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SAN FRANCISCO BAY TIDAL MARSH PROJECT
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Distribution, abundance, and reproductive success of tidal marsh birds

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EXECUTIVE SUMMARY

Human impacts on tidal salt marshes of San Francisco Bay have drastically reduced and degraded this important habitat. Tidal marshes are biologically productive, and are an integral part of the proper functioning of the overall bay ecosystem. They are also home to a number of state and federal listed endangered or threatened species of plants and animals. Recognizing the importance of this habitat in the San Francisco Bay, many agencies and organizations have planned or initiated wetland restoration projects in the Bay. Restoring wetlands to functioning tidal marsh habitat requires monitoring measures to assess the health and success of restoration sites relative to natural marshes.

Many bird species depend on tidal marsh habitat to nest and raise their young. Populations of these tidal marsh dependant birds have declined significantly due to the loss of habitat around the Bay. A number of these birds have special conservation status, such as the federally endangered California Clapper Rail (*Rallus longirostris obsoletus*), State of California threatened California Black Rail (*Laterallus jamaicensis coturniculus*), and four State Species of Special Concern: Alameda Song Sparrow (*Melospiza melodia pusillula*), San Pablo Song Sparrow (*M. m. samuelis*), Suisun Song Sparrow (*M. m. maxillaris*), and Salt Marsh Common Yellowthroat (*Geothlypis trichas sinuosa*). Although these birds have been previously studied, little is known of the long-term trends of their populations because of the lack of long-term monitoring studies.

PRBO Conservation Science (founded as the Point Reyes Bird Observatory) began a long-term monitoring project in 1996 to study the tidal marsh birds of the San Francisco Bay. Combined data from point count surveys and demographic data from nest monitoring provides a basis for understanding how tidal marsh birds respond to both physical and biological processes. This report presents the results of our 2004 breeding season studies in the San Francisco Bay.

We conducted point count surveys at 45 marshes in the 2004 breeding season (March through July). The point count method makes it possible to compare yearly bird population data at fixed points, and to assess patterns of abundance. Trained observers recorded birds detected by sight and sound within five minutes during two rounds of surveys at each site. Cumulative species richness (total number of species detected) was calculated across both rounds of surveys. A density index for each focal taxon (Song Sparrow, Common Yellowthroat, Marsh Wren (*Cistothorus palustris*), and Black Rail) was calculated for each point and each round using detections within 50 m of the observer; the mean at each site for each round was then averaged to produce a single density index for each site. Similarly derived data since 1996 are included for comparison with 2004 data. Song Sparrows were generally the most abundant of our focal species. Common Yellowthroats seem to prefer sites with tall vegetation, and consistently, abundance is highest in Suisun Bay and relatively low in San Francisco and San Pablo Bays. Similarly, Marsh Wrens prefer tall vegetation for breeding, and their abundance followed the same trend as the Common Yellowthroats, albeit with higher densities in San Francisco and San Pablo Bays.

Nests were monitored at five sites using standardized methodology that includes techniques to minimize disturbance to the birds and habitat. Nest monitoring allows measurement of reproductive success and therefore is an indication of population health. Nest survival probability was calculated both by basic proportion of successful nests, and by the Mayfield method, that calculates success based on average daily survival probability. Observers used behavioral clues to estimate territory boundaries and map breeding territories. The number of territories in the study area can be used to calculate the density of breeding birds at each marsh.

Analysis of 2004 data indicates that nest survival rate was near the long-term average within those sites previously surveyed. A total of 576 nests of 9 species were found in 2004. Of these, 477 were Song Sparrow nests. Since this species is the most abundant breeding species in SF Bay, Song Sparrows are an appropriate indicator species for trends in reproductive success. Reproductive success of Song Sparrows derived using the Mayfield method was approximately 16% at both San Pablo Bay and Suisun Bay sites. However, there was significant variation among different sites within each bay.

INTRODUCTION

Throughout the world, tidal salt marshes have faced and continue to endure threats from humans (Adam 2002). The tidal marshes of San Francisco Bay, since their establishment approximately 10,000 years ago (Atwater 1979, Atwater et al. 1979, Josselyn 1983), have played an important role in maintaining proper functioning of the Bay ecosystem. During the last 200 years, however, the system has been altered and broken down through human induced habitat conversion and loss (Nichols et al. 1986). Habitat losses in San Francisco Bay include a 79% reduction of tidal marsh habitat and 42% reduction of tidal flat habitat (Goals Project 1999).

Over the past ten years, through wetland acquisition and restoration, tidal marsh habitat has increased significantly in San Francisco Bay. Dozens of restoration projects are underway, ranging in size from a few ha to much larger efforts. In 1994, the Cargill Salt Company, owner and operator of almost all salt ponds within the San Francisco Bay estuary, sold nearly 4,000 ha of its salt pond complex in the North San Francisco Bay (which includes San Pablo Bay, hereafter, North Bay) to the State of California (Siegel and Bachand 2002). To further wetland restoration efforts, in March 2003, the state of California and the federal government purchased over 6,000 additional ha of salt pond operations in the South San Francisco Bay (hereafter, South Bay) from Cargill Salt (Sample 2003). Together, state and federal agencies and non-governmental organizations are developing strategies to restore much of these lands. While in the Napa-Sonoma wetlands much of the restoration has already started, the South Bay restoration is still within a general planning phase (Miles et al. 2004).

A dominant feature of the coastal tidal marsh habitat in San Francisco Bay is its avian community (Bollman et al. 1970, Josselyn 1983), and it is assumed that the significant amount of habitat lost in the past, reduced the numbers and diversity of birds substantially (Marshall and Dedrick 1994, see also Nichols et al. 1986). However, very little quantitative data on birds exists prior to the last half of the 20th century. Anecdotally, Grinnell and Wythe (1927) reported that Clapper Rail, formerly a common resident in the Bay, was rare.

This loss of tidal marsh habitat currently is reflected by the number of San Francisco Bay tidal marsh-dependent birds of special conservation status such as the Clapper Rail, Black Rail, Alameda Song Sparrow, San Pablo Song Sparrow, Suisun Song Sparrow, and Salt Marsh Common Yellowthroat (Nur et al. 1997, Goals Project 2000, Spautz and Nur 2002).

More recently, many of the species designated with a special conservation status, have been the focus of various studies (e.g. Clapper Rail - Harvey 1988, Albertson 1995, Garcia 1995; Black Rail - Manolis 1978, Evens et al. 1989, 1991, Evens and Nur 2002; Song Sparrow - Marshall 1948, Johnston 1956a, 1956b, Chan and Arcese 2002; Salt marsh Common Yellowthroat - Marshall and Dedrick 1994), yet little of this work has been long-term. Because of the lack of long-term monitoring, few quantitative data exist on the trends of tidal marsh birds for San Francisco Bay (but see Evens and Nur 2002).

PRBO Conservation Science (PRBO) has been studying San Francisco Bay's tidal marsh birds since the early 1980s, and in 1996 initiated a long-term monitoring project designed to examine the long-term demographic patterns of San Francisco Bay's tidal marsh birds. PRBO's research design includes a combination of annual point count data from over 60 sites in the Bay, annual demographic data collected at up to 5 sites in the Bay, as well as associated habitat and landscape level variables at each site (see Figure 1a, 1b, and Table 1). With these data, PRBO is now able to examine how tidal marsh birds respond to the heterogeneity of physical and biological processes found within the diverse landscape throughout the San Francisco Bay estuary (see Nur et al. 1997, Evens and Nur 2002, Stralberg et al. 2003, Spautz et al. in press).

PRBO is committed to reporting and presenting our data to the public and community annually through peer reviewed literature, progress reports, and this annual report on tidal marsh research. These annual reports provide an assessment of current conditions, as well as long-terms trends in the population biology of the tidal marsh bird community in the San Francisco Bay estuary. In this report, we also summarize results of analyses we completed in 2004 (see Spautz and Nur 2004), examining the impacts of the non-native perennial pepperweed (*Lepidium latifolium*) on the abundance, distribution, and reproductive success of San Francisco Bay tidal marsh birds. *Lepidium latifolium* (henceforth we refer to the species as "*Lepidium*") is native to southern Eurasia. It has spread throughout North America, particularly west of the Rocky Mountains (Renz 2000). It is a member of the mustard family (Brassicaceae) and can reach heights of 1.5 m (Renz 2000). It displaces native vegetation, and has the capacity to spread via underground roots and form vast monocultures (K. Boyer pers. comm.; Renz 2000). *Lepidium* may produce over 16 billion seeds per year per acre; however the dominant method of spread in most ecosystems is via transfer of root fragments, particularly via water (Renz 2000). This partly accounts for its initial establishment along tidal channels in the tidal marshes of the San Francisco Bay Estuary.

METHODS

Point count surveys

Variable radius point count surveys (Reynolds et al. 1980; Ralph et al. 1995; Nur et al. 1999) were conducted at 45 marshes during spring 2004 (Fig. 1a,b; Table 1). Surveys were conducted within 4 hours of sunrise, one or two times per site between 21 March and 25 June. Successive rounds were conducted at least 3 weeks apart.

Field biologists, with extensive knowledge of songs and calls of the birds in the area, conducted all surveys. Survey points (or stations) were placed 125 to 200 m apart, with one to 23 points per site depending on marsh size. The smallest marsh fragments were completely surveyed from one point. At each station, the observer recorded all birds detected by sight and sound for five minutes. For detections within 100 m from the observer, distance was estimated within 10 m bands; detection type (visual or auditory) was also recorded for each bird (WRMP 2002).

For each species, the minimum number of individuals present at each marsh site during the breeding season was estimated by counting all detections within 100 m of each point count station. Most surveys cover only a portion of a site and thus counts are usually incomplete; in addition, detection probabilities are less than 100% for many species. Cumulative species richness for each site was estimated by counting the total number of unique species detected across all surveys within the site.

A density index (birds detected per ha) for each focal taxon (including rails) at each point count station was estimated separately for each round of surveys. Based on prior analysis of detection rates at various distances (Nur et al. 1997), we restricted the data to detections within 50 m of the observer. If a specific station was surveyed more than once, we averaged across the multiple surveys to obtain a mean and variance estimate for the density index of each station. Stations were not always entirely surrounded by marsh habitat. Therefore, final breeding season density estimates for each station were adjusted based on the proportion of tidal marsh habitat present within the 50 m radius of the station. Density estimates for each site were estimated as the average of all point count station estimates within the site.

At all point count stations, biologists collect data on vegetation and habitat characteristics within 50 m radius of the point count location, using the relevé method (Ralph et al. 1993, Nur et al. 1997). Using these vegetation data, we investigated whether *Lepidium* affected the ecology of breeding tidal marsh birds in the San Francisco Bay Estuary. We examined bird point count survey data collected during the spring of 2000 and 2001 for relationships between *Lepidium* percent cover at each survey point, and the abundance of three endemic subspecies of tidal marsh Song Sparrow and Marsh Wren, the presence of the California Black Rail and Salt Marsh Common Yellowthroat, overall species richness, and species diversity. We looked for relationships at several scales, controlling for variation among bays (i.e., Suisun Bay, San Pablo Bay, and San Francisco Bay), among marshes, and local habitat characteristics. For detailed descriptions of our methods see Spautz and Nur (2004).

Reproductive success

Nest monitoring allows measurement of reproductive success (e.g., clutch size, number of broods, number of nesting attempts) in specific habitats and provides information on population health (Martin and Geupel 1993).

Field biologists searched for and monitored nests at China Camp State Park (Marin County), Petaluma River Marsh (a.k.a. Carl's Marsh, Sonoma County), Pond 2A (Solano County), Benicia State Park (Solano County), and Rush Ranch (Solano County) (Figure 1; Table 1) in tidal marsh habitat during the breeding season (March 1 to July 30, 2004). Nests have been annually monitored by PRBO at two of these sites (China Camp and Benicia State Parks) since 1996 and at Rush Ranch in all but one year since 1996. Within 2-4 focal study plots per site, we searched intensively for the nests of Song Sparrow, Common Yellowthroat, Marsh Wren, Black Rail, and Red-winged Blackbird (*Agelaius phoeniceus*); nests of other species were also found opportunistically. All known nests were monitored using a standard protocol (Martin and Geupel 1993). Nests were usually visited every 2-4 days (range: 1 to 7 days) and careful attention was given to minimize human disturbance. Frequent visits to nests allowed more accurate estimates for the dates of predation events as well as egg laying, hatching of eggs, and fledging of young, all of which are valuable for the estimation of daily survival rate and nest success.

Nests were located at all stages (construction, egg-laying, incubation, and nestling periods, as well as after use). Nest contents were recorded at each visit and the ultimate outcome of each nest was decided based on nest condition and behavior of the breeding pair. Nestlings were banded on the 7th or 8th day with USGS bands and a unique combination of colored leg bands to facilitate field identification.

