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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 the tidal salt marshes of the San Francisco Bay estuary 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, many agencies and organizations have planned or completed wetland restoration projects in the Bay. Restoring wetlands to functioning tidal marsh habitat requires monitoring 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 dependent 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*). The subject of studies in the past, the population biology of these species still is not well known, nor have long-term population trends been established due to 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 population status and processes of tidal marsh birds of the Bay. Synthesizing data from point count surveys and demographic data from reproductive studies has provided insights into how tidal marsh birds respond to both physical and biological processes. An important topic of recent study has been the response of tidal marsh birds to ongoing restoration projects. This report summarizes results of our 2005 studies in the Bay.

We conducted point count surveys at 42 sites in the 2005 breeding season (March through May). A density index for each focal taxon (Song Sparrow, Common Yellowthroat, Marsh Wren (*Cistothorus palustris*), and Black Rail) was calculated for each point 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 2005 data. The density index of Song Sparrows in Central and South San Francisco Bays (Alameda Song Sparrows) was the second highest (2003 highest) recorded since monitoring began in 1996. The density index of Salt Marsh Common Yellowthroats in San Pablo, Central, and South San Francisco Bays was the highest ever recorded. Marsh Wrens also had the highest density index ever recorded in San Pablo Bay.

Nests were monitored at five marshes using standardized methodology. Nest monitoring allows measurement of reproductive success and therefore is an indication of population health. Nest survival probability, one component of reproductive success, was calculated both by the overall proportion of successful nests, and by the Mayfield method, which provides an estimate of the daily probability of nest survival. Observers also used behavioral clues to estimate territory boundaries and map breeding territories.

Analysis of 2005 data indicates that nest survival rate was near the long-term average compared with sites previously surveyed. A total of 797 nests of 12 bird species were found in 2005. Of these, 673 were Song Sparrow nests. Since this species is the most abundant breeding species in SF Bay and endemic Song Sparrow subspecies are restricted to tidal marsh habitat, this species is used as an indicator species to reveal patterns of reproductive success. Nest survival rate of Song Sparrows increased slightly to approximately 18% at both San Pablo Bay and Suisun Bay sites. However, there was significant variation among the different sites within each bay. Of particular note, nest survival for Song Sparrows at the two young restoration sites (Pond 2A and Carl’s Marsh) was very similar to that observed at the three mature marsh sites (China Camp, Benicia, and Rush Ranch).

In 2005, researchers from several organizations collaborated with PRBO to survey nearly 70 sites in the San Francisco Estuary for breeding Clapper Rails. PRBO biologists performed surveys at 15 of these sites and have received summarized data from collaborators at an additional 31 sites. Of these 46 surveys, rails were not detected at 19 sites, including all 9 Suisun Bay sites. In most cases, the abundance of rails differed substantially between the 2005 and historical numbers where we have comparable data from past surveys.

In an analysis completed this year, we analyzed eight years (1997-2004) of nest data using survival-time analysis (Nur et al. 2004). We examined variation in nest survival with respect to nest height (measured as the vertical distance between the ground and the bottom of the nest cup) and associated vegetation, specifically the plant species acting as the primary support for the nest, and the plant species providing the primary concealment for the nest. We assumed that variation in nest characteristics affects nest survival and birds choosing optimal nest sites will have increased breeding success (Caccamise 1977, Nur et al. 2004). The ultimate aim of our analysis was to develop a model able to parsimoniously predict nest survival among and within marshes, so that we understand those nest characteristics most crucial to nest survivorship, and use this knowledge to inform restoration efforts in the San Francisco 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, Spautz and Nur *in press* a, Spautz and Nur in press b, Chan and Spautz *in press*; see also Nichols et al. 1986). However, little quantitative data on birds exist 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.

The loss of tidal marsh habitat is reflected by the number of San Francisco Bay tidal marsh-dependent birds with special conservation status, such as the California Clapper Rail, California 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 1956, 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 population study 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,b 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).

In addition, 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 will continue to 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 the results of 2 posters we presented at the State of the Estuary conference in 2005, examining the role of nest height in the Song Sparrow nest success (Abbaspour et al. 2005) and preliminary results of a Bay-wide Clapper Rail population survey (Liu et al. 2005).

METHODS

<u>Point count surveys</u>

Variable radius point count surveys (Reynolds et al. 1980; Ralph et al. 1995; Nur et al. 1999) were conducted twice at each of 42 sites during spring 2005 (Fig. 1a,b; Table 1). Surveys were conducted within 4 hours of sunrise, twice between March 21 and May 31. 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).

A density index (birds detected per ha) for each focal taxon (including rails) was estimated at each site. 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. The apparent density index is an underestimate of true density since detection probabilities are considerably less than 100% for many species; for Song Sparrows and Black Rails, detection probabilities are about 30% (Nur et al. 1997).

Cumulative species richness for each site was estimated by counting the total number of unique species detected across all surveys within the site.

Reproductive success

Nest monitoring allows measurement of a number of parameters associated with reproductive success (clutch size, number of broods, number of nesting attempts) and with our long term study we are able to examine how these parameters vary across space and time as well as providing information on population health and sustainability (Martin and Geupel 1993).

Field biologists searched for and monitored nests at China Camp State Park (Marin County), Carl's Marsh (Sonoma County), Pond 2A (Solano County), Benicia State Recreation Area (Solano County), and Rush Ranch (Solano County) (Figure 1; Table 1) in tidal marsh habitat during the breeding season (March 1 to July 31, 2005). Nests have been monitored by PRBO at two sites of these sites (China Camp and Benicia) annually since 1996 and at Rush Ranch in all but one year since 1996. Within 2-4 focal study plots per site, we intensively searched for the nests of Song Sparrow, Common Yellowthroat, Marsh Wren, and Black Rail; nests of other species were also opportunistically found. All known nests were monitored using a standard protocol (Martin and Geupel 1993). Nests were usually visited every 2-4 days (range: 1 to 10 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 dates of 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 termination of the nesting attempt). Nest contents were recorded at each visit and the ultimate outcome of each nest (success or failure) was decided based on nest condition and behavior of the breeding pair. Nestlings were banded on the 7^{th} or 8^{th} day with USGS numbered bands and a unique combination of colored leg bands to facilitate field identification after fledging.

We calculated nesting success of a specific site (defined as the proportion of the total number of nests that fledged at least 1 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 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 highly 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

Since 1996 PRBO has been banding Song Sparrows and Common Yellowthroats in the San Pablo and Suisun bays; in 1997, we initiated individual, unique color-banding of Song Sparrows. In the future these 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, and thus determine season-long reproductive success. In the beginning of the season, biologists used mist nests to opportunistically capture and band birds, primarily Song Sparrows. During the breeding season, biologists used more direct methods, targeting specific unbanded pairs with known nest locations. In addition, many nestlings 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).

