in a manner that incorporates heterogeneity. Note that nbreg analyzes log(count), and thus coefficients obtained estimate trends on a log-scale; coefficients from a linear regression estimate a constant proportionate change from year to year.

We also analyzed two community-wide, multi-species metrics: total individuals detected and bird species diversity. For the former, we summed total number of individuals detected for 21 of the 22 species, excluding Red-winged blackbirds because they were very patchily distributed (either absent or highly abundant) and thus tended to swamp variation in the other 21 species.

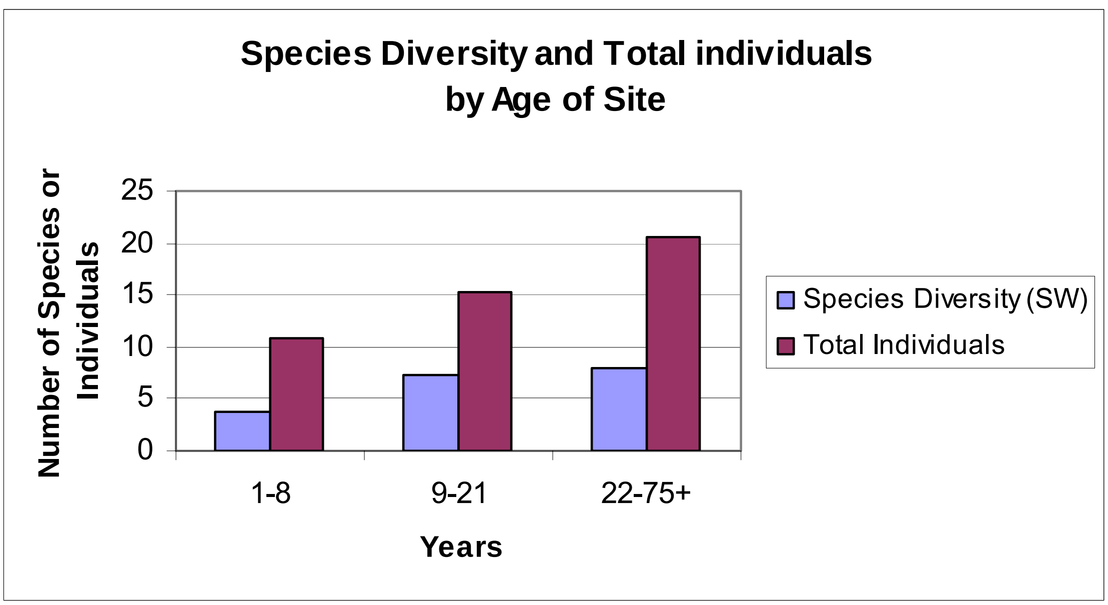
We analyzed bird species diversity using a transformation of the commonly used Shannon index (the latter symbolized H' [Nur et al. 1999]). The transformed index used here is N_1, where $N_1 = e^{H'}$. The advantage of N_1 over H' is that N_1 is measured in terms of species, instead of bits of information. This makes N_1 more easily interpretable, and species diversity (measured as N_1) and richness can easily be compared (Nur et al. 1999). To determine whether trends differed between restored and mature habitat we tested for the significance of an interaction in trend. To determine non-linearity of trend we tested for the significance of a quadratic term (in the presence of a linear term) with respect to year.

RESULTS

Overall Patterns

Bird species diversity for all species (Shannon Index) and "Total Individuals" for the set of 21 species are shown in Figure 1 with respect to "Age" of riparian habitat. The latter was grouped into early restoration (Years 1 – 8), middle-age restoration (Years 9 – 21), and older, mature sites (Years 75 or greater). The oldest sites had the most individuals and greatest diversity, though diversity in middle-age restoration was almost as great as that observed at the oldest sites.

Figure 1.



The patterns that obtained in general among the three habitat types (young riparian, middle-aged riparian, and mature riparian) were also manifest at the individual site level. Table 2 summarizes results for seven sites of interest.