We calculated nesting success of a specific site (defined as the proportion of the total number of nests that fledged at least one chick) and also daily survival rate for each site using the Mayfield method (Mayfield 1975). We estimated the daily survival rates of nests at each site separately for each nesting stage (egg laying/incubation and nestling). We also estimated an overall nest survival for each site by combining the separate nest survival rates for each stage (Johnson 1979, Nur et al. 1999)

Territory mapping

For defined plots within each nest-monitoring site, we mapped the breeding territories of all individuals of all species. The region mapped included the territories where nests were monitored (where territory boundaries were the most accurately discerned), but also included additional adjacent habitat. We defined the approximate territory boundary by observing the behavior of each bird, particularly singing and territory defense behavior. The entire area being mapped was visited at least four times during the breeding season, twice during the first half of the season to produce mid-season maps (before May 1), and at least twice during the late season (between May 1 and June 30). Although territories boundaries are dynamic, and individuals often appear or disappear during the course of the season (PRBO unpubl. data), the best possible estimates of territory locations and the locations of color-banded birds were made by combining data at mid-season and at late season. Here we only present territorial data from the late season, because by that time inconspicuous individuals are usually detected and territory boundaries are probably more accurately mapped than earlier in the season.

We counted the number of territories in each study area within each marsh and divided it by the area studied to derive a density of breeding birds for each marsh. This number can be compared with the density index derived from point count surveys to determine the relative accuracy of the survey sampling methods.

Banding and Recapture/Resighting

Since 1996, PRBO has been color banding Song Sparrows in the North Bay and Suisun. In the future much of this data will be used to estimate demographic parameters such as survival, dispersal, and ultimately recruitment of new breeders. Presently, the banded individuals allow PRBO to monitor unique pairs throughout the breeding season. In the beginning of the season, biologists used mist nests to opportunistically capture and band Song Sparrows. During the breeding season, biologists used more direct methods, targeting specific unbanded pairs with known nest locations. In addition, all hatchlings were banded just prior to fledging. Morphometric data (wing-length, fat scores, etc.; Ralph et al. 1993) and sometimes plumage characteristics (e.g., color) are noted at capture (see Nur et al. 1997).

RESULTS AND DISCUSSION

While the mean density index for Song Sparrows decreased slightly from 2003, the density indexes for the Common Yellowthroat and the Marsh Wren slightly increased (excluding densities of Marsh Wrens in San Francisco Bay). Ecologically significant results are presented and discussed below.

Point count survey overview

The total number of birds of all taxa detected ranged from 20 to approximately 500 birds per site (mean = 188.2; SD = 117.0), depending on marsh size and marsh characteristics. Species richness ranged from 1 to 27 species (mean = 12.6; SD = 6.2) per site across the region (Table 2, Table 3).

Song Sparrows

Densities - Within each bay, Song Sparrows were the most abundant of the focal species detected using our point count survey methods. Song Sparrow densities in San Francisco Bay (i.e. Alameda Song Sparrow) were consistently lower than found within San Pablo Bay (i.e., San Pablo Song Sparrow) and Suisun Bay (Suisun Song Sparrow) (Figure 2a). However, since 1996, while densities of the San Pablo and Suisun Song Sparrows have remained relatively stable, densities of Alameda Song Sparrow have increased. In the past 2 years, densities are nearly comparable across all 3 bays.

In 2004, the only noticeable change in Song Sparrow density at the bay level occurred within San Francisco Bay, where the average density across sites decreased from 5.9 birds/ha to 4.1 birds/ha.

Reproductive success - Song Sparrows are the predominant nesting passerine in the tidal marshes of the San Francisco Estuary. They nest at high densities, relative to other avian species that nest within the tidal marsh. Nesting densities observed here are some of the highest reported for any non-colonial bird species (Johnston 1956b, L. Grenier, in prep.). Estimated nest survival rate (per nest), from initiation of laying to fledging) was similar in 2004 to the long term averages at each site (Figure 3). At China Camp, nest survival was somewhat lower than average in 2004 (sixth highest of nine years), but at

Benicia State Park, nest survival was the second-highest reported, among 9 years. Of interest were the very low estimates of nest survival rate observed at Carl's Marsh and Rush Ranch (Figure 3).

After separating out nest survival during specific periods of the nesting cycle, it appears that the lower nest survival rate for Carl's Marsh is the result of poor survival during the incubation phase (Table 4). Carl's Marsh is a newly restored marsh (restored to tidal action in 1994) and lack of adequate cover or complex nesting structure may subject Song Sparrows to increased predation or increased chance of flooding (PRBO unpubl. data). Interestingly, Rush Ranch, an ancient marsh, also has very reduced low nest survival rate. At Rush Ranch, however, it does not appear to be a significant reduction during any specific period of the breeding season, but rather, a small but consistent reduction in survival rate over all periods. Rush Ranch may provide attractive nesting habitat for Song Sparrows; however, we hypothesize that Rush Ranch may be experiencing higher predator activity throughout the breeding season. Note that Rush Ranch has had consistently low survival rates compared to other mature marsh sites (lowest of such sites in 5 of 8 years).

It is also valuable to contrast these two sites with China Camp and Benicia State Park, two sites with significantly higher nest survival. All or most of the increase in total nest survival is the result of higher nest survival during the incubation period (Table 4). Furthermore, the difference in nest survival rates between Rush Ranch on the one hand and China Camp and Benicia on the other is due to differences in predation rates. These latter sites may support reduced predator populations or reduced access to nests by predators. We observed the highest nest survival at Pond 2A, where survival rates were higher during all periods of the breeding season. The survival rate during the nestling period for all areas is similar (except perhaps Rush Ranch) and this period is characterized by large amounts of activity and movement at or near the nest. Since the most common cause of nest failure is predation, the difference between mortality rates during the egg stage and the nestling stage is likely due to differences in predation rates, though mortality due to flooding is also greater during the nestling stage.

In comparison, Song Sparrow nest survival estimates are lower than for Red-winged Blackbirds, which was the only other species with enough nesting data to estimate specific site/year nest survival rates (estimated overall daily nest survival for Red-winged Blackbirds: 2002 Rush Ranch: 0.929; 2003 Benicia SP: 0.966; 2004 Carl's Marsh: 0.964). Red-winged blackbirds do not experience the significant drop in nest survival during the nestling stage. Instead, nest survival appears to be much more constant through the entire breeding period (PRBO unpubl. data).

In all cases overall nest success (estimated as the proportion of the total nests found that successfully fledged at least one young) showed relationships similar to the nest survival rates (Table 4, Table 5).

Reproductive success is not only related to nest success, but is also a function of the number of attempts to nest each season. There is considerable variation across sites in both the number of attempts per pair as well as the success of the nesting attempt (Table 6). In this preliminary analysis, no differentiation is made as to whether previous attempts were successful. In 2004, on average, there were only half as many second nesting attempts as there were first nests. This varied from China Camp where the number of first and second attempts was similar to locations such as Benicia where there were many fewer second attempts. In China Camp, nest initiation begins three weeks earlier than in the eastern sites (PRBO unpubl. data) and it may be that this early start to breeding allows birds to more easily attempt a second nest. However, in all sites, three or more nesting attempts by an individual pair were very limited, and in most cases these nesting attempts resulted in failure. Nest success for nest attempts greater than two was only 0.061.

<u>Salt marsh Common Yellowthroat</u>

Densities - At the bay level, densities of Common Yellowthroat were at or slightly above long-term averages (Figure 2b). Densities were much higher in Suisun than San Pablo Bay, and lowest in San Francisco Bay. Tracking changes in Common Yellowthroat density is difficult using standard point count density indices, as variability is high. While some preliminary analyses have already been performed using distance sampling, we hope to implement this method to a greater extent, making use of improved statistical capabilities of the program DISTANCE, and thus examine trends in the population with greater statistical power (cf. Nur et al. 1997, Buckland et al. 2001).

Reproductive success - Common Yellowthroat nests are difficult to find. Since 2000, a total of 21 nests have been found, and in only 14 of these was the fate of the nesting attempt known. A total of six nests were confirmed to have fledged at least one young (see Table 5 for 2004 data; 2000-2003 PRBO unpubl. data). These data suggest nest success rates close to that observed with Song Sparrows, as does an estimate of daily nest survival across all sites and years using 7 nests (daily survival rate of nest: 0.935;

nest survival rate: 0.219). Developing a method that improves our ability to estimate Common Yellowthroat nesting success is a high priority for future tidal marsh research. Maintaining and expanding long-term nesting research efforts in the Suisun Bay (where Common Yellowthroat are by far the most abundant) will be essential.

<u>Marsh Wren</u>

Densities - While a small but long term increase in Marsh Wren density may have occurred within the Suisun Bay, the increase in density is more pronounced within San Pablo Bay, where Marsh Wren densities have doubled since 1996 (Figure 2c). Marsh Wrens appear to numerically respond quickly to marsh restoration, and many of the newly restored marshes contain high densities of Marsh Wrens. However, Marsh Wrens are similar to Common Yellowthroats, in that they require tall vegetation for nesting, and therefore, many of these new sites that contain high numbers of Marsh Wren, may not contain significant breeding populations at this time.

Reproductive Success - In 2004 we found significant numbers of Marsh Wren nests within the nest-monitoring sites; primarily within the recently restored Pond 2A and Petaluma River Marsh (Carl's Marsh). Of 19 Marsh Wren nests whose fates were known, 8 were known to be successful (Table 5). This nest success rate was higher than any other nesting species.

<u>Restoration sites</u>

Restoration sites are rapidly changing in both the vegetation and habitat structure for territory and nesting, as well as food resources for breeding birds. In addition, as restoration marshes become more productive, these marshes will attract more species, increasing competition and predation. Therefore in order to assess the current ability of specific marsh sites to support the tidal marsh avian community (and in particular sensitive species and species of special concern) tracking changes to avian numbers, reproductive success, and demographics is extremely important. PRBO is committed to monitoring restoration sites as well as ancient marshes, in order to assess trends in the avian community within the estuary. In 2004, density indices at all the focal restoration and ancient marshes were relatively unchanged (Figure 4a-g). In 2003, at Rush Ranch, Marsh Wren density was the lowest observed since 1996. In 2004, Marsh Wren densities increased, but still were below the long-term average for the site (Figure 4g).

In contrast to China Camp (an ancient San Pablo Bay marsh), more recently restored San Pablo Bay marshes including Pond 2a and Petaluma River Marsh (Carl's Marsh), have lower Song Sparrow densities (Figure 4a, 4b, 4c, respectively), though densities of Song Sparrows at Benicia and Rush Ranch were lower than at the San Pablo restoration marshes. More striking, are the higher densities of Marsh Wren observed in the newly restored marsh sites, compared to ancient sites. The difference was most pronounced when comparing China Camp to restoration sites (a 20-fold difference); at Benicia and Rush Ranch, the difference is much reduced (a 2 to 3-fold difference). Marsh Wrens are highly aggressive and territorial, and the significant numbers in these newly restored marshes may be a limiting factor to increased Song Sparrow densities and reproductive success. Whether or not Marsh Wren density will decrease with marsh age or whether Marsh Wrens have a deleterious effect on Song Sparrow reproductive success are important questions that could have significant impacts to Marsh restoration strategies. PRBO will continue to monitor these important sites to further examine the ecological processes linked with marsh restoration.

Territory density

Estimates of density using territory mapping are usually higher than estimates using raw point count data (without using distance-based analyses) as much more time is spent within a specific area and, therefore, detection rates are higher. However, Song sparrow territories showed the general pattern we observed within point count survey data (Table 8). There was variation both within and among marsh sites. However, this variation can be a result of 1) actual density differences, 2) differences in detectability due to habitat or behavior, and 3) certain sites or regions may take considerably more effort to survey. In the future we will try to examine methods of controlling for much of the variation associated with sampling and effort.

Banding Data

In 2004, banding effort at nest-monitoring sites was similar to past years (Table 9). In future years, we expect to use these data to estimate specific demographic parameters such as survival and dispersal.

Effects of Lepidium (this section from Spautz and Nur 2004)

We found *Lepidium* more commonly in Suisun Bay and San Pablo Bay than in San Francisco Bay (Figure 5). Because there is no current intensively field-documented map of *Lepidium* distribution in the region, it is not clear whether the relatively lower levels of *Lepidium* in San Francisco Bay in our data reflect realities in the field. It is clear however, that *Lepidium* has extensively invaded more of the brackish marshes in Suisun Bay, such as Rush Ranch, than it has PRBO's study sites in the South San Francisco Bay.