Clapper Rail surveys

Censuses were conducted from January through April in 2005. Most marshes were surveyed 3 times in a 2-hour period around sunrise and sunset using a linear transect method, with 10 minutes per listening station. Two to nine listening stations were placed 200-400 m apart, depending on marsh size. All Clapper Rail vocalizations were recorded with the time, direction and distance from the listening station. If no Clapper Rail had been previously detected at a listening station after three surveys, tape playback of California Clapper Rail vocalizations was utilized to stimulate a response. Vocalizations were assumed to represent 1-2 rails, except when known to be a single individual or a pair. A mean based on the minimum and maximum number of Clapper Rails detected was calculated for each survey site. The mean number of Clapper Rails at each survey point was then used to calculate an approximate density (birds/hectare). Detectability of Clapper Rail vocalizations decreases at 200 m, so densities were calculated using detections out to 200 m. Survey areas were calculated using marsh areas generated by the Invasive Spartina Project and by the San Francisco Estuary Institute's Bay Area EcoAtlas Version 1.50b4.

Nest height analysis

After nesting was completed, we measured the physical attributes and vegetation associated with each nest. These attributes include: height from ground (measured as the vertical distance between the ground and the bottom of the nest cup), primary nesting substrate, and plant species providing the principal concealment for the nest. For the purposes of analysis, primary nesting substrate and principal concealing vegetation were divided into five groups: *Salicornia*, *Distichlis*, *Grindelia*, *Scirpus* (all species), and Other. These vegetation measurements provide information on types of habitats chosen by species and the consequences of particular habitat choices to the likelihood that nests succeeded in producing offspring (Martin et al. 1997).

We analyzed daily nest survival rates (= 1 – daily nest mortality rates) using "survival time analysis" (Nur et al. 2004). We used the Cox proportional hazards regression model, which estimates the probability a nest fails during a 1-day interval as a function of age of the nest, and included the covariates nest height, marsh site, nesting substrate and concealment. The hazard ratio h represents the proportionate increase in the daily nest failure rate with an increase of one unit in the independent variable (i.e., when h>1 the daily probability of failure increases with an increase in the independent variable). We present results of Cox models for the entire nesting period (25 days) as well as for the egg stage only (14 days) and the nestling stage (11 days). Using the Akaike Information Criterion corrected for small sample size (AIC_c, Nur et al. 2004), we compared amongst models that considered combinations of three independent variables (nest height, site, and plant substrate).

RESULTS AND DISCUSSION

Point count surveys

The mean density indices for Song Sparrows and Marsh Wrens increased in San Francisco Bay and San Pablo Bay from 2004 but did not increase in Suisun Bay and the Delta. For Common Yellowthroats, density indices increased slightly in San Francisco and San Pablo bays and the Delta, but decreased significantly in Suisun Bay (Figure 2). Species richness ranged from 10 to 37 species (mean = 17.6 species; s.d. = 6.1) per site across the region (Table 2).

Song Sparrow density indices

Within each bay, Song Sparrows are the most abundant of the focal species detected using our point count survey methods. Although Song Sparrow density indices in San Francisco Bay (i.e. Alameda Song Sparrow) have been consistently lower than found within San Pablo Bay (i.e., San Pablo Song Sparrow) and Suisun Bay (Suisun Song Sparrow) they have shown a generally increasing trend (Figure 2a). From 2004 to 2005, the mean density indices of Song Sparrows in San Francisco Bay increased from 3.6 birds detected per ha to 4.9 birds detected per ha. The density indices of San Pablo Song Sparrows and Suisun Song Sparrows have remained relatively stable since 1996. In the past three years, density indices have been similar in San Francisco and Suisun Bays, but higher in San Pablo Bay

Common Yellowthroat density indices

Density indices of Common Yellowthroat showed an overall increase from 1996-2005 (Figure 2b). Yellowthroat density increased strongly between 2002 and 2004 but then decreased in 2005 to the level observed in 2002. In San Francisco and Suisun Bays there have been steady increases observed from 1998 to 2005. Density indices are still much higher in Suisun Bay than San Pablo Bay, and lowest in San Francisco Bay. Tracking changes in Common Yellowthroat densities is difficult using standard point count density indices, as variability in detections among sites is high. While some preliminary analyses have already been performed we hope to implement distance sampling to a greater extent which may provide additional power to examine trends in the population. (cf. Nur et al. 1997, Buckland et al. 2001).

Marsh Wren density indices

The steady increase in mean density indices of Marsh Wrens continued in San Pablo Bay (Figure 2c). Marsh Wrens heavily use tall vegetation (Spautz et al. in press), and the relatively high proportion of young restored marshes surveyed in San Pablo Bay possessing large *Scirpus* patches could partially account for this trend. Suisun Bay and the Delta had the highest mean density indices of Marsh Wrens, and both showed stability in density from 2004 to 2005.

Reproductive success

Song Sparrows

Song sparrows are the most common nesting bird in the tidal marshes of the San Francisco Bay Estuary. Nesting densities observed here are some of the highest reported for any non-colonial bird species (Johnston 1956). Estimated nest survival rate (per nest), from initiation of laying to fledging over all sites was similar in 2005 to the long term average among all sites (Figure 3). However, individual sites did show substantial variation of nest survival.

Of the five marshes, Pond 2A had the highest rate of nest success, similar to 2004 (Figure 3). Nest success at Pond 2A was one of the three highest ever recorded, 31% (Table 4), dating back to 1996. The success rate at the other two San Pablo Bay marshes, China Camp and Carl's Marsh, was markedly lower. It is worth noting that predation events at Pond 2A had a higher proportion that involved damage to the nest structure, the opposite trend observed at the other four marshes, where most depredated nests showed no damage. It is possible that larger nest predators, such as raccoons (*Procyon lotor*) or Northern Harriers (*Circus cyaneus*), are responsible for a higher portion of nest failures at Pond 2A instead of smaller nest predators, such as Norway rats (*Rattus norvegicus*) or Pacific gopher snakes (*Pituophis catenifer*) which would be expected to cause less damage to the nest structure.

China Camp had the lowest rate of nest success in 2005 (12.3%) and had one of its poorest breeding seasons ever over 10 seasons of nest monitoring. About 25% of nest failures at China Camp were due to flooding. There was a significant amount of heavy rain in the early breeding season, which likely compounded the difficulties of nesting at China Camp, as the average vegetation height in that marsh is lower than at the other four marshes, as is the nest height.

Carl's Marsh also had a low nest survival rate (13%), though double the rate in 2004 (6.4%, Table 4). Survival during egg and nestling periods rose among years, but the laying and incubation periods remained a time of higher failure than the nestling period.

The contrast between the two San Pablo Bay restoration marshes, Pond 2A and Carl's Marsh, is striking. A deeper analysis is warranted, but at first glance it appears that the predator suites at the two marshes may be different, possibly related to Pond 2A's isolation by water from sources of predators such as the human development and agriculture in close proximity to Carl's Marsh. An earlier analysis demonstrated that proximity to open water (bay or major channel) accounted for a large proportion of variation in nest success among sites (Chan et al. 2002). The vegetation at Pond 2A is also taller, denser, and more complex than at Carl's Marsh, despite their similarity in age (Pond 2A breached in 1995, Carl's Marsh, 1994), so there are likely better refugia from predators.

Nest success at Rush Ranch and Benicia, the two Suisun Bay marshes, was relatively high (Figure 3). Rush Ranch had the highest rate of nests surviving to fledging since the first year monitoring began, 1996. Benicia had its 3rd highest rate of nest success in 10 years of monitoring.