Table 2. Bird species diversity and "Total individuals" for 21 species at 7 sites, 2002 to 2005.

Successional Stage	Site	diversity	(SE)	Total Individuals*	(SE)
Early	FAFI	3.49	(.29)	10.3	(1.62)
	TRPL	2.43	(.28)	5.37	(1.02)
	MIBR	4.16	(0.21)	11.67	(1.01)
Middle	CWGR	7.21	(.38)	15.25	(2.73)
Late	TAFO	7.7	(0.33)	18.48	(0.98)
	VALE	7.1	(0.63)	19.53	(2.32)
	ORFO	8.79	(.73)	23.57	(2.33)

Trends over time for the study species at all sites

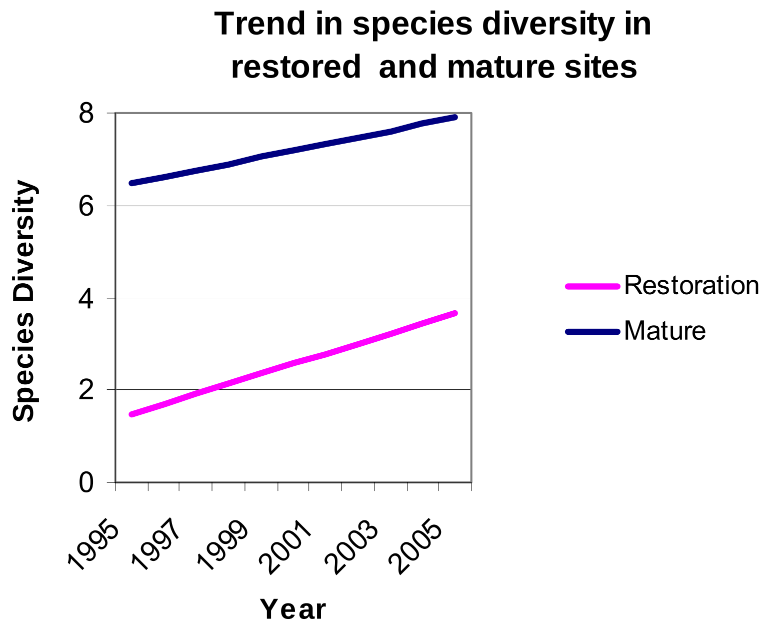
Ten species demonstrated positive trends over time and 12 species negative trends. Five species were significantly increasing (at $P < 0.10$ level) and in fact all five showed trends that were significant at the $P = 0.003$ or better level (Bushtit, Song Sparrow, Tree Swallow, White-breasted Nuthatch, and Western Scrub-jay) . Four species demonstrated trends that were significantly declining at the $P < 0.05$ level (Ash-throated Flycatcher, Bewick's Wren, Oak Titmouse, and Red-winged Blackbird) and one species (Bullock's Oriole) demonstrated a declining trend with ($0.10 < P < 0.05$). For the other 12 species, the estimated trends were not significant ($P > 0.10$).

There were often differences between trends observed in mature vs. restored habitat. Because sample size differed between the two types of habitat, the overall results summarized above reflect the differential contribution of the two habitat types. Therefore we analyzed restored and mature riparian habitat separately and present results in the next section.

Comparative trends in restored and mature riparian habitat

We first summarize trends in species diversity. Species diversity increased on both restoration and mature riparian sites. On restoration sites, the increase was +0.221 (S.E. = 0.41); in mature sites, the increase was +0.142 (S.E. = 0.32) per year. The trends are illustrated in Figure 2.

Figure 2.



Results for trends in abundance for each of the 22 species, by habitat type (restored and mature) are shown in Appendix 1. In mature habitat, 9 species had positive trends with 5 of these displaying significant ($P < 0.10$) trends; 13 species had negative trends with 6 of these significant ($P < 0.1$). In restored habitat, 16 species had positive trends, with 4 of these species demonstrating significant ($P < 0.1$) trends; 6 species had negative trends, but none were significantly negative. Table 3.A depicts trends for all 11 species with significant ($P < 0.10$) trends in mature habitat. Table 3.B depicts trends for all 4 species with significant ($P < 0.10$) trends in restored habitat.