We showed that there were generally positive associations between *Lepidium* and all bird metrics except Black Rail; but that when controlling for variation among Bays, marshes, and other local habitat scale characteristics, these relationships were not significant, except with Common Yellowthroat (Table 7, see also Spautz and Nur 2004). Thus only the Common Yellowthroat was associated specifically with *Lepidium*, and this response led to a higher probability of Common Yellowthroats occurring where *Lepidium* cover was highest. Using nesting data on our most common marsh nesting species, the Song Sparrow, and controlling for variation among sites, nests built in *Lepidium* were neither more nor less likely to fail for any reason. Song Sparrow territories with more *Lepidium* were closer together, implying that *Lepidium* may actually be associated with higher habitat quality as perceived by the Song Sparrows. There is significant overlap in distribution of Clapper Rails and *Lepidium*, but more information is needed to determine whether *Lepidium* is likely to invade areas currently of high quality for Clapper Rails, and what the impacts are likely to be. We also recommend additional studies of the impacts of *Lepidium* on the Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*), on invertebrates, on native plants, and on the tidal marsh food chain in marshes across the estuarine salinity gradient.

GOALS FOR 2005

We believe that the collection of long-term data at a variety of locations and of contrasting site types (e.g., ancient vs. restored) is an important strategy towards tracking changes in the health of the San Francisco Estuary. Therefore, we will continue to monitor and collect habitat data at all of our long-term nest-monitoring study sites (China Camp State Park, Benicia State Park, and Rush Ranch) as well as their newly “paired” long-term restoration monitoring sites (Petaluma River Marsh (Carl’s Marsh), and Pond 2A). In addition, we will continue to monitor marsh bird abundance and diversity at additional ancient and restored sites (e.g., Greenpoint restoration marsh, Black John Slough (an ancient marsh), White Slough). It is also hoped that in the future, an additional restoration site in Suisun can be initiated to pair with the Rush Ranch site.

PRBO will also continue to conduct point count and area surveys at a majority of our long-term sites throughout the San Francisco Estuary. PRBO will develop several studies directed at reducing the variability associated with point count sampling. Through refined field methods such as double-observer point counts (Nichols et al. 2000), and by examining others ways to reduce sampling variability through small changes in study design, or survey effort, it is hoped that we will be able to increase our ability to track changes for all tidal marsh birds.

Since 1996, PRBO has maintained a banding program within the long-term monitoring sites. In 2005, PRBO hopes to expand banding effort at our long-terms sites, as well as begin to analyze and track trends in demographic variables such as survival and dispersal and examine the differences between old and young marshes.

Finally in 2005, PRBO will begin the first year of a 2 year project to assess Clapper Rail populations throughout the San Francisco Estuary. PRBO, in conjunction with Avocet Research Associates, and other groups, will survey over 60 sites in 2005 and 2006. In addition, 18-20 of these sites will be sampled in both years. The product will be the first San Francisco Estuary wide assessment of Clapper Rail populations since 1992-93.

LIST OF PRBO PRODUCTS RELATED TO TIDAL MARSH WORK IN 2004

In 2004, PRBO produced a number of papers and presentations that have examined much of what is discussed in this annual report, but at greater detail. Below is a list of peer-reviewed articles, internal PRBO reports, and talks/posters that have abstracts available. Please feel free to contact PRBO to receive a reprint of any of these papers.

Peer-reviewed articles

Greenberg, R., N. Nur, H. Spautz, J. C. Nordby, P. Marra, B. Schmeling, C. Djerdum, B. Olson, G. Shriver, M. Winter, J. Williams, and C. Elphick. (in press). *Between the* *devil and the deep blue sea: nesting ecology of tidal marsh sparrows.* Proceedings of the Vertebrates of Tidal Marshes Symposium, October 24-26, 2002, Patuxent, MD. Studies in Avian Biology

Spautz, H., N. Nur, D. Stralberg, and Y. Chan. (in press). *Multiple-scale predictors of tidal marsh breeding bird abundance and distribution in the San Francisco Estuary*. Proceedings of the Vertebrates of Tidal Marshes Symposium, October 24-26, 2002, Patuxent, MD. Studies in Avian Biology

Takekawa, J., I. Woo, H. Spautz, N. Nur, L. Grenier, K. Malamud-Roam, C. Nordby, A. Cohen, F. Malamud-Roam, and S. Wainwright-De La Cruz (in press) *Environmental threats to tidal marsh vertebrates of the San Francisco Estuary.* Proceedings of the Vertebrates of Tidal Marshes Symposium, October 24-26, 2002, Patuxent, MD. Studies in Avian Biology

PRBO Reports

Spautz, H. and N. Nur. 2004. *Impacts of non-native perennial Pepperweed* (Lepidium latifolium) *on abundance, distribution, and reproductive success of San Francisco Bay tidal marsh birds.* A report to the US Fish and Wildlife Service, Coastal Program. Available from: http://www.prbo.org/cms/docs/wetlands/lepidium04.pdf

Presentations

Nur, N., H. Spautz, D. Stralberg and N. Warnock. 2004. *Tidal marsh birds of Suisun Marsh: Population status, habitat associations and patterns of reproductive success.* Oral presentation at the Suisun Marsh Workshop, Bay Delta Science Consortium, March 2004.

Nur, N., H. Spautz, D. Stralberg and N. Warnock. 2004. *Response of avian populations to tidal marsh restoration in the San Francisco Estuary*. Poster paper presented at the Third Biennial CALFED Bay-Delta Program Science Conference. Sacramento, CA. October 4-6, 2004.

Nur, N., H. Spautz, N. Warnock, J. Evens, J. Kelly, L. Liu, J. Harley and M. Herzog. 2004. *IRWM pilot project: Monitoring birds in tidal wetlands of the San Francisco*

Estuary. Poster paper presented at the Third Biennial CALFED Bay-Delta Program Science Conference. Sacramento, CA. October 4-6, 2004.

Simenstad, C, M. Orr, S. Crooks, H. Spautz, M. Vasey and D. Reed. 2004. *Vegetation structure along the Bay-Delta wetland restoration gradient.* Poster paper presented at the Third Biennial CALFED Bay-Delta Program Science Conference. Sacramento, CA. October 4-6, 2004.

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Table 1. List of marsh sites in San Francisco Bay surveyed during the 2004 breeding season. See also Fig. 1 and 2.

# on map	Site Name	Number of point count stations	Point Count	Vegetation Survey	Nest Plot	Area Survey
	San Pablo Bay					
1	Petaluma Marsh	11	X			
2	Bahia Restoration Marsh	10	X	X		X
3	Black John Slough B	10	X	X		
4	Bahia Peninsula	10	X	X		X
5	Black John Slough A	10	X	X		
6	Green Point Restoration Marsh	6	X	X		
7	Petaluma River Marsh (Carl's Marsh)	10	X	X	X	X
8	Corte Madera Ecological Reserve	10	X	X		
9	China Camp A and B	16	X	X	X	
10	China Camp Fragments	2	X			
11	Petaluma River Mouth	10	X	X		
12	Lower Tubbs Island	8	X	X		
13	Tolay Creek	7	X			
14	Tubbs Island Levee Setback	n/a				X
15	Coon Island	10	X	X		X
16	Pond 2A Restoration	10	X	X	X	X
17	Bull Island	10	X	X		X
18	Mare Island A	10	X	X		
19	Mare Island B	10	X	X		
20	White Slough Marsh	5	X	X		
	Delta					
33	Brown's Island	10	X	X		X
34	Sherman Island	10	X	X		X

Table 1 (continued). List of marsh sites in San Francisco Bay surveyed during the 2004 breeding season. See also Fig. 1 and 2.

# on map	Site Name	Number of point count stations	Point Count	Vegetation Survey	Nest Plot	Area Survey
	Suisun Bay					
21	Benicia State Park	10	X	X	X	
22	Goodyear B	10	X			
23	Bullhead Marsh	10	X	X		
24	Pt. Edith	17	X	X		
25	Grey Goose	6	X	X		
26	Sheldrake House Pond	8	X	X		X
27	Pt Edith Restoration	6	X			
28	Rush Ranch A	10	X	X	X	
29	Hill Slough West Restoration	10	X	X		X
30	Delta King	12	X	X		X
31	Blacklock	10	X	X		X
32	Overlook	9	X	X		
	San Francisco Bay					
35	Hoffman Marsh	5		X		
36	Emeryville Crescent	5	X	X		
37	Inner Bair Island	13	X			
38	Outer Bair West	3	X			
39	Outer Bair East	11	X			
40	Hayward Regional Shoreline	11	X	X		
41	Whaletail	6	X	X		
42	Faber-Laumeister tract	11	X	X		
43	Palo Alto Baylands	9	X	X		
44	Dumbarton West	13	X	X		
45	Newark Slough	7	X	X		
46	New Chicago Marsh	6	X	X		

Table 2. Total number of birds detected in San Francisco Bay tidal marshes during breeding season survey; detections within 100 m, excluding flyovers.

# on map	Site Name	Black Rail	Clapper Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Song Sparrow	Species Richness
	San Pablo Bay							
1	Petaluma Marsh	7	0	78	189	32	210	20
2	Bahia Restoration Marsh	0	0	0	0	20	4	11
3	Black John Slough B	6	0	36	5	24	136	18
4	Bahia Peninsula	0	1	0	0	63	3	21
5	Black John Slough A	1	0	27	20	18	120	18
6	Green Point Restoration Marsh	0	0	8	64	1	69	18
7	Petaluma River Marsh (Carl's Marsh)	2	0	2	73	31	165	24
8	Corte Madera Ecological Reserve	1	0	1	0	11	110	17
9	China Camp A and B	19	0	0	3	1	372	20
10	China Camp Fragments	0	0	0	0	0	17	14
11	Petaluma River Mouth	5	0	2	0	0	112	17
12	Lower Tubbs Island	4	0	13	95	1	180	27
13	Tolay Creek	0	0	2	2	34	50	19
14	Tubbs Island Levee Setback	No point count surveys in 2004						
15	Coon Island	10	1	19	83	0	287	12
16	Pond 2A Restoration	2	0	34	118	0	190	15
17	Bull Island	2	0	24	169	4	174	15
18	Mare Island A	10	0	0	0	0	66	3
19	Mare Island B	3	0	0	4	7	174	7
20	White Slough Marsh	0	0	7	56	0	47	17
	Delta							
33	Brown's Island	3	0	34	142	0	133	21
34	Sherman Island	7	0	66	109	11	170	18

Table 2 (continued). Total number of birds detected during breeding season survey; detections within 100 m, excluding flyovers.

# on map	Site Name	Black Rail	Clapper Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Song Sparrow	Species Richness
	Suisun Bay							
21	Benicia State Park	7	0	16	41	53	80	20
22	Goodyear B	1	0	56	106	2	143	19
23	Bullhead Marsh	7	0	70	76	1	123	16
24	Pt. Edith	10	0	16	62	11	100	25
25	Grey Goose	0	0	48	27	6	46	14
26	Sheldrake House Pond	0	0	13	26	55	18	12
27	Pt Edith Restoration	0	0	21	47	7	94	14
28	Rush Ranch A	7	0	41	64	109	86	12
29	Hill Slough West Restoration							
30	Delta King							
31	Blacklock	0	0	4	29	0	25	12
32	Overlook							
	San Francisco Bay							
35	Hoffman Marsh	No point count surveys in 2004						
36	Emeryville Crescent	0	0	0	0	0	59	17
37	Inner Bair Island	0	0	0	0	7	34	35
38	Outer Bair West	0	0	0	0	0	6	5
39	Outer Bair East	0	0	0	11	0	84	25
40	Hayward Regional Shoreline	0	1	0	37	3	59	30
41	Whaletail	0	0	0	7	0	39	9
42	Faber-Laumeister tract	0	5	11	6	18	64	19
43	Palo Alto Baylands	2	7	4	21	4	116	34
44	Dumbarton West	0	1	8	8	0	190	14
45	Newark Slough	0	0	0	2	0	47	10
46	New Chicago Marsh	0	0	0	0	7	15	15

Table 3. Mean relative abundance over two breeding season site visits (birds/ha); based on variable circular plots and detections within 50 m. (standard error in parentheses)