There was an effort to control wild pigs at Rush Ranch between the 2004 and 2005 breeding seasons (K. Poerner, pers. comm.), and it is possible that it was successful in reducing nest failures, both from active predation and from habitat destruction.

Common Yellowthroats

Common Yellowthroat nests were once again difficult to find. Only six active nests were found this year, spread across three marshes. Four of the nests fledged young and two were depredated.

Marsh Wrens

Within the nest monitoring sites, Marsh Wren nests were the second most common species found. They were primarily found within the recently restored Pond 2A and Carl's Marsh. The proportion of successful Marsh Wren nests dropped to 32% in 2005 from 42% in 2004. Weather (n = 5, 26 %) and predation (n = 14, 74%) were the causes of nest failures.

Other marsh birds

We found nests of 13 bird species, including a Virginia Rail (*Rallus limicola*) nest at Pond 2A, the second one documented in 10 seasons of nest monitoring. Three active Clapper Rail and three active Black Rail nests were found.

Territory density

Estimates of density using territory mapping are generally higher than estimates of relative density as much more time is spent within a specific area and, therefore, detection rates are higher. In addition, territory mapping is conducted only on breeding pairs which are much more conspicuous than non-breeding individuals. Only territory mapping and distance-sampling (Nur et al. 1997) can provide estimates of absolute density. There was considerable variation in density among marsh sites and to a lesser degree within marsh sites (Table 6). Pond 2A and China Camp demonstrated the highest breeding densities, greater than 13 breeding birds per hectare for both sites. The density index derived from point counts at Pond 2A was 35% of the density as calculated from territory mapping, possibly due to the dense and tall vegetation at this site. Density indices from point counts at the two Suisun Bay sites were both about 50% of densities using the territory mapping method. Densities in 2005 were comparable to densities in 2004, as well as densities observed in previous years (cf. Nur et al. 1997).

Banding data

In 2005, banding effort at nest-monitoring sites was increased from past years. A total of 359 Song Sparrows were banded (Table 7). This includes 32 adult birds and 5 juveniles caught in target-netting efforts on the plots, and 327 birds banded as nestlings. More Song Sparrows were banded in 2005 than in 2003-04 combined, and the highest yearly total of nestlings banded since 2000 (Table 8). It is our hope that this enhanced effort coupled with an intensive re-sighting effort in 2006 will enable us to establish a benchmark estimate for population recruitment that can be further investigated in future studies. We also will begin to look at juvenile dispersal within marshes, drawing on resightings since 1998.

Clapper Rail surveys

Population trends

There were no Clapper Rail detections at 19 of 49 sites, including all 9 Suisun Bay sites (Table 9, Figure 5). At those sites where rails were detected, breeding density varied between 0.1 and 3.0 birds per hectare (Table 9). Comparing data from historical surveys and 2005 surveys was difficult, as survey methodology and analysis has evolved.

Clapper Rails in Central San Francisco Bay increased dramatically at the two marshes comprising the Corte Madera Ecological Reserve, but the small population in Richardson Bay was not detected in 2005 (Figure 5, Table 9). The trend on the west side of San Pablo Bay also was generally positive, with population increases in the marshes north and south of the mouth of Gallinas Creek. The small population in the mid- and upper reaches of Gallinas Creek was also still present in 2005.

The population trend in the eastern portions of San Pablo Bay and in Suisun Bay is generally negative, as Clapper Rails were not detected in Suisun Bay in 2005, or at the upper reaches of the Napa River. The small Clapper Rail population at the fragmented marshes north of Pt. Pinole was absent in 2005. The population at White Slough near Vallejo showed a sharp decline.

Extirpations at isolated marshes such as Richardson Bay and Pt. Pinole north may be occurring. It is unknown whether small satellite subpopulations are succumbing to predation, or if Clapper Rails are immigrating to larger marshes, as several of the larger marshes outside of Suisun Bay show a population increase. It is also possible that human activities near some of the sites, such as highway construction at White Slough, are having a negative effect.

In the past, the Clapper Rail breeding range has been assumed to exclude Suisun Bay. It is possible that the rails detected in Suisun Bay in 1992-1993 moved into this area during a dry period that increased the availability of suitable habitat in west Suisun Bay. It is also possible that Clapper Rails are very difficult to detect in Suisun Bay, likely because of the lower density there. Surveys in Suisun Bay in 2005 did not detect Clapper Rails, but the entire area was not surveyed, so it is possible that there is still a small population in the extensive marshes in this area.

Influence of nest height on nesting success

We found that nest height differs considerably both within and among marshes. Mean nest height varied from 19 cm (s.d. = 6.5 cm) at Petaluma River Mouth to 40 cm (s.d. = 10.0) at Pond 2A. Overall, as nest height increased the proportion of nests surviving to fledge young decreased (Figure 6). However, when we controlled for site differences, this trend was not significant. The effect of nest height on estimated survival over the entire nesting period, controlling for site differences, is shown in Figure 7.

Survival decreased with increasing nest height during both the egg and nestling stages (Figure 8); the decrease appears somewhat stronger in the egg stage than the nestling stage. However, in Cox regression models that control for site effects, the hazard ratios were similar ($h = 1.033 \pm 0.024$ and $h = 1.029 \pm 0.033$) for the egg and nestling stages, respectively.

Interestingly, the effect of nest height on survival differed among marshes. All marshes demonstrated either increased mortality rates with an increase in nest height ($h > 1$) or weak effects, except Petaluma River Marsh ($h < 1$; Table 10). The decrease in nest mortality with increasing nest height at Petaluma River Marsh was apparent during the egg stage but not the nestling stage.

The apparent difference in the relationship of nest height to nest survival among marshes suggests nest height exerts a stronger influence upon survival at some marshes than others. If this relationship is strongly influenced by predation, as Caccamise (1977) suggests, then this may indicate that there are different predation pressures at each marsh. Petaluma River Marsh (a.k.a. "Carl's Marsh"), the only one of our study sites exhibiting a strong positive effect of nest height on nest survival, has more direct access to surrounding upland than other sites and has a cross-levee extending into the marsh plain. Weatherhead and Blouin-Demers (2004) suggest that snakes are important nest predators and may be particularly attracted to habitat edges. Gopher snakes have been the most frequently encountered species of snake in the San Francisco Bay tidal marshes (PRBO, *unpublished data*). They are commonly found in grasslands, and may have more success locating nests at lower nest heights in tidal marshes, thus leading to higher rates of predation.

Johnston (1956) suggested that nest success was highly influenced by tide regimes. Collins and Resh (1985) determined that nests at Petaluma Ancient Marsh must exceed a height of 20 cm in order to escape flooding. However, we have found that depredated nests outnumber flooded nests by a ratio of at least 3:1 at all study sites. This suggests that tidal flooding at our study sites is a less important factor than nest predation in determining success in relation to nest height. Furthermore, only at Petaluma River Marsh were low-lying nests at a survival disadvantage.

Comparison of competing models using AIC_c demonstrated that nest height was an important predictor variable; this variable was included in the top two ranking models (Table 11). Furthermore, the optimal model (M1 in Table 11) included the interaction of nest height with site, confirming the finding that the effect of nest height depended on site. Models with plant substrate as a predictor had notably lower AIC_c scores compared to the optimal model ($\Delta AIC_c > 6$, compared with Model M1). Though nesting in a particular plant substrate may not confer a direct advantage to the Song Sparrows, it may be that nesting in a variety of vegetation types positively influences nest success for the population overall by making it more difficult for predators to key into nest sites (Kern 1993).