Table 3. Trends for all species with significant (P < 0.10) trends over time

A) mature habitat.

Species	Slope	Significance (P value)
increasing		
American Goldfinch	.131	.004
Bushtit	.227	.00
Song Sparrow	.064	.001
White-breasted Nuthatch	.08	.004
Western Scrubjay	.165	.00
decreasing		
Ash-throated Flycatcher	-.077	.003
House Wren	-.032	.055
Mourning Dove	-.106	.022
Oak Titmouse	-.069	.001
Bewick's Wren	-.079	.004
Bullock's Oriole	-.061	.054

B) restored habitat

Species	Slope	Significance (P value)
increasing		
Common Yellowthroat	.087	.08
Song Sparrow	.143	.00
Spotted Towhee	.304	.001
Tree Swallow	.242	.004

It is worth noting that four of the six species significantly declining in mature habitat are cavity-nesters. We have no ready explanation for this finding, but concern is warranted.

Results for Tree Swallows were complicated by the fact that nestboxes were provided in 2005, which may have biased detections. Therefore, we have analyzed this species both including and excluding 2005. Results in Table 3 (above) include 2005; results depicted in Figure 3 (below) exclude Tree Swallow detections in 2005. The important point was that the **differences** in slope for Tree Swallows were similar whether or not 2005 data were included.

Figures 3, 4, and 5 depict trends for 3 species (Tree Swallows, Song Sparrows, and Spotted Towhees), each of which demonstrated significant differences in trends ($P < 0.001$, $P = 0.032$, and $P = 0.002$, respectively), comparing restored and mature riparian habitat.

Figure 3.

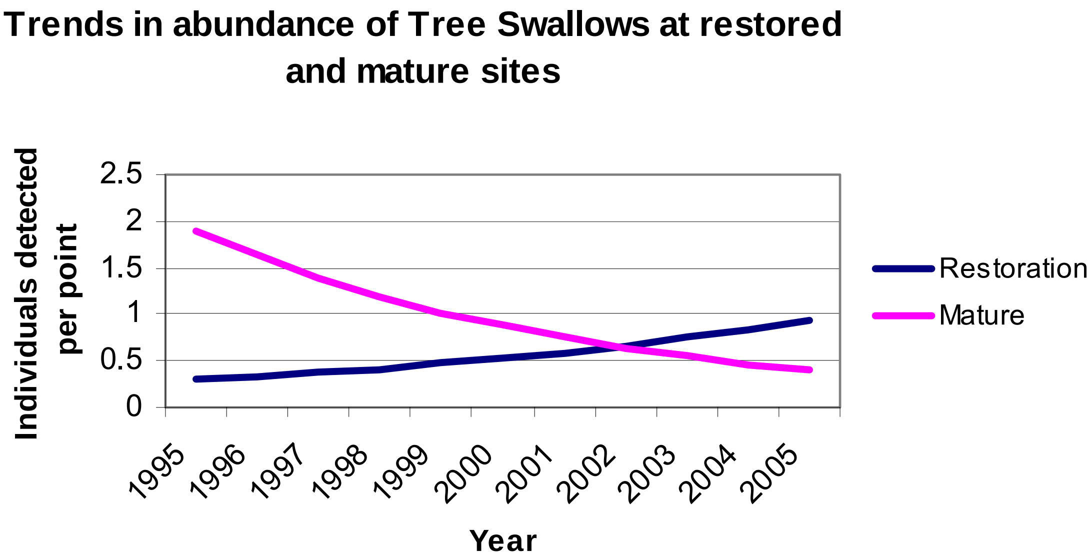


Figure 4.