# on map	Site Name	Black Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Savannah Sparrow	Song Sparrow
	San Pablo Bay						
1	Petaluma Marsh	0.58 (0.28)	0.23 (0.18)	1.22 (0.30)	0.06 (0.09)	0 (0)	4.05 (0.46)
2	Bahia Restoration Marsh	0 (0)	0 (0)	0 (0)	5.90 (5.20)	2.95 (1.90)	0 (0)
3	Black John Slough B	0.32 (0.27)	1.41 (0.50)	0.13 (0.13)	0.70 (0.20)	0.25 (0.13)	6.37 (0.82)
4	Bahia Peninsula	0	0	0	5.92	0.57	0.50
5	Black John Slough A	0 (0)	1.06 (0.39)	0.57 (0.24)	0.49 (0.19)	0 (0)	5.21 (0.79)
6	Green Point Restoration Marsh	0 (0)	0.33 (0.27)	4.83 (1.31)	0 (0)	0 (0)	4.51 (0.78)
7	Petaluma River Marsh (Carl's Marsh)	0.08 (0.12)	0 (0)	3.73 (0.45)	0.13 (0.19)	0 (0)	5.53 (1.26)
8	Corte Madera Ecological Reserve	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3.45 (0.53)
9	China Camp A and B	0.44 (0.19)	0 (0)	0.04 (0.06)	0 (0)	0 (0)	8.00 (0.69)
10	China Camp Fragments	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3.89 (1.55)
11	Petaluma River Mouth	0 (0)	0.06 (0.15)	0 (0)	0 (0)	0 (0)	4.97 (2.10)
12	Lower Tubbs Island	0.64 (0)	0.16 (0.23)	4.56 (0.77)	0 (0)	0 (0)	11.49 (1.33)
13	Tolay Creek	0 (0)	0.36 (0)	0.09 (0.15)	2.64 (3.62)	0.36 (0.60)	3.73 (0.65)
14	Tubbs Island Levee Setback	No point count surveys in 2004					
15	Coon Island	0.42 (0.37)	0.42 (0.20)	2.76 (0.54)	0 (0)	0 (0)	8.13 (0.93)
16	Pond 2A Restoration	0.13 (0.19)	0.62 (0.32)	4.09 (0.62)	0 (0)	0 (0)	5.32 (1.09)
17	Bull Island	0.06 (0.09)	0.66 (0.26)	9.68 (1.55)	0.13 (0.13)	0 (0)	5.58 (1.02)
18	Mare Island A	0.47 (0.30)	0 (0)	0 (0)	0 (0)	0 (0)	2.31 (0.49)
19	Mare Island B	0.14 (0.13)	0 (0)	0.20 (0.20)	0.29 (0.29)	0.08 (0.09)	5.90 (0.39)
20	White Slough Marsh	0 (0)	1.03 (0.58)	8.83 (0.54)	0 (0)	0 (0)	8.93 (2.67)
	Delta						
33	Brown's Island	0.06 (0.09)	1.27 (0.40)	5.54 (0.43)	0 (0)	0 (0)	3.12 (0.87)
34	Sherman Island	0.19 (0.16)	1.72 (0.30)	3.70 (0.69)	0.45 (0.24)	0 (0)	5.36 (0.69)

Table 3 (continued). Mean relative abundance over two breeding season site visits (birds/ha); based on variable circular plots and detections within 50 m. (standard error in parentheses)

# on map	Site Name	Black Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Savannah Sparrow	Song Sparrow
	Suisun Bay						
21	Benicia State Park	0.21 (0.10)	0.35 (0.26)	1.49 (0.17)	1.70 (1.04)	0 (0)	3.54 (0.37)
22	Goodyear B	0 (0)	2.93 (0.36)	6.43 (0.59)	0.13 (0.13)	0.38 (0.22)	6.56 (0.68)
23	Bullhead Marsh	0.32 (0.26)	4.14 (0.52)	5.94 (0.69)	0 (0)	0.13 (0.14)	7.41 (0.91)
24	Pt. Edith	0.39 (0.19)	2.83 (0.36)	7.92 (1.64)	0.59 (0.34)	0 (0)	6.07 (0.89)
25	Grey Goose	0	9.35	6.23	1.28	1.82	9.39
26	Sheldrake House Pond	0 (0)	2.93	5.73	1.34	0.51	3.82
27	Pt Edith Restoration	0 (0)	1.93 (1.24)	3.89 (1.86)	0.42 (0.42)	0 (0)	8.19 (1.53)
28	Rush Ranch A	0.13 (0)	1.35 (0.37)	2.23 (0.22)	3.07 (1.03)	0 (0)	3.62 (0.82)
29	Hill Slough West Restoration	0 (0)	0.25	1.15	0.25	0.38	3.44
30	Delta King	0	0.53	0.54	0.11	0.64	2.33
31	Blacklock	0	0.85	5.79	0	1.32	4.96
32	Overlook	0 (0)	1.27	1.7	0.28	0	4.48
	San Francisco Bay						
35	Hoffman Marsh	No point count surveys in 2004					
36	Emeryville Crescent	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5.37 (0.95)
37	Inner Bair Island	0 (0)	0 (0)	0 (0)	0.21 (0.36)	0.95 (0.78)	2.19 (1.16)
38	Outer Bair West	0 (0)	0 (0)	0 (0)	0 (0)	1.70 (0)	5.09 (0)
39	Outer Bair East	0 (0)	0 (0)	0.41 (0.24)	0 (0)	0.69 (0.22)	2.97 (0.67)
40	Hayward Regional Shoreline	0 (0)	0 (0)	1.26 (0.38)	0 (0)	0.35 (0.28)	1.90 (0.54)
41	Whaletail	0	0	1.49	0	1.49	5.52
42	Faber-Laumeister tract	0 (0)	1.22 (0.45)	0 (0)	1.85 (4.80)	0 (0)	2.97 (1.04)
43	Palo Alto Baylands	0.11 (0.15)	0.14 (0.14)	0.43 (0.22)	0 (0)	0 (0)	6.51 (1.17)
44	Dumbarton West	0 (0)	0.28 (0.19)	0.26 (0.28)	0 (0)	0.06 (0.09)	4.90 (1.10)
45	Newark Slough	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5.04 (1.20)
46	New Chicago Marsh	0 (0)	0 (0)	0 (0)	0.42 (0)	0 (0)	2.07 (1.50)

Table 4. Song Sparrow nest survival probability: Mayfield method and proportion of nests successful. A comparison of San Pablo Bay Song Sparrow (*Melospiza melodia samuelis*) at China Camp State Park, Carl's Marsh, and Pond 2A and Suisun Song Sparrow (*M. m. maxillaris*) at Benicia State Park and Rush Ranch for the 2004 field season. Overall nest survival rate for entire nesting period is also shown in Figure 4.

Site	Nest Phase	Sample size	Daily Mayfield nest success [1]		Mayfield nest success rate for period [2]	Mayfield period nest success 95% confidence interval		Raw Proportion Successful [3]
			Rate	SE		Lower	Upper	
San Pablo Bay								
China Camp	Overall		0.923	0.008	**0.160**	0.129	0.190	0.217
	Laying / Incubation		0.951	0.008	0.507	0.449	0.565	
	Nestling		0.876	0.016	0.297	0.249	0.346	
Carl's Marsh	Overall		0.886	0.013	**0.064**	0.043	0.085	0.117
	Laying / Incubation		0.895	0.015	0.218	0.170	0.267	
	Nestling		0.865	0.026	0.260	0.193	0.340	
Pond 2A	Overall		0.941	0.019	**0.249**	0.133	0.364	0.222
	Laying / Incubation		0.987	0.013	0.840	0.694	0.987	
	Nestling		0.890	0.037	0.346	0.216	0.476	
Suisun Bay								
Benicia	Overall		0.933	0.011	**0.208**	0.150	0.266	0.291
	Laying / Incubation		0.986	0.007	0.822	0.741	0.902	
	Nestling		0.860	0.024	0.253	0.187	0.318	
Rush Ranch	Overall		0.910	0.027	**0.115**	0.036	0.194	0.111
	Laying / Incubation		0.933	0.026	0.388	0.238	0.538	
	Nestling		0.810	0.086	0.145	0.005	0.285	

1 The Mayfield method of calculating nest survival probability or success takes into account the number of days each nest was under observation (see text)

2 The success rate for each phase or period of the nest cycle is calculated as the daily survival for the period to the nth power where n = the number of days in the period: laying = 1.996 days, incubation = 11.661, nestling = 9.145.

3 The proportion successful is the number of nests that fledged at least one young divided by the total number of active nests found. Here the sample size includes only nests used for Mayfield calculations, i.e. nests observed while still active.

Table 5. Nests of breeding birds located during the 2004 breeding season at tidal marsh study sites in China Camp State Park, Petaluma River Marsh (Carl's Marsh), Pond 2A, Benicia State Park, and Rush Ranch.

Species	China Camp [1]	Petaluma River Marsh (Carl's Marsh) [1]	Pond 2A [1]	Benicia [1]	Rush Ranch [1]	Total nests found [1]
American Goldfinch [2]	1:1(1)	0	0	0	0	1:1(1)
Black Rail	3:2(2)	1:1(1)	0	3:1(1)	0	7:4(4)
Clapper Rail	2:1(1)	0	0	0	0	2:1(1)
Common Yellowthroat	0	1:1(0)	2:1(1)	1:1(0)	2:2(0)	6:5(1)
Mallard [3]	1:1(0)	1:0(0)	0	1:1(1)	0	3:2(1)
Marsh Wren	1:0(0)	29:12(5)	19:7(3)	9:0(0)	6:0(0)	64:19(8)
Ring-necked Pheasant [4]	0	0	0	1:1(1)	0	1:1(1)
Red-winged Blackbird	0	8:7(3)	0	1:1(0)	2:1(0)	11:9(3)
Song Sparrow	143:103(31)	103:76(12)	54:33(12)	141:79(0)	36:25(4)	477:316(59)

1 Total nests found : Total nests of known fate (number of successful nests)
2 Carduelis tristis
3 Anas platyrhynchos
4 Phasianus colchicus

Table 6. Comparison of Song Sparrow nesting success at nest monitoring sites in 2004 breeding season. Shown are proportion of nests that are successful. Ancient marshes shown in *italics*.

	Attempt 1		Attempt 2		Attempt 3		Attempt 4		Attempt 5	
Marsh	**Nests**	**Nest Success**	**Nests**	**Nest Success**	**Nests**	**Nest Success**	**Nests**	**Nest Success**	**Nests**	**Nest Success**
China Camp State Park	*56*	*0.268*	*41*	*0.268*	*8*	*0.000*	*2*	*0.500*	*0*	*0.000*
Petaluma River Marsh	43	0.140	20	0.200	6	0.000	5	0.000	1	0.000
Pond 2A	25	0.280	10	0.400	3	0.000	1	0.000	0	0.000
Benicia State Park	*28*	*0.286*	*12*	*0.250*	*6*	*0.167*	*1*	*0.000*	*0*	*0.000*
Grand Total	152	0.224	83	0.265	23	0.043	9	0.111	1	0.000

Table 7. Relationship between *Lepidium* cover and Common Yellowthroat presence controlling for differences among bays and other habitat variables; data from 2000-2001. Results are from logistic regression showing best-fitting model predicting presence (coded 1) or absence (coded 0) of Common Yellowthroats at each survey point in relation to *Lepidium latifolium* (proportion cover, natural log-transformed), Bay (San Francisco Bay; San Pablo Bay; Suisun Bay) and ten additional local scale variables using backwards step-wise regression. Pseudo R^2 for the model = 0.412; N = 329 survey points. We show the coefficient and *P*-values for the final variables retained and the partial pseudo R^2 for each; P-values are from likelihood ratio tests with 1 degree of freedom, except for test of Bay effect (df = 2). The variables percent total vegetation cover, width of closest channel, number of stems below 30 cm height, and total number of stems were dropped from the final model.

Variable	β Coefficient *P*	Partial R^2
Lepidium cover, log-transformed	$\beta = + 0.610$ $P = 0.009$	0.016
Vegetation species richness	$\beta = + 1.550$ $P = 0.032$	0.011
Vegetation species diversity	$\beta = - 0.179$ $P = 0.009$	0.016
proportion shrub cover	$\beta = + 0.085$ $P = 0.004$	0.020
proportion channel cover	$\beta = - 0.062$ $P = 0.001$	0.032
Distance to closest channel	$\beta = - 0.023$ $P = 0.003$	0.037
Number of stems over 30 cm	$\beta = + 0.284$ $P < 0.001$	0.045
Bay	$P < 0.001$	0.070

Table 8. Song Sparrow territorial densities at nest monitoring sites, 2004. For territory mapping method, please see text.

Marsh	**number of territories**	**area (ha)**	**breeding density (pairs/ha)**	**breeding density (birds/ha)**
China Camp State Park				
Plot A	67	11.49	5.83	11.76
Plot B	69	10.14	6.80	13.60
Total	**136**	**21.63**	**6.29**	**12.58**
Petaluma River Marsh (Carl's Marsh)				
Plot A	38	9.02	4.21	8.42
Plot B	37	13.55	2.73	5.46
Total	**75**	**22.57**	**3.32**	**6.64**
Benicia State Park				
Plot A	71	14.26	4.98	9.96
Plot B	53	13.52	3.92	7.84
Total	**124**	**27.78**	**4.46**	**8.92**
Rush Ranch				
Plot A	41	8.05	5.09	10.18
Plot B	26	21.20	1.23	2.46
Total	**67**	**29.25**	**2.29**	**4.58**

Table 9. Summary of banding effort in 2004 field season (*Italics are ancient marshes*).