GOALS FOR 2006

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 reproductive data at two of our long-term nest-monitoring study sites, China Camp and Benicia, as well as one long-term restoration monitoring site, Carl's Marsh. In addition, we will continue to monitor marsh bird abundance and diversity at additional ancient and restored sites.

PRBO will also continue to conduct point count and area surveys at a majority of our long-term sites throughout the San Francisco Estuary. Efforts in 2006 will focus on comparing bird populations and the species assemblage in restored and mature marshes in South San Francisco Bay to complement studies that we have conducted in the North Bay, Suisun, and the Western Delta (through the BREACH 2 Project and the Integrated Regional Wetland Monitoring [IRWM] Project). We will also conduct a series of surveys at Rush Ranch in areas that may be suitable Yellow Rail wintering habitat, to follow up on several incidental detections.

In 2006 we hope to begin an exploration of the use of nest cameras to determine what predators are responsible for nest failures. There is a growing body of evidence that suggest that, in addition to mammals and birds, snakes may play a large role, even in tidal marshes (Weatherhead, 2004; PRBO unpubl. data).

In 2005 field work was completed for the IRWM Project, and in 2006 analysis, integration, and write-up will be completed. Preliminary results of the 2003-2005 field seasons were presented at the State of the Estuary Conference (Herzog et al. 2005, Nur & Baye 2005). In conjunction with D. Stralberg (PRBO), co-PI of the Landscape Ecology Team of IRWM, analyses of nest survival in relation to fine scale variation in vegetation and channel morphology will be completed and presented at scientific meetings. In addition, bird data will be integrated with information on benthic invertebrates and fish, also collected as part of the IRWM project.

In 2006 PRBO will complete the two year project to assess Clapper Rail populations throughout the San Francisco Bay Estuary. PRBO, in conjunction with Avocet Research Associates and other groups, will have surveyed about 90 sites in 2005 and 2006. In addition, 18-20 of these will be sampled in both years. The product will be the first San Francisco Bay Estuary-wide assessment of Clapper Rail populations since 1992-93.

Since 1996, PRBO has maintained a banding and resighting program within the long-term monitoring sites. In 2006, PRBO hopes to expand banding effort in our long-term 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. We intend to estimate the total number of fledglings produced per pair, incorporating clutch size and number of breeding attempts, to provide a more complete measure of reproductive success.

Also, in 2006, PRBO will be developing several studies directed at reducing the variability associated with point count sampling. Through these refined field methods it is hoped that we will be able to increase our ability to track changes for all tidal marsh birds.

LIST OF PRBO PRODUCTS RELATED TO TIDAL MARSH WORK IN 2005

In 2005, 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 (mherzog@prbo.org) to receive a reprint of any of these papers.

<u>Peer-reviewed articles</u>

Chan, Y., and H. Spautz, H. *In press*. Bird Species of Special Concern account: Alameda Song Sparrow. *in* Western Birds (D. Shuford and T. Gardali, Eds.).

Spautz, H., and N. Nur. *In press*. Bird Species of Special Concern account: Samuel's Song Sparrow. *in* Western Birds (D. Shuford and T. Gardali, Eds.).

Spautz, H. and N. Nur. *In press*. Bird Species of Special Concern account: Suisun Song Sparrow. *in* Western Birds (D. Shuford and T. Gardali, Eds.).

Spautz, H., N. Nur, D. Stralberg, and Y. Chan. *In press*. Multiple-scale habitat relationships of tidal marsh breeding birds in the San Francisco Bay estuary. Environmental threats to tidal marsh vertebrates of the San Francisco Estuary. Studies in Avian Biology.

Takekawa, J.Y., Woo, I., Spautz, H., Nur, N., Grenier, J.L., Malamud-Roam, K., Nordby, J.C., Cohen, A.N., Malamud-Roam, F., and Wainwright-De La Cruz, S.E. *In press.* Environmental threats to tidal marsh vertebrates of the San Francisco Bay Estuary. Studies in Avian Biology.

PRBO Reports

Herzog M, Liu L, Evens J, Nur N, Warnock N. 2005. Temporal and spatial patterns in population trends in California Clapper Rails (*Rallus longirostris obsoletus*). 2005 Progress Report to California Dept. Fish and Game.

Nur, N., Herzog, M., Gaines, T., and Liu, L. 2005. Filling Data Gaps to Improve Planning and Monitoring: A Pilot Project to Assess Impacts of Tidal Marsh Restoration and Seasonal Wetland Enhancement Projects on Bird Populations in Suisun Marsh. Report to Bay Delta Science Consortium and Association of Bay Area Governments.

Posters

Abbaspour P, Robinson A, Nur N, Herzog M, Liu L. 2005. Nest characteristics and breeding success in tidal marsh Song Sparrows. Presented at the 2005 American Ornithologists Union Conference. Santa Barbara, CA.

Abbaspour P, Robinson A, Nur N, Herzog M, Liu L, and Warnock, N. 2005. Nest characteristics and breeding success in tidal marsh Song Sparrows: survival-time analysis of nest height and associated vegetation. Presented at the 2005 State of the Estuary. Oakland, CA.

Kelly, J.P., K. Etienne, D. Stralberg, and D. M. McCaustland. Landscape use by herons and egrets in the San Francisco Estuary. 7th Biennial State of the Estuary Conference. Oakland, CA. October 2005.

Liu L, Evens J, Herzog M, Nur N, Spautz H. 2005. California Clapper Rail population trends in the San Francisco Bay Estuary. Presented at the 2005 American Ornithologists Union Conference. Santa Barbara, CA.

Liu L, Evens J, Herzog M, Stralberg D, Nur N, Spautz H, and Wilcox, C. 2005. California Clapper Rail population trends in the San Francisco Bay Estuary. Presented at the 2005 State of the Estuary. Oakland, CA.

Presentations

Herzog, M. 2005. Birds within the San Francisco Bay Estuary: Ecology and Conservation. Presented at the NERR Tidal Marsh Workshop, Maritime Academy, Vallejo, CA

Herzog M, Stralberg D, Nur N, Tuxen K, Kelly M, Liu L, Valdez S, and Warnock N. 2005. Response of birds to vegetation, habitat characteristics, and landscape features in restored marshes. Presented at the 2005 State of the Estuary, Oakland, CA.

Nur, N., and P.R. Baye. Evaluating restoration success from the perspective of plants and animal. Paper given at 2005 State of the Estuary Conference, Oakland, CA.

Nur, N, Herzog, M, Warnock N, Stralberg D, Liu L, Spautz H. 2005. Advancing restoration science through research, monitoring, and modeling of bird populations dependent on tidal marsh habitat in San Francisco Estuary. Presented at the 2005 American Ornithologists Union Conference. Santa Barbara, CA.

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Funding for work done in 2005 was provided by Bernard Osher Foundation, Bernice Barbour Foundation, Marin Community Foundation, Long Foundation, Richard Grand Foundation, Rintels Charitable Trust, California Dept. of Water Resources, San Francisco State University, California State Coastal Conservancy, Bay-Delta Science Consortium, Marin Audubon Society, U.S. Fish and Wildlife Service's Coastal Program, and CALFED Bay/Delta Program.