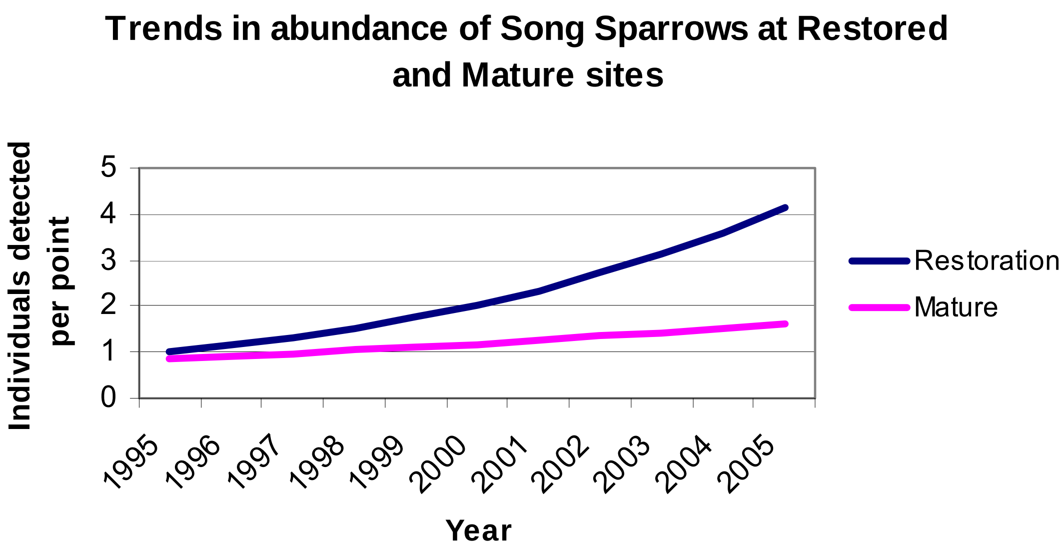
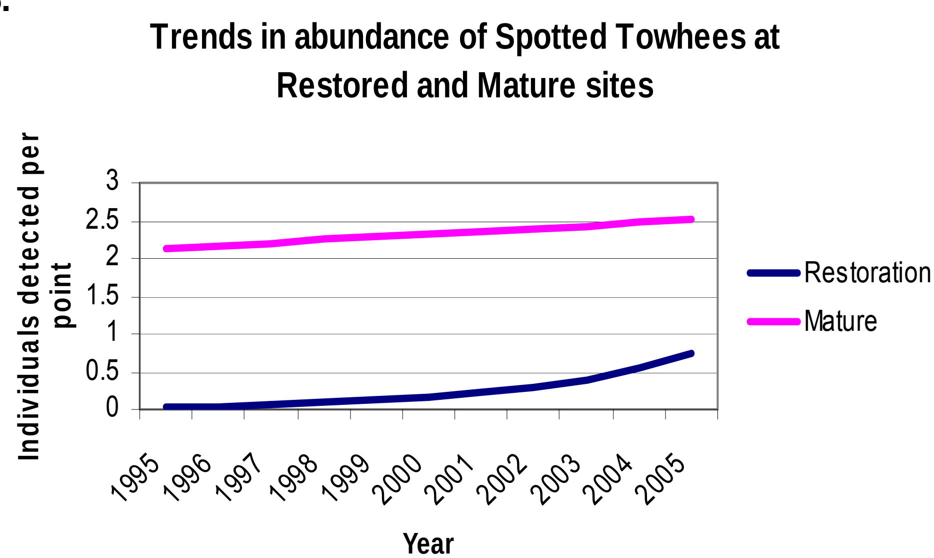


Figure 5.