Site	**Total Captured**	**Adults**		**Nestlings**
		New	**Recaptures**	
China Camp	*60*	*8*	*3*	*49*
Petaluma River Marsh (Carl's Marsh)	26	5	0	21
Pond 2A	4	0	0	4
Benicia State Park	*46*	*7*	*0*	*39*
Rush Ranch	*11*	*1*	*1*	*9*

Figure 1a. Map of 2004 San Francisco Bay Tidal Marsh Study sites. North Bay region. See Table 1 for site names.

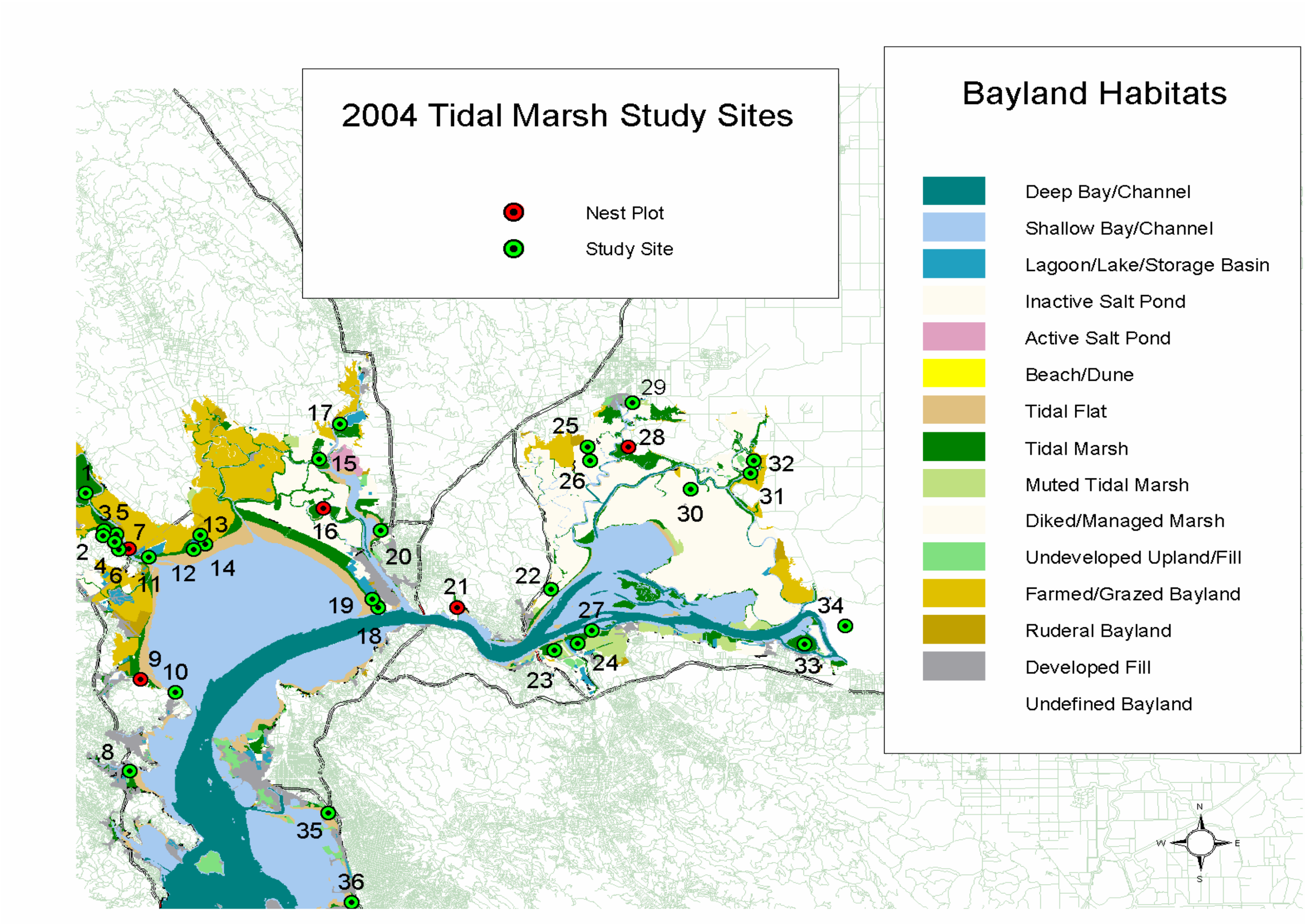

Figure 1b. Map of 2004 San Francisco Bay Tidal Marsh Study sites. South Bay region. See Table 1 for site names.

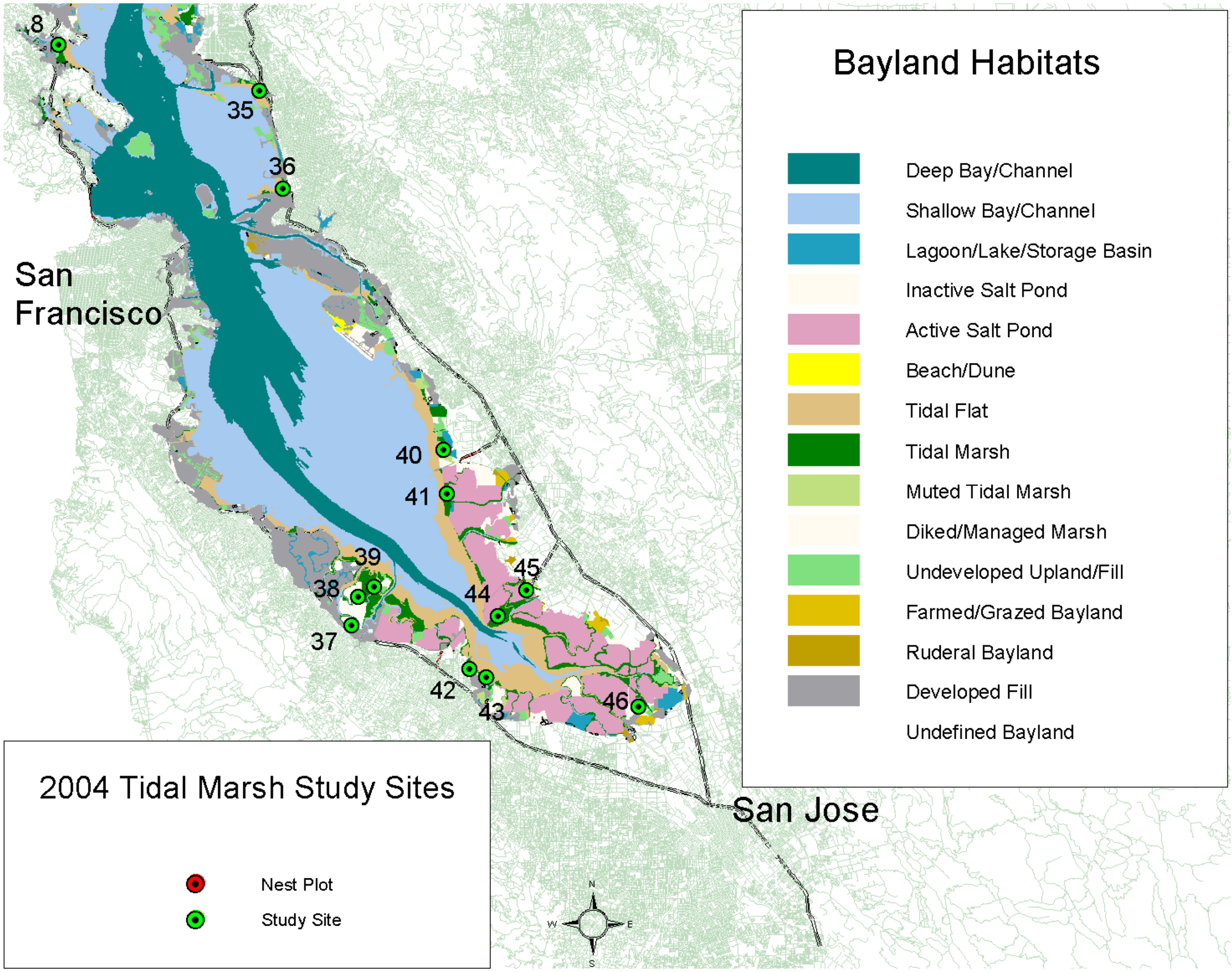

Figure 2a. Adjusted density indices by bay of Song Sparrow in the San Francisco Estuary: 1996-2004.

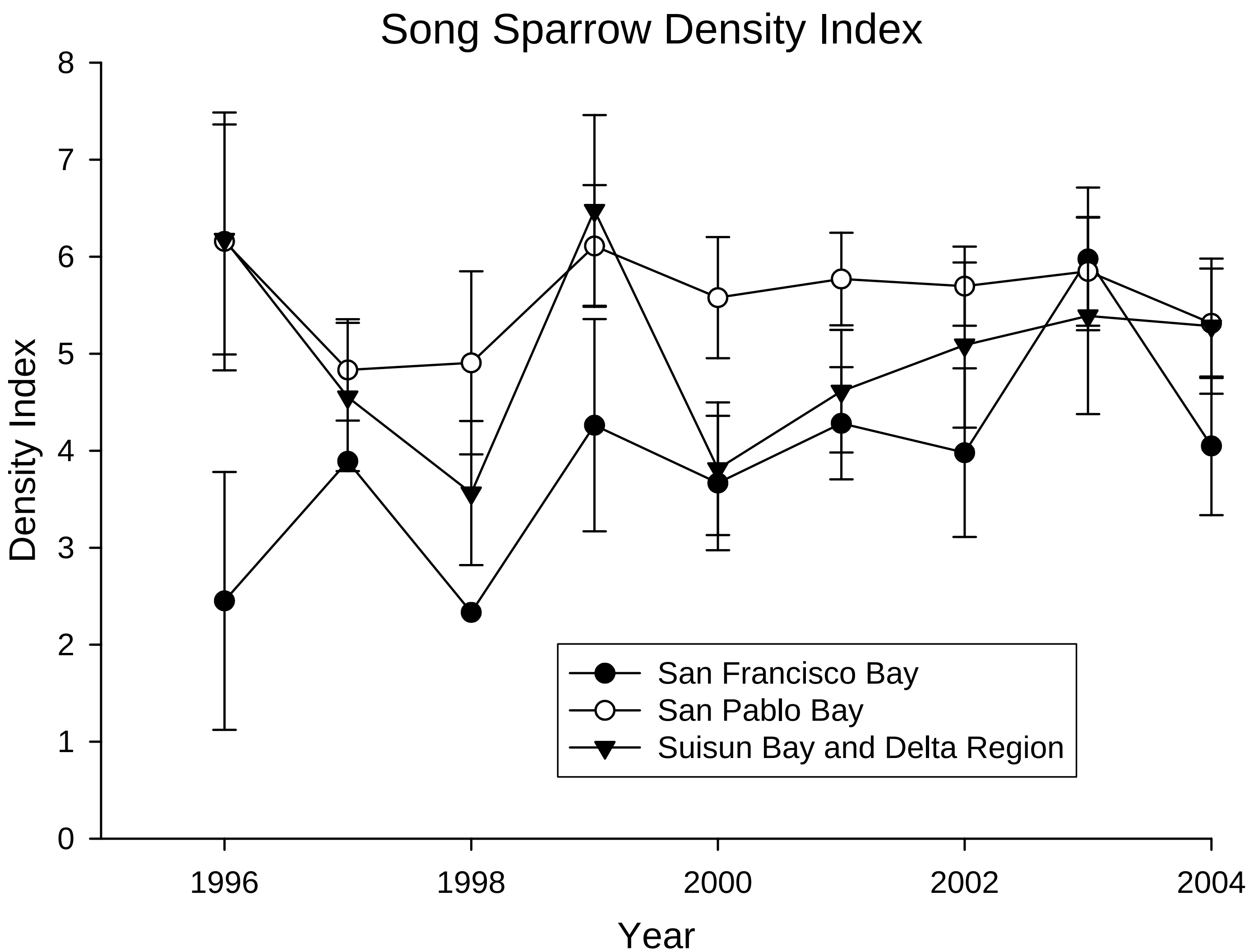

Figure 2b. Adjusted density indices by bay of Salt Marsh Common Yellowthroat in the San Francisco Estuary: 1996-2004.