Permission to work with California State Species of Special Concern, and State Threatened and Endangered Species, was given to PRBO by California Dept. Fish and Game Memorandum of Understanding.

We would like to thank the following agencies and private landowners for support and access to study sites: California State Parks and Recreation, California Department of Fish and Game, U. S. Fish and Wildlife Service: San Pablo Bay National Wildlife Refuge (esp. G. Downard, and C. Smith) and Don Edwards San Francisco Bay NWR (esp. J. Albertson, C. Morris, and M. Kolar), East Bay Regional Park District, Hayward Regional Shoreline, City of Palo Alto, Peninsula Open Space Trust, Port Sonoma Marina, Solano County Farmlands and Open Space, Sonoma Land Trust, the City of

Vallejo, Greg Tonnesen, Delta King Ranch, Shelldrake Duck Club, Wickland Oil Martinez, and Marin County Parks.

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Figure 1a. Map of 2005 San Francisco Bay Tidal Marsh study sites, North Bay region. See Table 1 for site names.

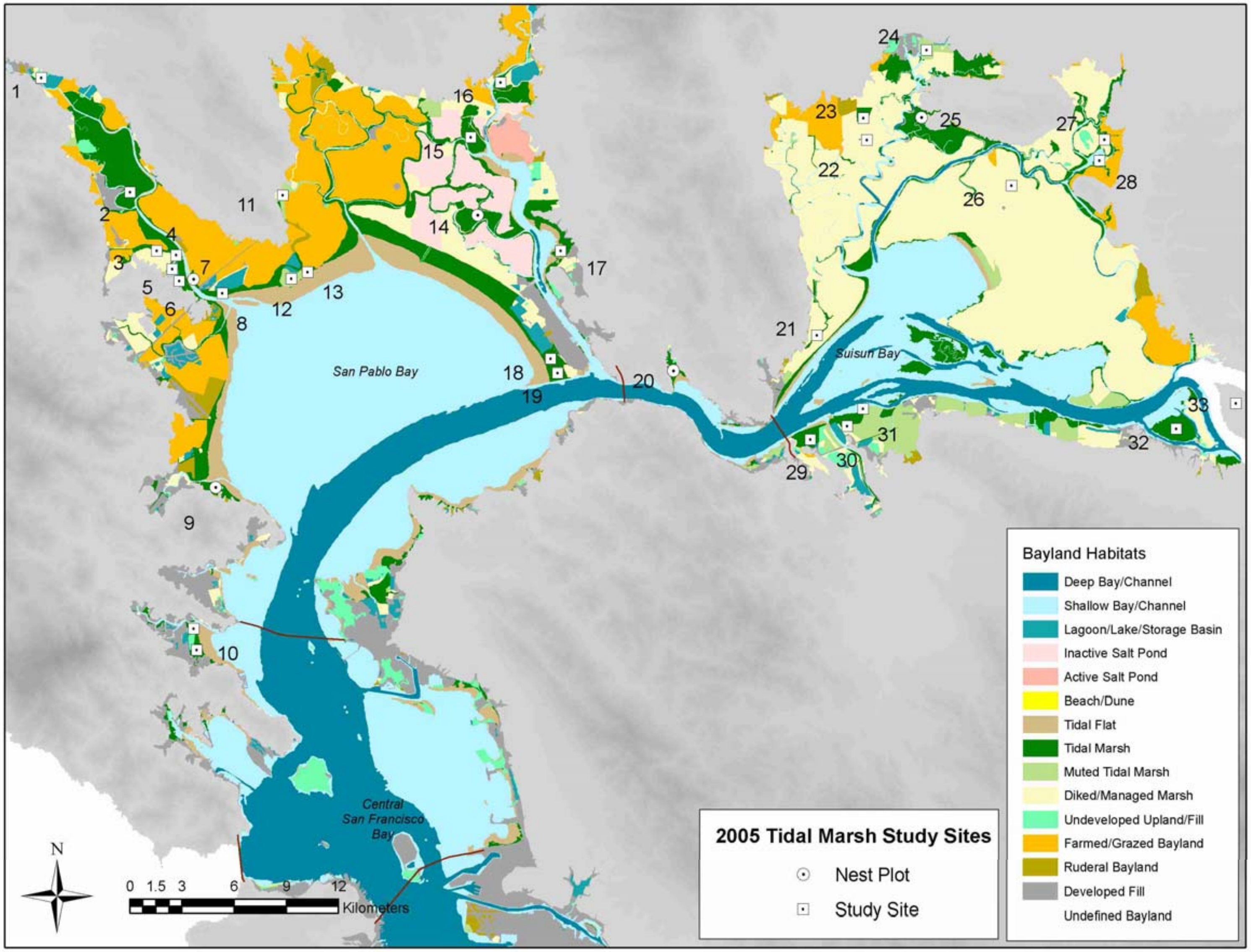

Figure 1b. Map of 2005 San Francisco Bay Tidal Marsh study sites, South Bay region. See Table 1 for site names.