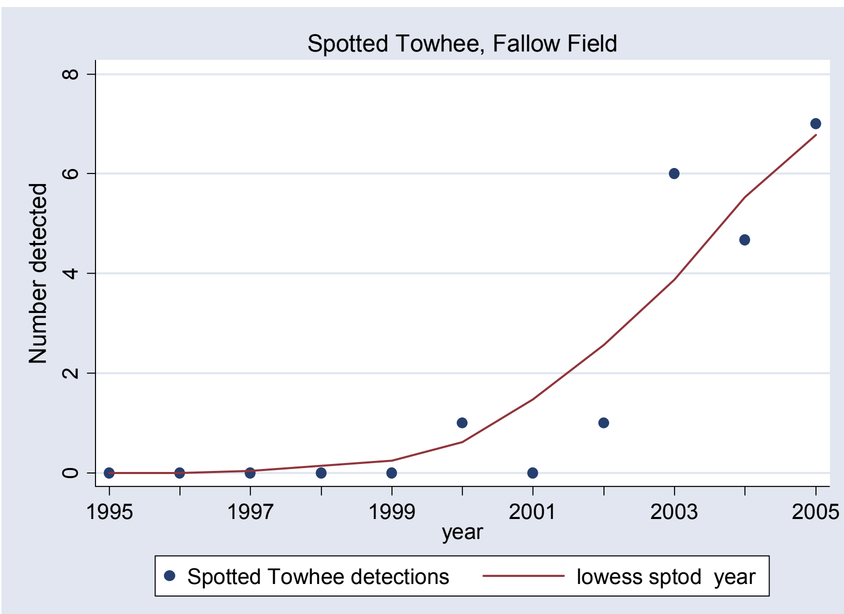


All three species demonstrated significant positive trends at restoration sites. However, the trends were tending to converge for Spotted Towhees but clearly diverging for Song Sparrows.

Trends at individual sites.

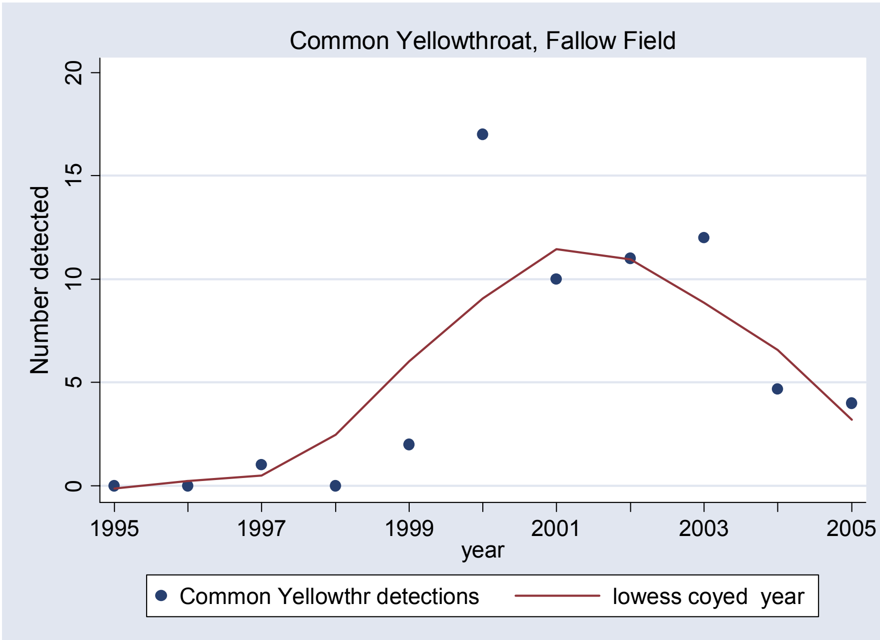
It is instructive to consider population trends at individual sites. For this exercise we focused on two sites with 11-year time series, Tall Forest (mature riparian) and Fallow Field (restored site). Figure 6 depicts the change in abundance index for Spotted Towhees at Fallow Field from 1995 to 2005. No Spotted Towhees were detected early in the restoration period and considerable numbers were detected only in years 9, 10, and 11 since restoration began. Thus there was a big spike in numbers between years 8 and 9. Note that Spotted Towhees are closely and positively associated with trees (Nur et al. 2005) and often forage in, and nest near, leaf litter.

Figure 6.