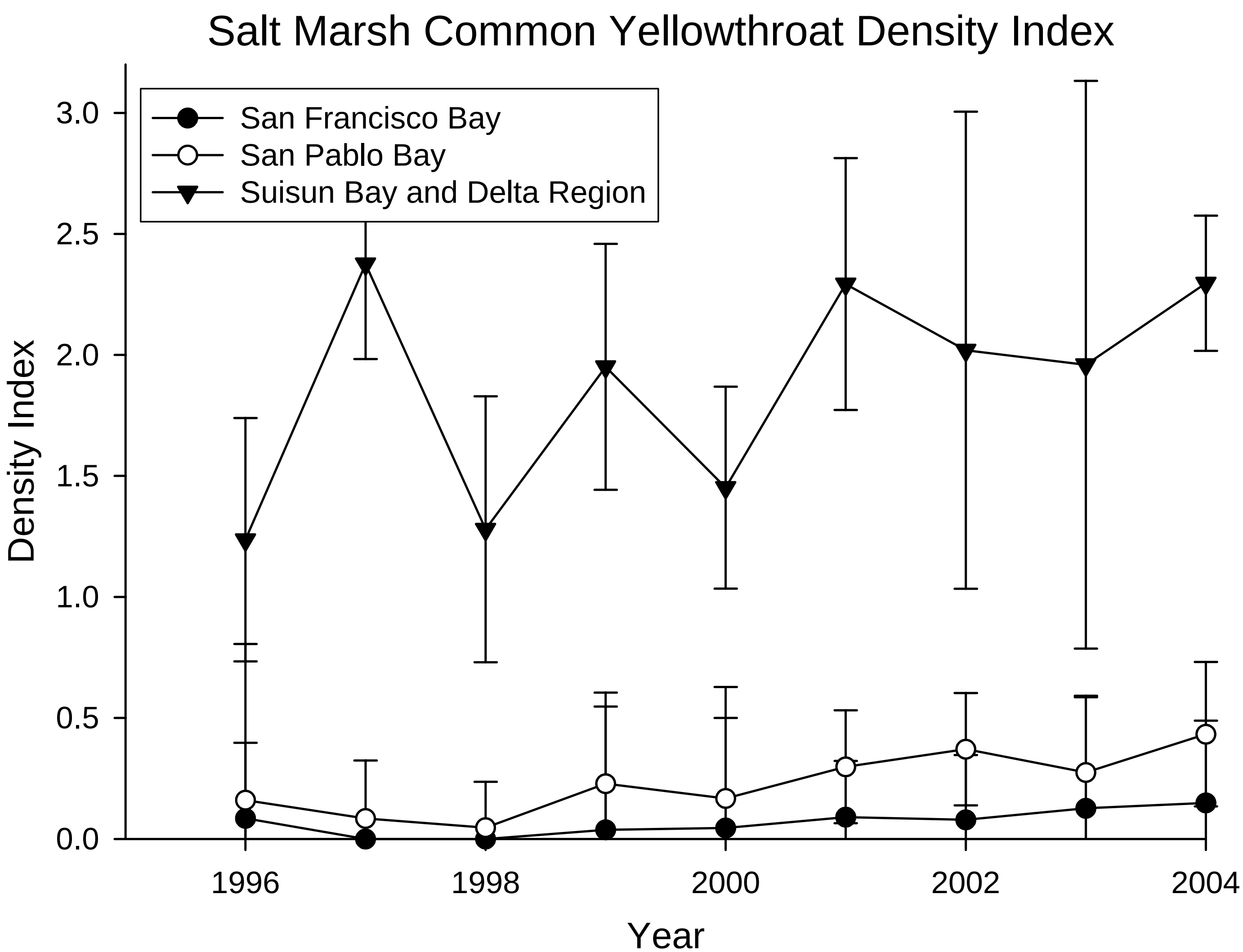

Figure 2c. Adjusted density indices by bay of Marsh Wren in the San Francisco Estuary: 1996-2004.

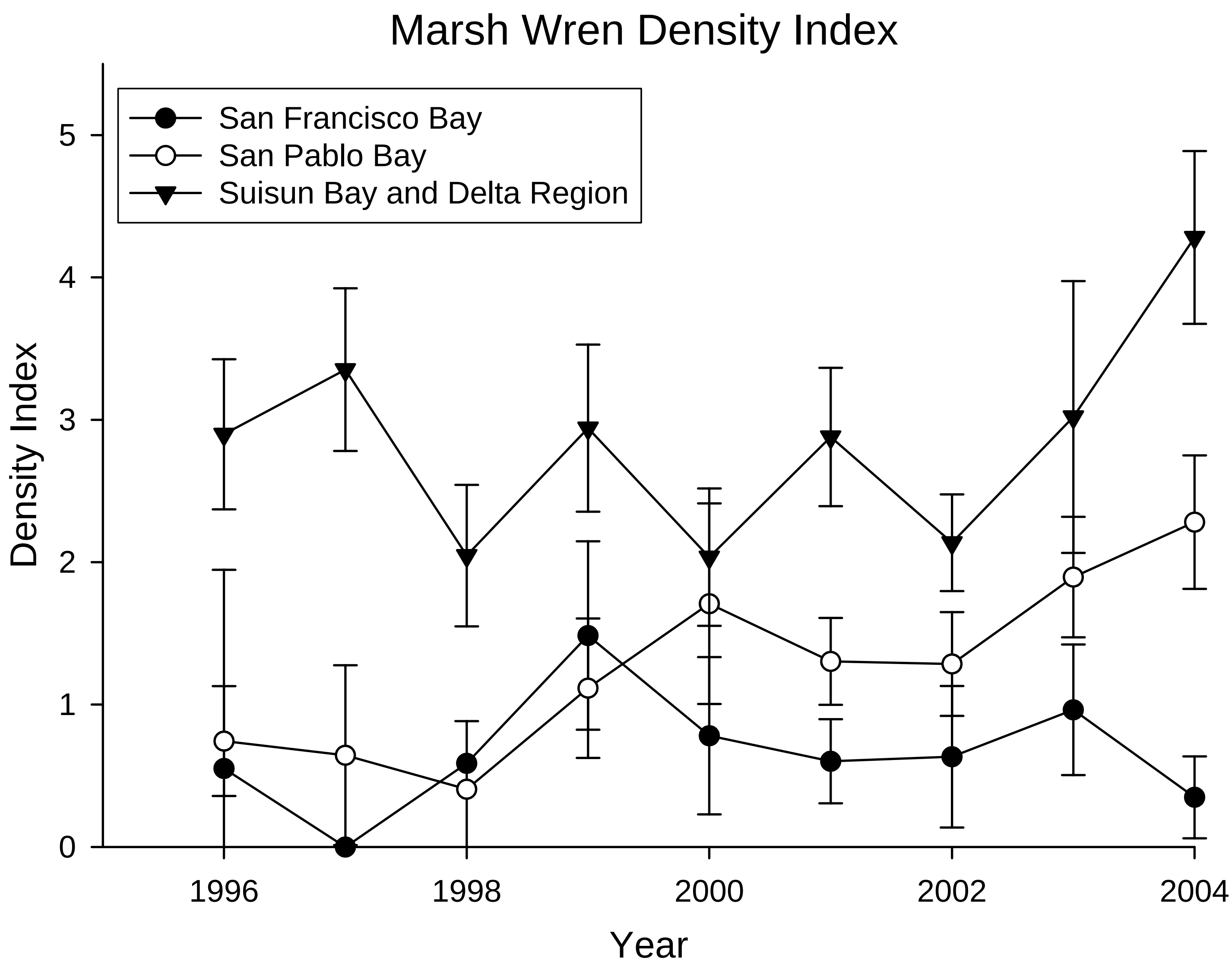

Figure 3. San Francisco Bay tidal marsh Song Sparrow nesting success from 1996 to 2004.

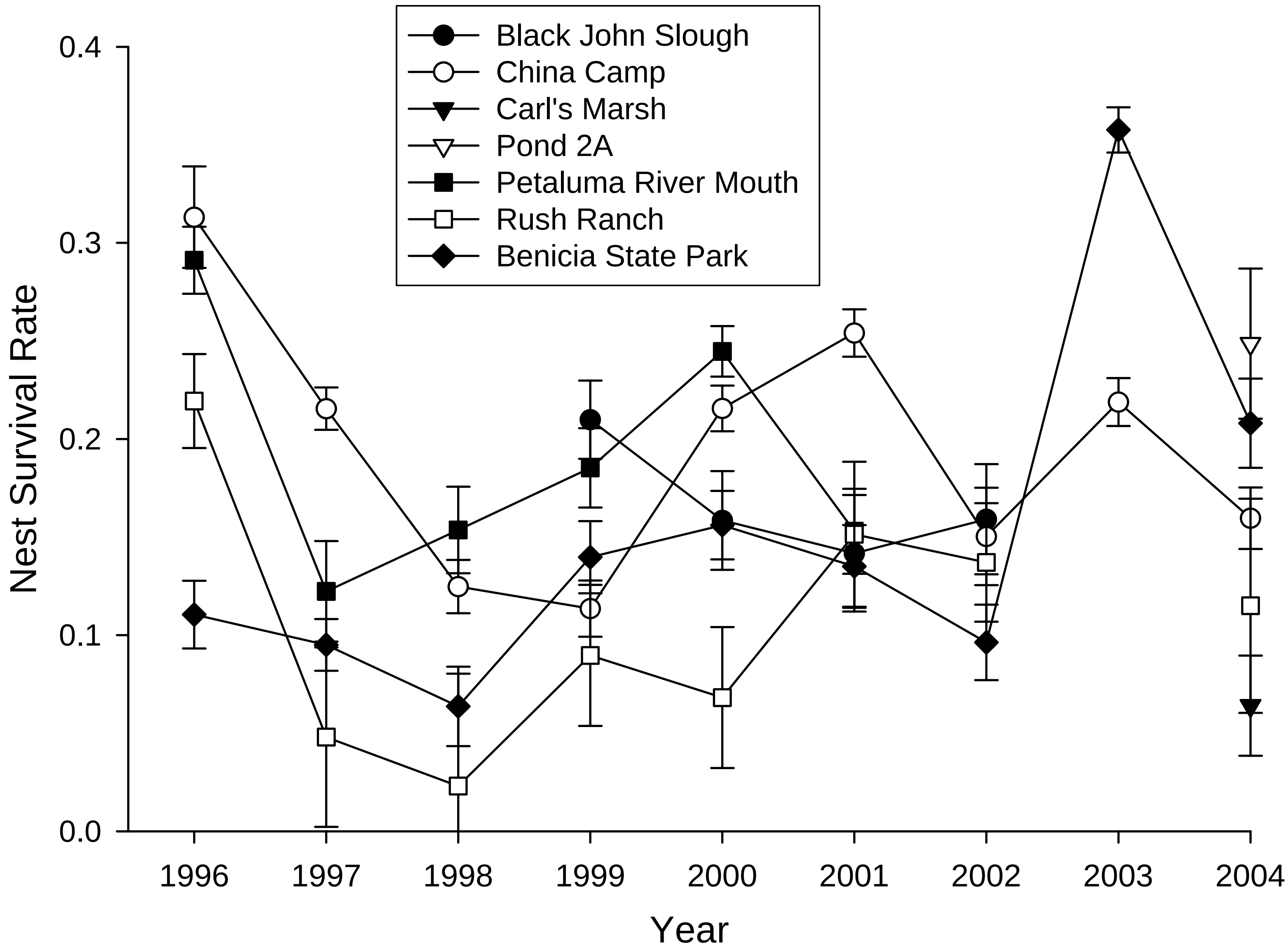

Figure 4a. Population trends of focal avian species at Greenpoint Restoration Marsh.