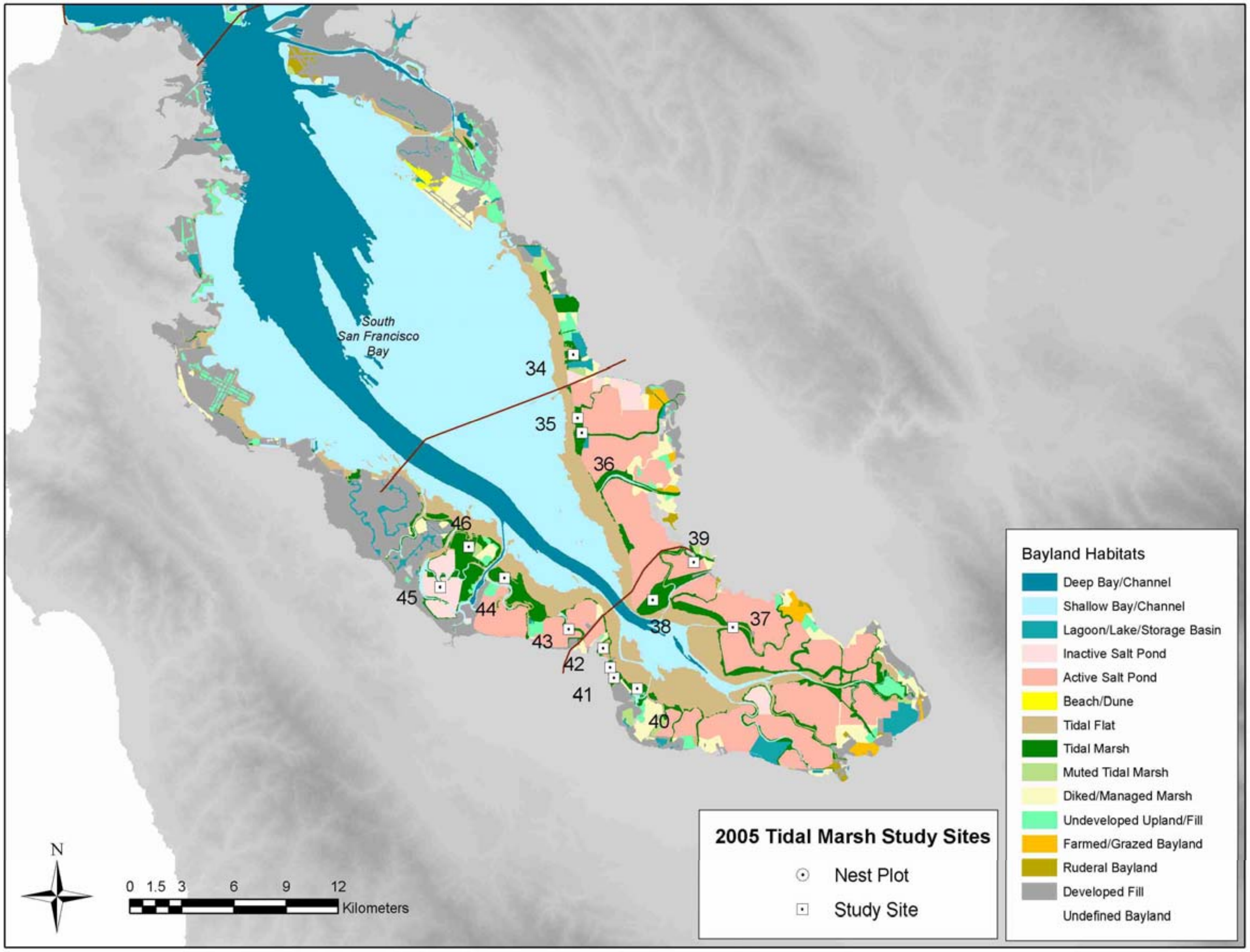

Figure 2a. Density indices by bay of Song Sparrow in the San Francisco Estuary: 1996-2005.

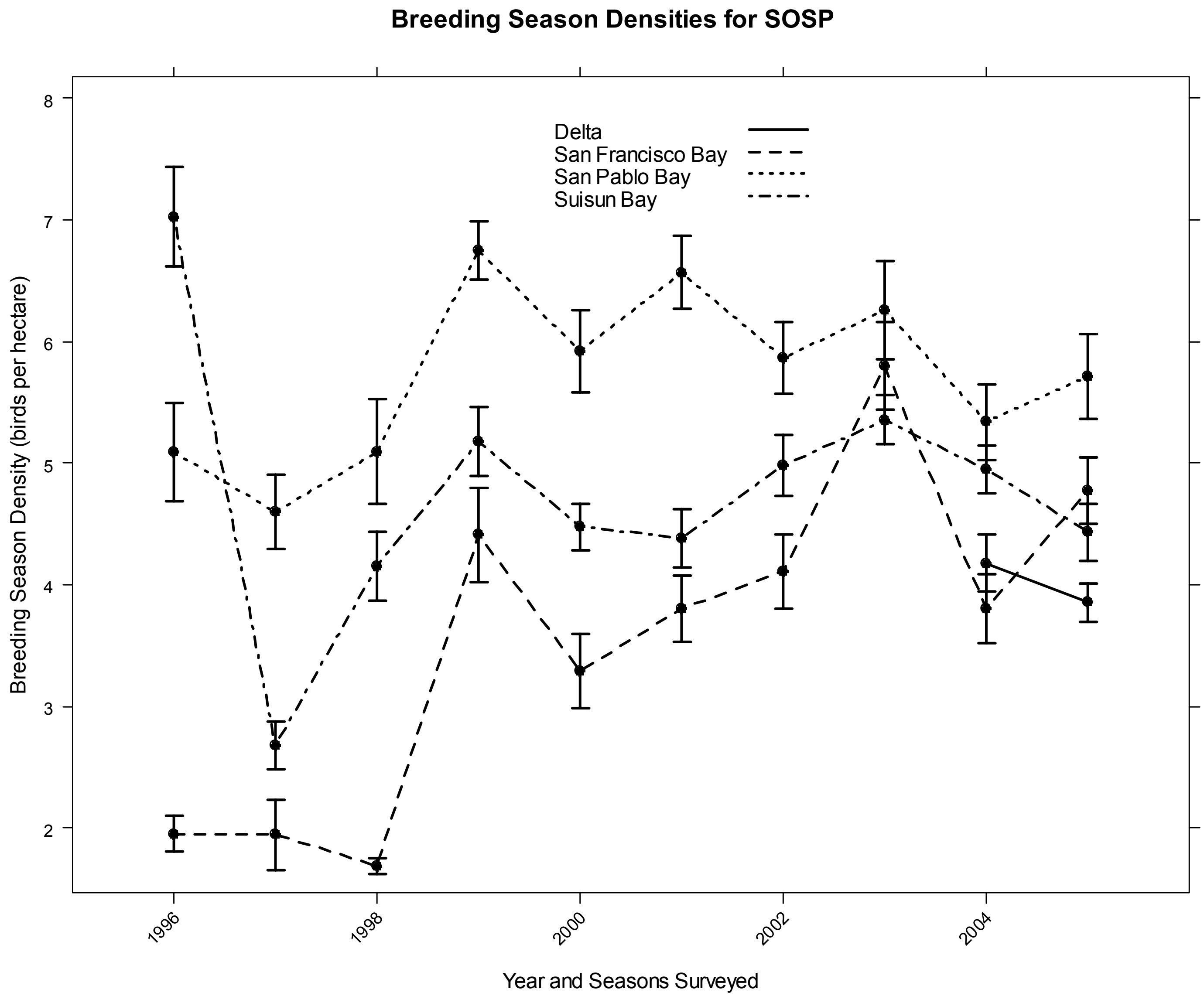

Figure 2b. Density indices by bay of Salt Marsh Common Yellowthroat in the San Francisco Estuary: 1996-2005.