In contrast, Common Yellowthroats demonstrated a very different pattern. This species is negatively associated with trees but positively associated with shrubs and herbaceous understory (Nur et al. 2005). Therefore it is not surprising that numbers first increased (as shrubs increased), but then decreased after year 9 (Figure 7).

Figure 7.

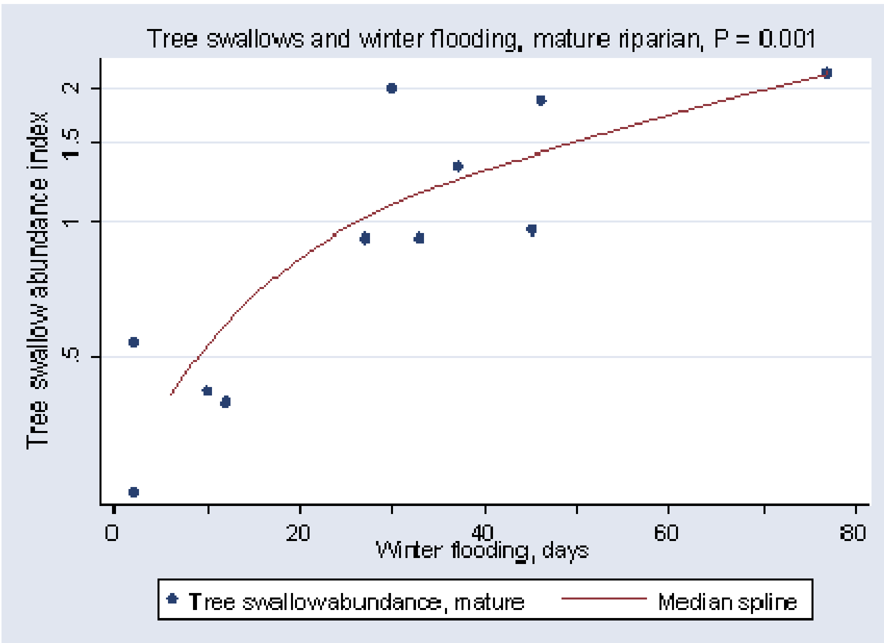


Influence of flood, rain, and climate variables on bird abundance

We examined the effect of the 13 flood, rain, and climate variables on four species: Common Yellowthroat, Song Sparrow, Spotted Towhee, and Tree Swallow. For the first three species there was a significant negative effect of winter flooding on abundance in the subsequent spring, but only in restoration sites ($P < 0.001$, for all 3 species). For Song Sparrows, the estimated effect was a relative decrease in abundance of 2.4% with an increase of 1 flood day (S.E. = 0.5%). For Common Yellowthroats, the estimated effect was similar: 3.2% relative decrease in abundance with each additional day of winter flooding (S.E. = 0.7%). There was no significant effect of winter flooding on abundance for Common Yellowthroat, Song Sparrow, or Spotted Towhee in mature sites ($P > 0.10$). Spring flood days also had a negative effect on abundance of these three species, but only in restoration sites ($P < 0.05$); the effect was never as strong as with winter floods.

In contrast, there was a positive effect of winter flooding on Tree swallow abundance in the following spring. This effect was restricted to mature sites ($P = 0.001$; Figure 8). The estimated effect was an increase in relative abundance of 1.9% (S.E. = 0.5%) with an increase of 1 winter flood day. In restoration sites, there was no effect. The relationship of Tree Swallow abundance to winter flooding is shown in Figure 8 on a logarithmic scale (since the nbreg analysis is conducted on log(count)). In years with little winter flooding, Tree swallow abundance in the following spring was the lowest observed during the study; in years with moderate to high winter flooding, there was only a minor effect of winter flooding on abundance