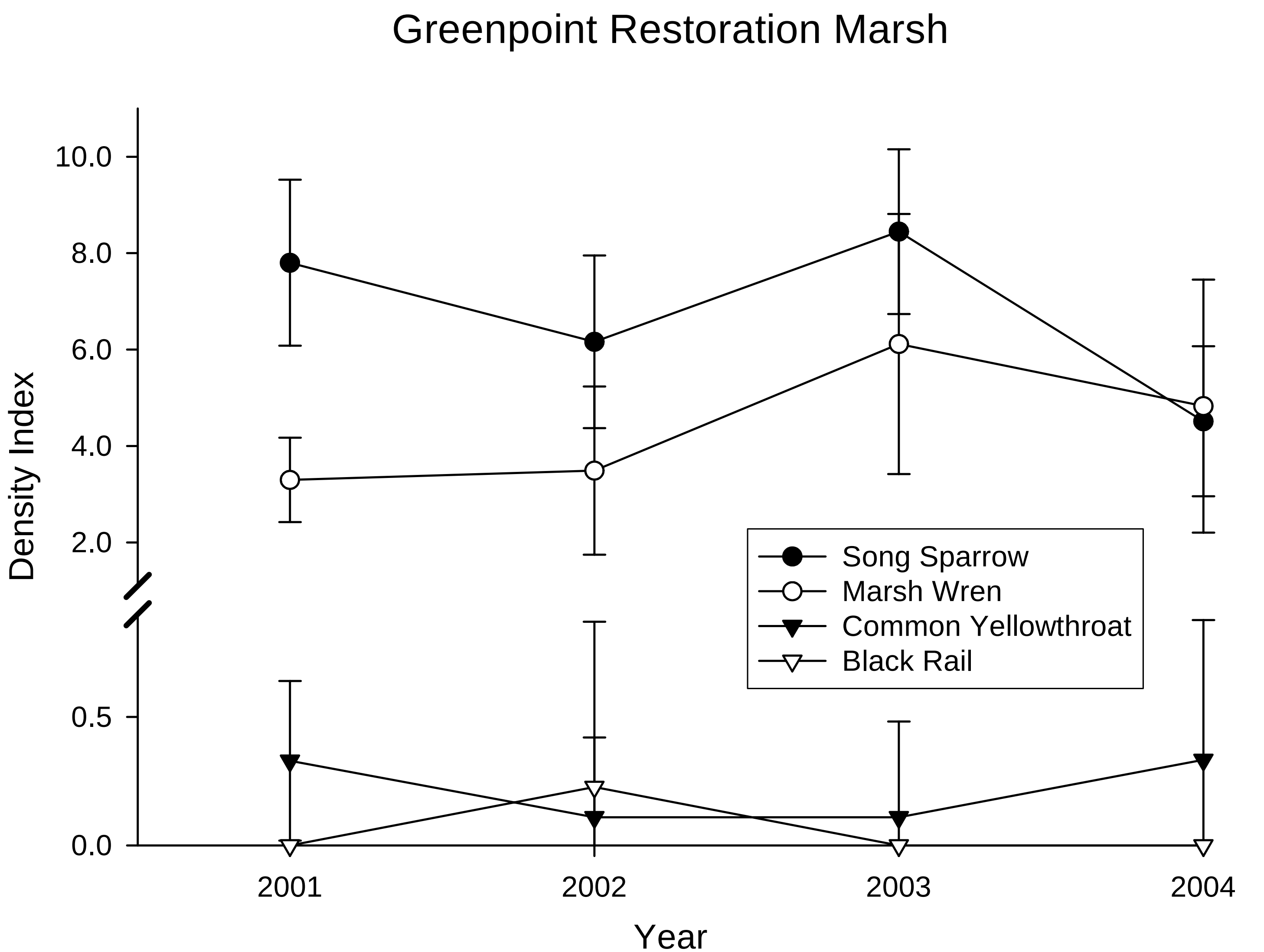

Figure 4b. Population trends of focal avian species at Petaluma River Marsh (Carl's Marsh).

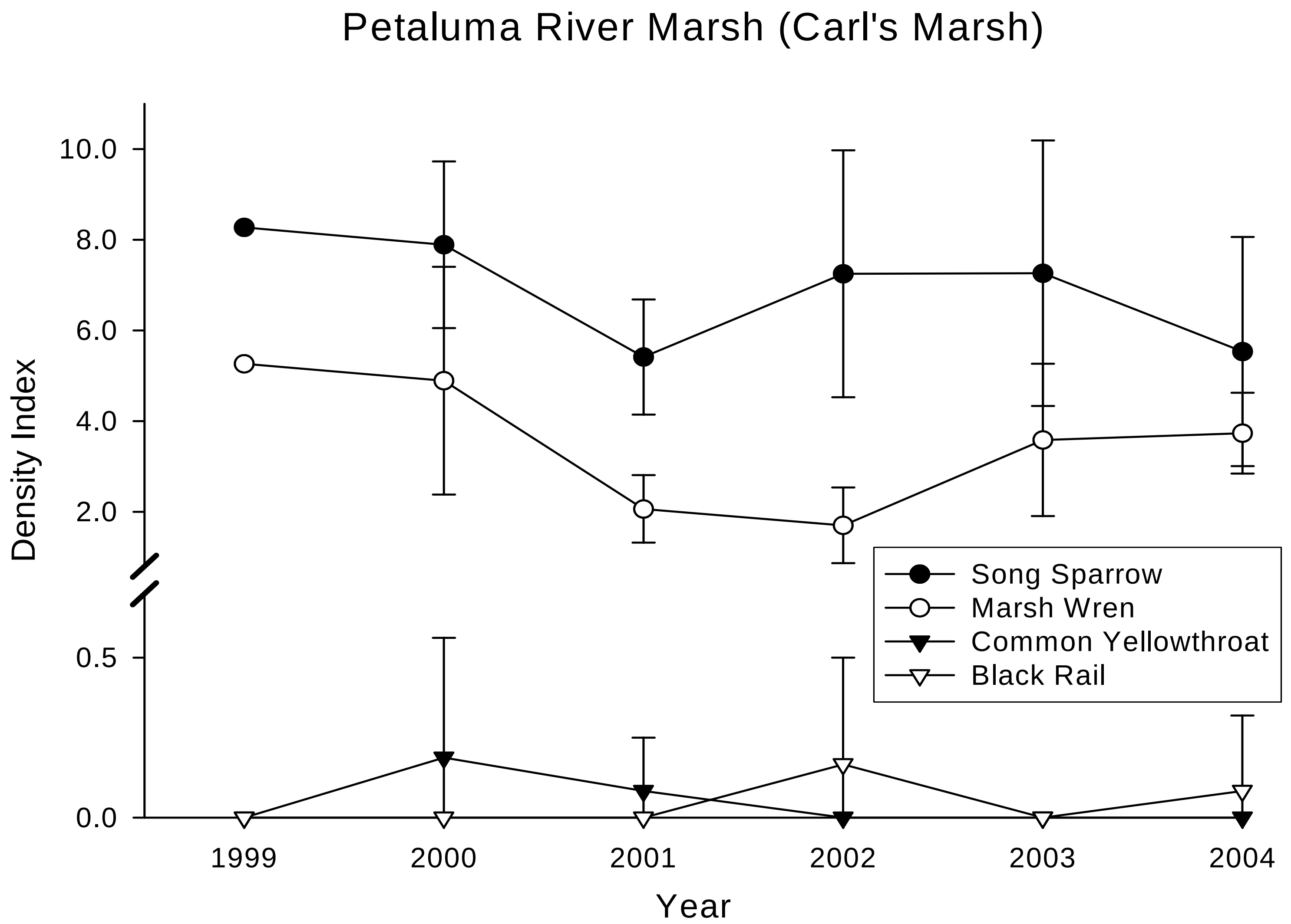

Figure 4c. Population trends of focal avian species at Pond 2A.

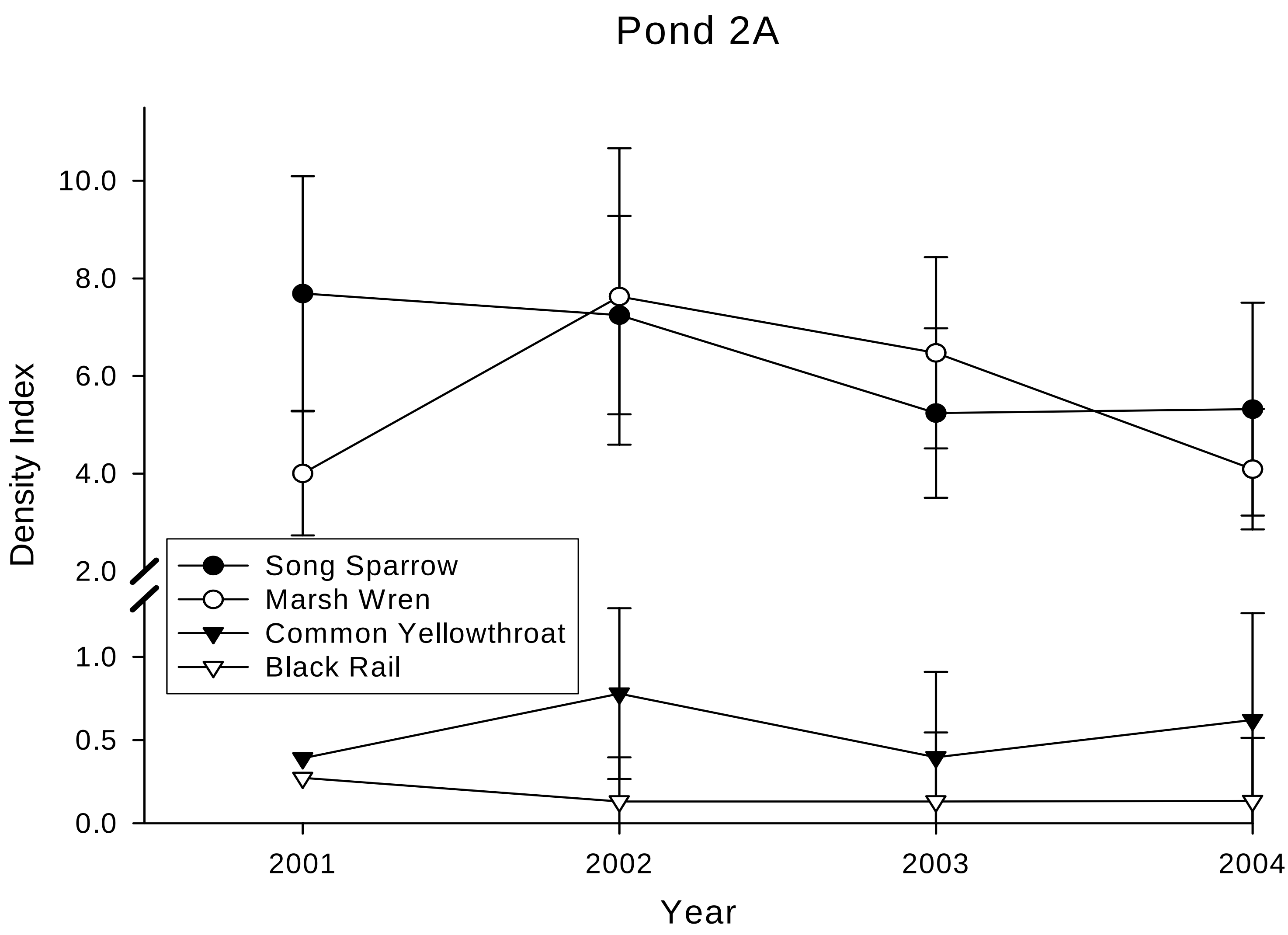

Figure 4d. Population trends of focal avian species at White Slough Marsh.

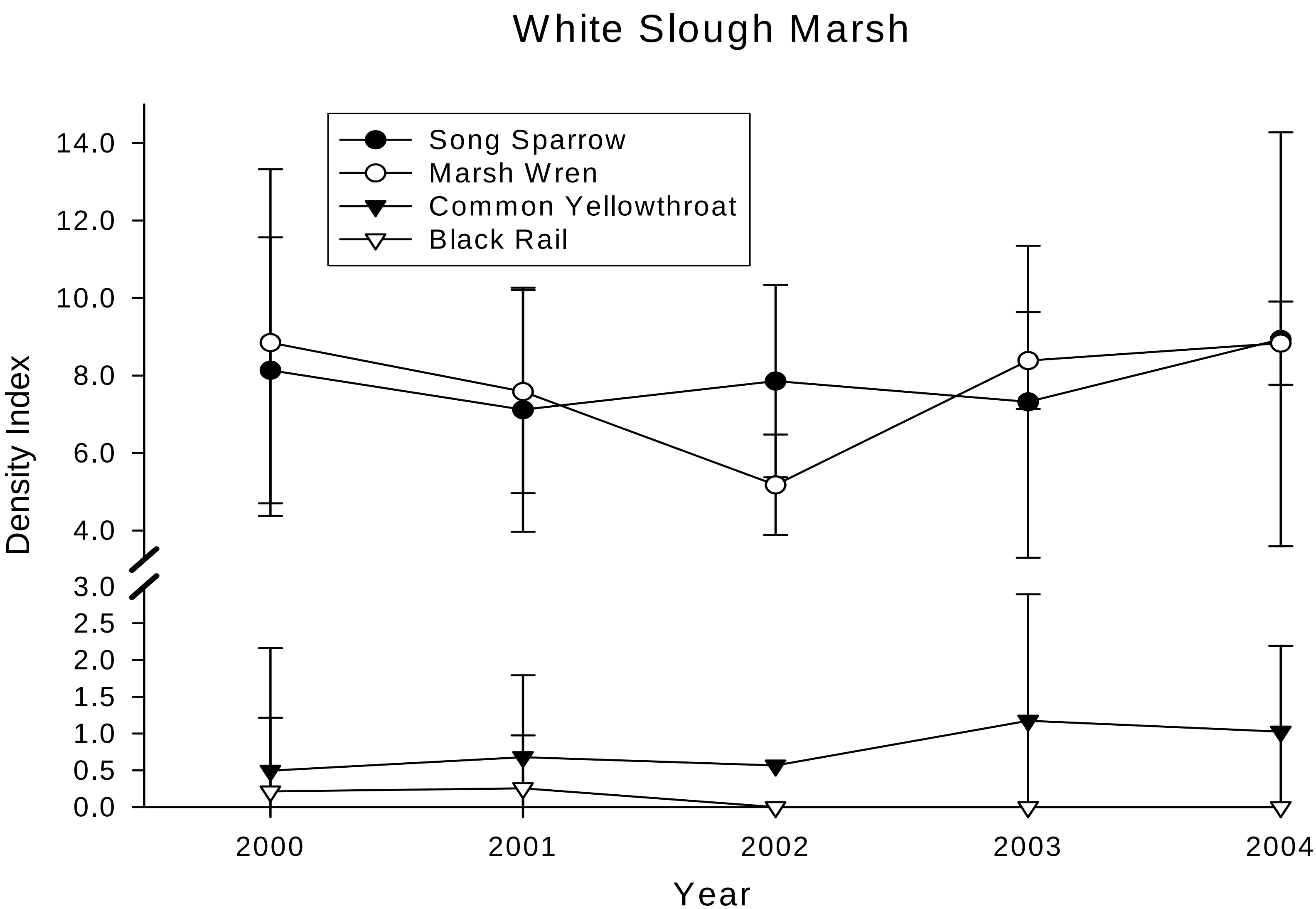

Figure 4e. Population trends of focal avian species at China Camp State Park.