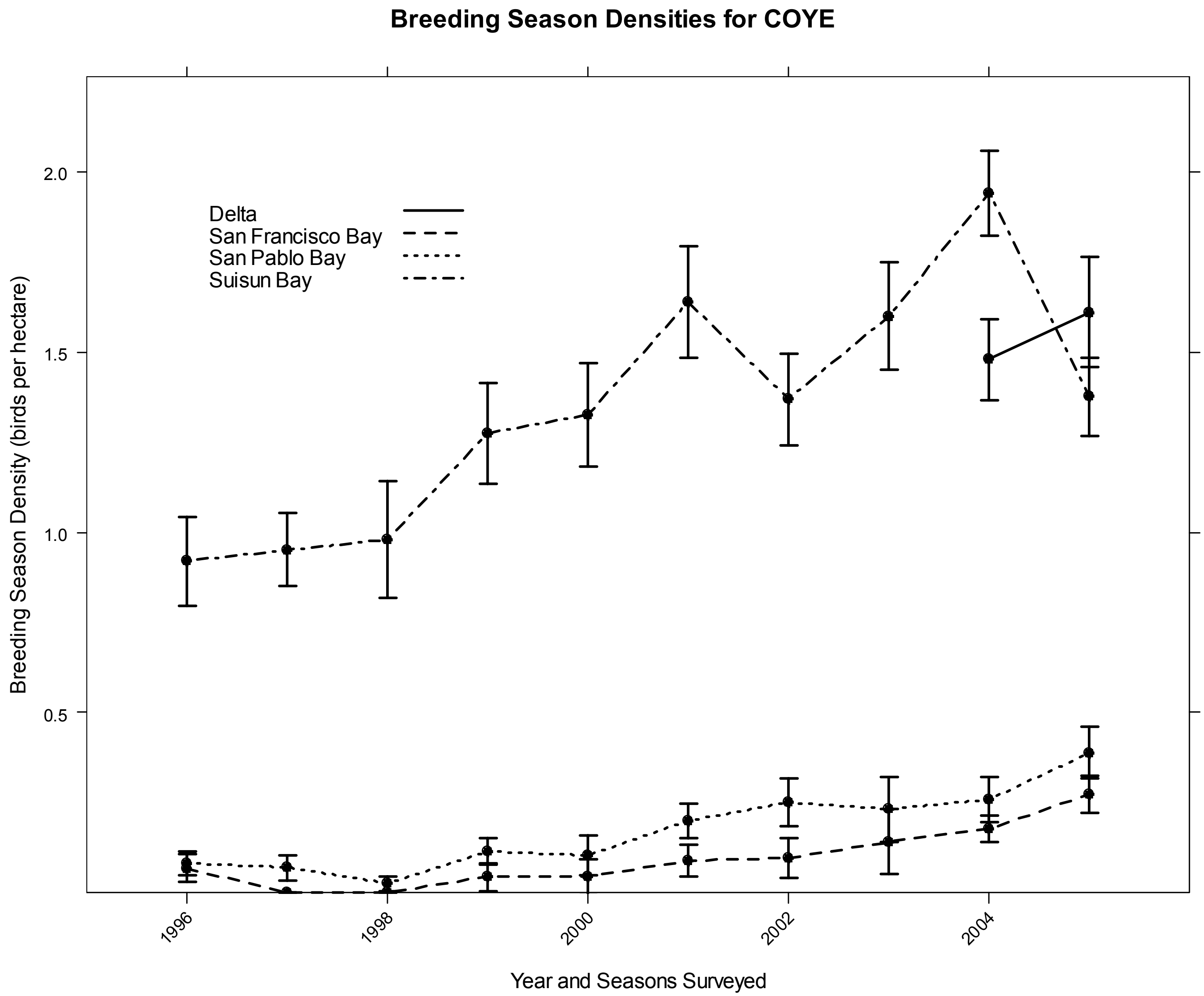

Figure 2c. Density indices by bay of Marsh Wren in the San Francisco Estuary: 1996-2005.

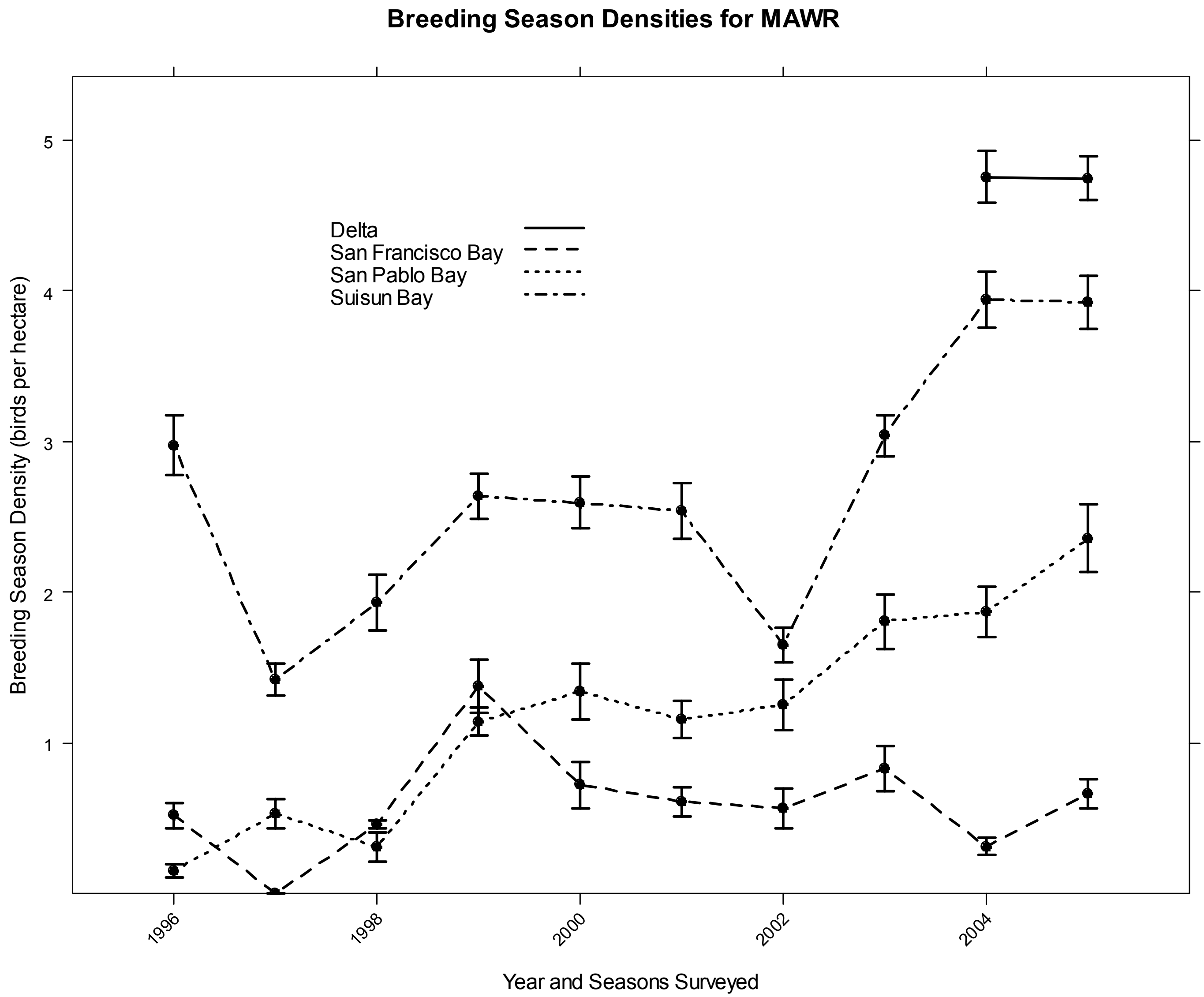

Figure 3. San Francisco Bay tidal marsh Song Sparrow nesting success: estimated probability nesting attempt survives to fledging of young (Mayfield) from 1996 to 2005.