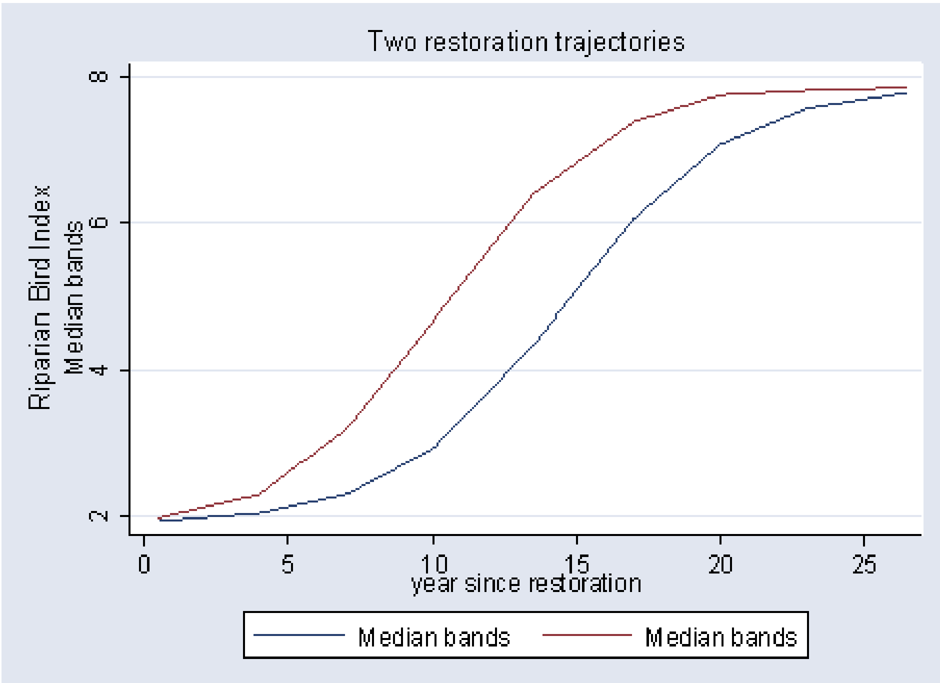
Figure 8.



DISCUSSION

Consistent differences in species diversity and total abundance were observed comparing young restoration, middle-aged restoration, and mature sites. Nevertheless there was also some site to site variation within each classification. The results obtained here suggest that there is some variation in trajectory of a restoration site over time as it matures. Figure 9 presents a conceptual model illustrating variation in trajectory: Each site may demonstrate a similar sigmoidal response (a rapid increase in bird abundance or diversity, followed by attainment of a plateau), but there may be variation in the timing. Thus two sites of the same restoration age may have different quantitative characteristics pertaining to the bird community and yet the two sites may show a similar change over time. Vegetation characteristics (including composition and structure) are likely to explain variability in bird response over time, but one should not exclude other food web effects (i.e., prey abundance and predator activity).

Figure 9



Results presented here demonstrate that population trends for many species differed between restored and mature habitats. That populations were often increasing in restored habitat is not surprising (16 out of 22 species were increasing, whether significant or not), but more surprising was than many species were declining in mature habitat. Six species demonstrated significant declines over the 11-year period and another six species demonstrated nonsignificant declines. The cause of such decline is not known, but a worthwhile subject for future investigations. In particular, we note that cavity nesters were especially likely to demonstrate significant negative trends in mature habitat.

These results stand in contrast to the findings of Gardali et al. (2006), who found that along the Sacramento River, over a similar time period (1993-2004), riparian landbird species generally demonstrated positive trends in both mature (remnant) riparian habitat as well as in restored riparian habitat, with only one species demonstrating negative population trends in both mature and restored habitat, the Lazuli Bunting (*Passerina amoena*). In this study, however, we did not analyze Lazuli Bunting population trends due to the low abundance of this species, which was likely more abundant in the 19th and early 20th centuries. One explanation for the differences observed between our study and that of Gardali et al. (2006) is that habitat loss has been greater along the Sacramento River than in or near the Cosumnes River Preserve and thus restoration in the former area has benefited bird populations breeding in the diminished remnant habitat. Note that along the Sacramento River there is no patch of riparian habitat as large as that observed in the Cosumnes River Preserve at Tall Forest.