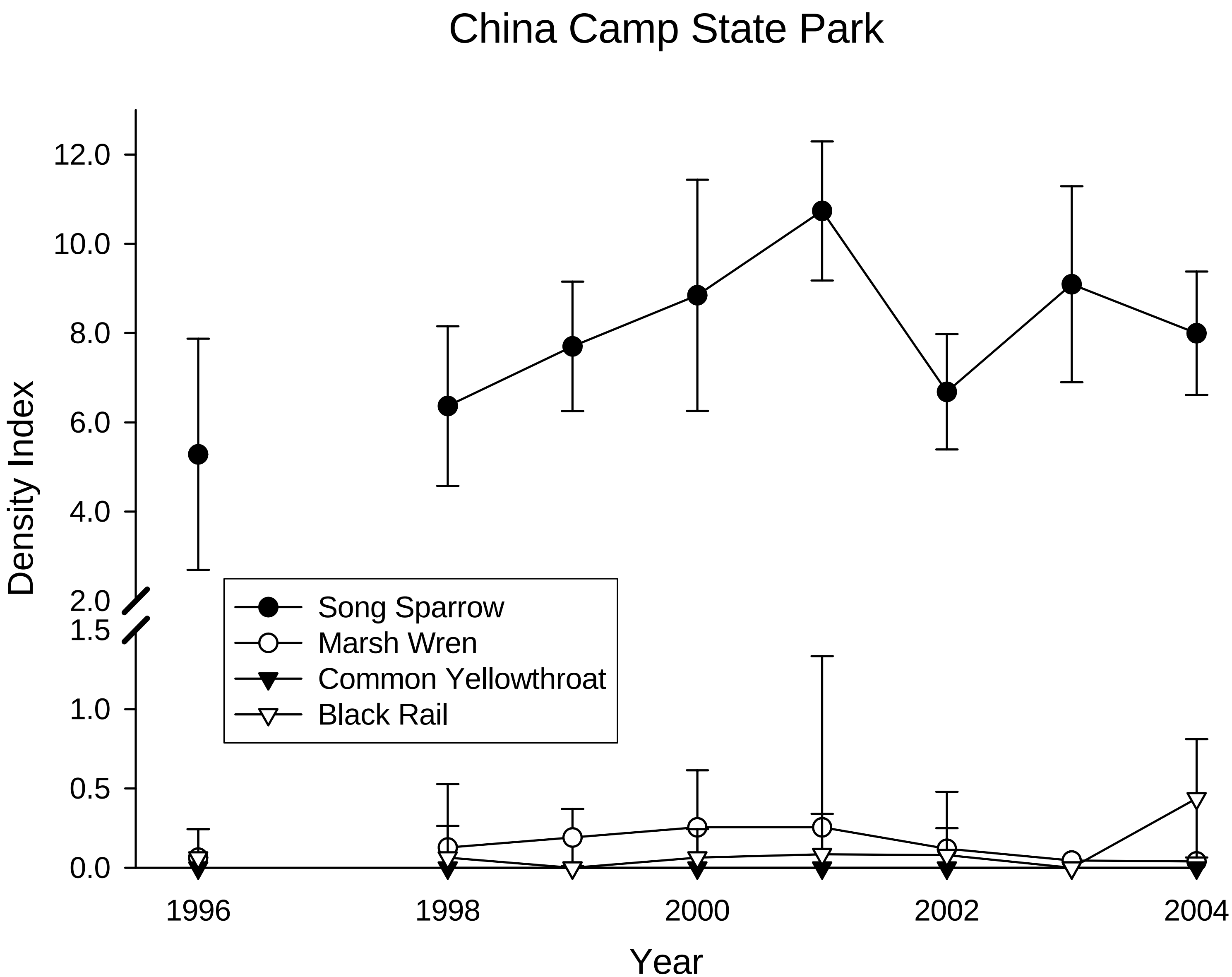

Figure 4f. Population trends of focal avian species at Benicia State Park.

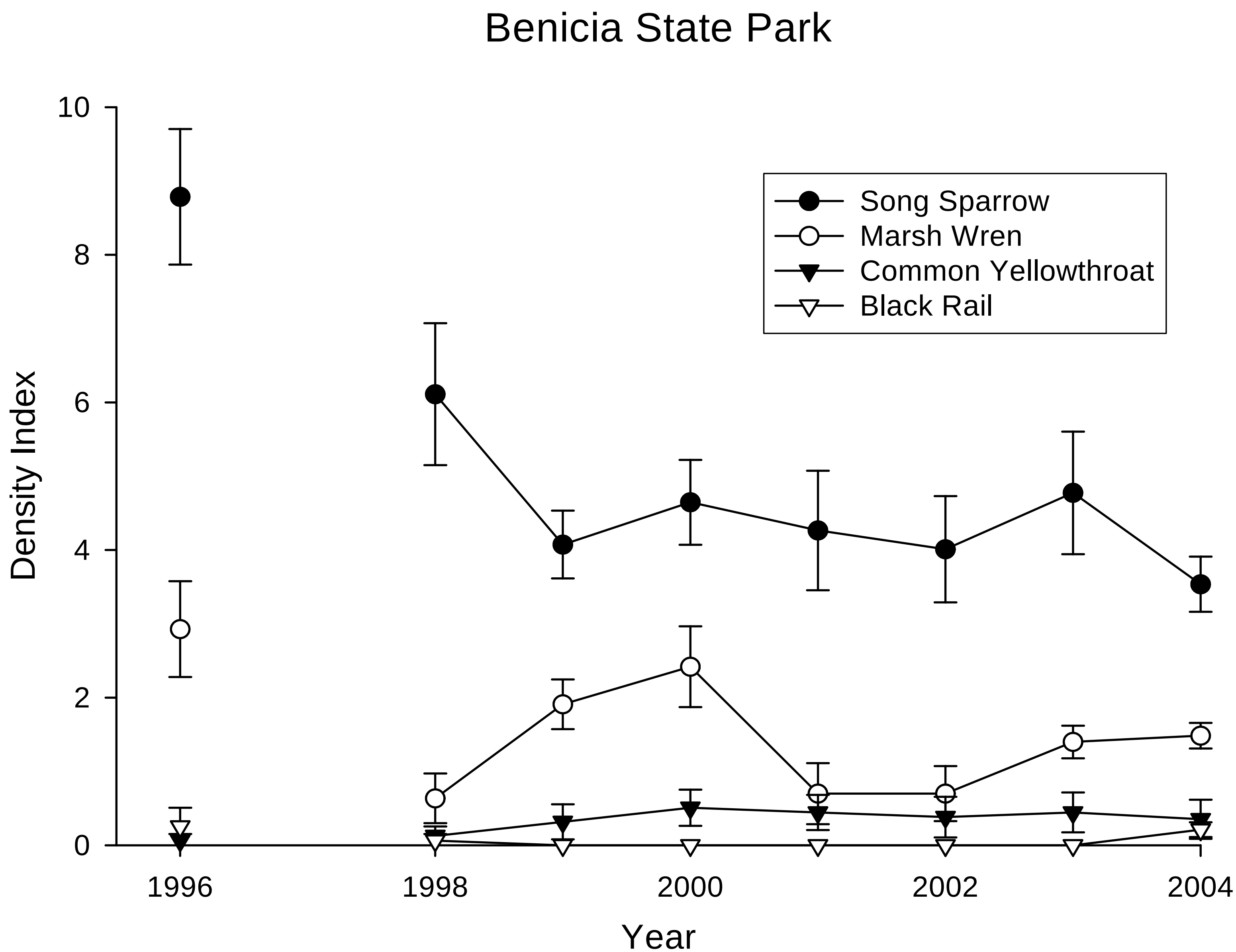

Figure 4g. Population trends of focal avian species at Rush Ranch.

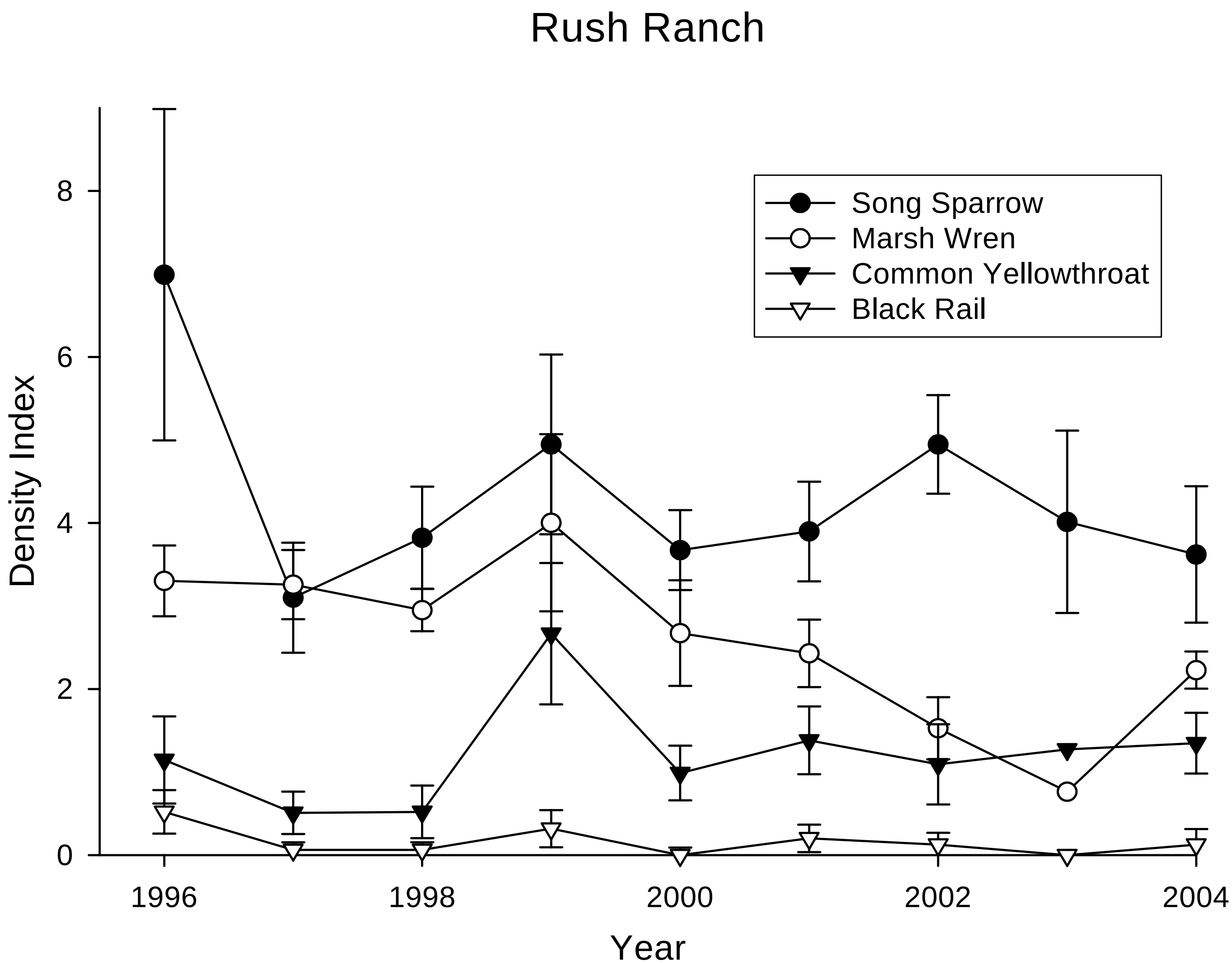

Figure 5. Mean Lepidium cover at PRBO bird survey sites in the San Francisco Estuary, 2000-2001. Nest plots are indicated by name. Marsh sites are categorized by mean percent *Lepidium* cover calculated within 50 m of bird survey points. Habitat spatial data courtesy SFEI (1998).