The apparent population declines for many species may reflect generally low reproductive rates (especially low rates of nest survival) observed for riparian songbirds in the Central Valley in general and at CRP in particular (Haff et al. 2000, Howell et al. 2006). Predation rates at CRP appear to be very high (Haff et al. 2000), both from native and non-native (e.g., Black Rat *Rattus rattus*). Immigration from neighboring areas and adult and juvenile survival rates are other demographic processes which need to be quantified in order to understand observed population trends.

Tree Swallows demonstrated a positive response to winter flooding: their breeding season abundance increased as a function of the extent of flooding in the immediately preceding winter. Tree Swallows feed on flying insects, which often have an aquatic life stage, and insect abundance may have been enhanced in years of extensive winter flooding. In contrast, terrestrial bird species demonstrated a negative response to winter flooding in terms of abundance, which may reflect changes in vegetation associated with flooding. Thus, Song Sparrows evidenced two divergent responses to winter flooding: reproductive success was greater in the subsequent spring with greater winter flooding (Howell et al. 2006) but the abundance of adults was lower during the same time period.

Population responses often differed depending on restoration state. For example, the depression in abundance of adult songbirds in relation to flooding the preceding winter was only observed at restoration sites.

This study demonstrates the critical role restored riparian habitat plays in maintaining or augmenting populations of a broad suite of landbird species. Linkages between population processes of riparian songbirds and the adjacent floodplain were demonstrated with the mechanisms depending on species and on site (restored vs. mature sites).

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Appendix 1

Estimated Trends for 22 Riparian Bird Species, Cosumnes Study, 1995 to 2005.

Coefficient is Proportional Change per year (= Percent change /100)

Species	mature Habitat Trend	P value	Restoration Trend	P value	Difference in Trends P value
American Goldfinch	+0.131	0.004	+0.032	P>.2	P>.2
Ash-throated Flycatcher	-0.077	0.003	+0.161	P>.2	P>.2
Bewick's Wren	-0.079	0.004	+0.420	P>.2	P>.2
Brown-headed Cowbird	-0.026	P>.2	+.048	P>.2	P>.2
Black-headed Grosbeak	-0.010	P>.2	+1.013	P>.2	P>.2
Blue Grosbeak	-0.028	P>.2	+0.056	P>.2	P>.2
Bullock's Oriole	-0.061	0.054	-0.272	P>.2	P>.2
Bushtit	+0.227	0.001	+0.110	P>.2	P>.2
Common Yellowthroat	+0.020	P>.2	+0.087	0.075	P>.2
Downy Woodpecker	+0.022	P>.2	-0.092	P>.2	P>.2
House Finch	+0.023	P>.2	+0.025	P>.2	P>.2
House Wren	-0.032	0.055	+0.002	P>.2	P>.2
Mourning Dove	-0.106	0.022	+0.158	P>.2	P>.2
Nuttall's Woodpecker	-0.024	P>.2	-0.092	P>.2	P>.2
Oak Titmouse	-0.069	0.001	-0.302	P>.2	P>.2
Red-winged Blackbird	-0.033	P>.2	+0.008	P>.2	P>.2
Song Sparrow	+0.064	0.001	+0.143	0.001	P = 0.032
Spotted Towhee	+0.010	P>.2	+0.304	0.001	P = 0.002
Tree Swallow	-0.034	P>.2	+0.242	0.004	P < 0.001
White-breasted Nuthatch	+0.080	0.004	-0.001	P>.2	P>.2
Western Scrub-Jay	+0.165	0.001	+0.190	P>.2	P>.2
Wrentit	-0.056	0.17	-.001	P>.2	P>.2

Note: Results from Negative Binomial Regression

Note: Restoration = True Restoration (excludes levee sites)

Sample Size: mature : N = 465; Restoration: N = 141; 2005 data included for Tree Swallows (see text)