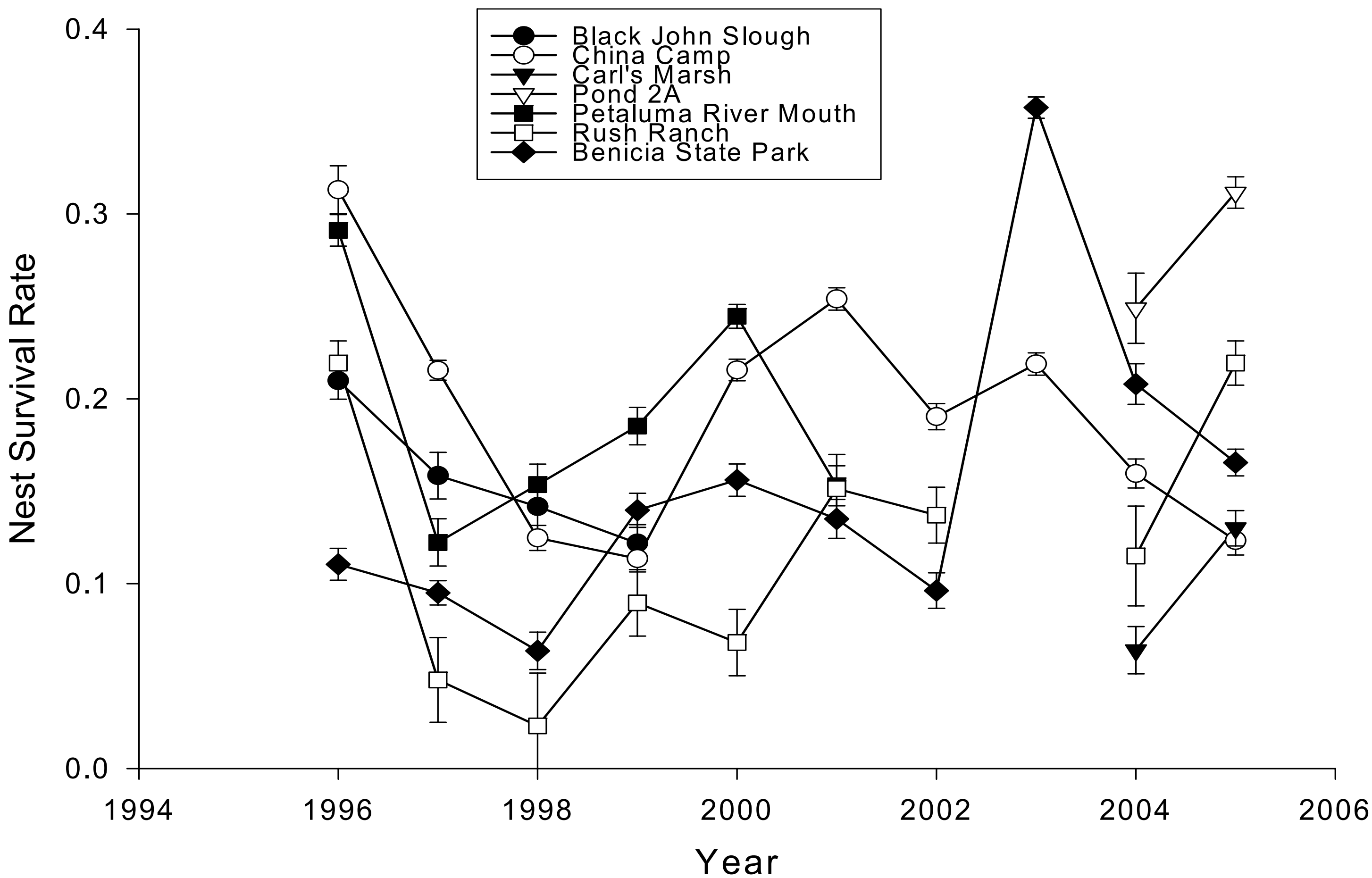

Figure 4a. Population trends of focal avian species at Greenpoint Restoration Marsh.

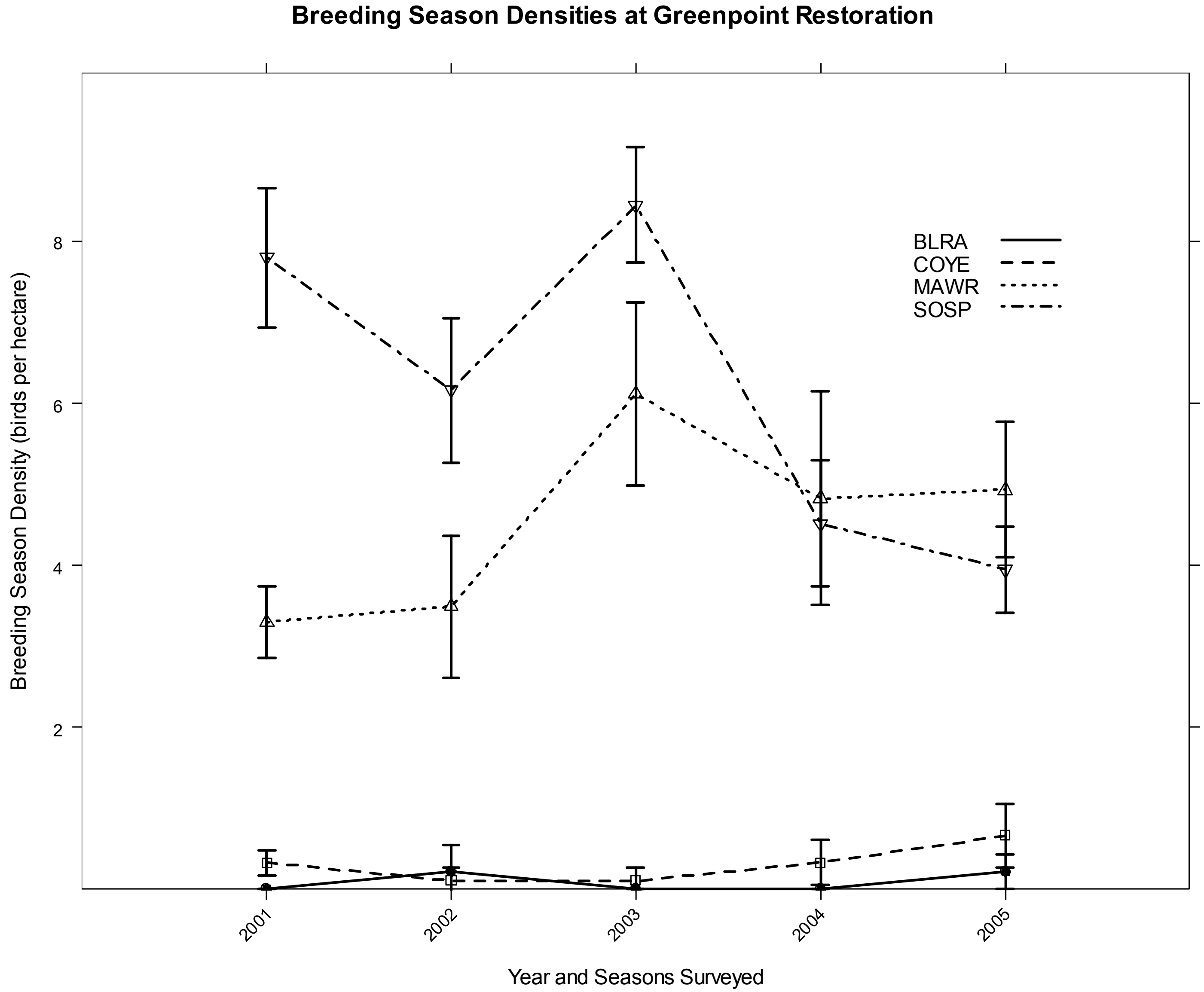

Figure 4b. Population trends of focal avian species at Petaluma River Marsh (Carl's Marsh).

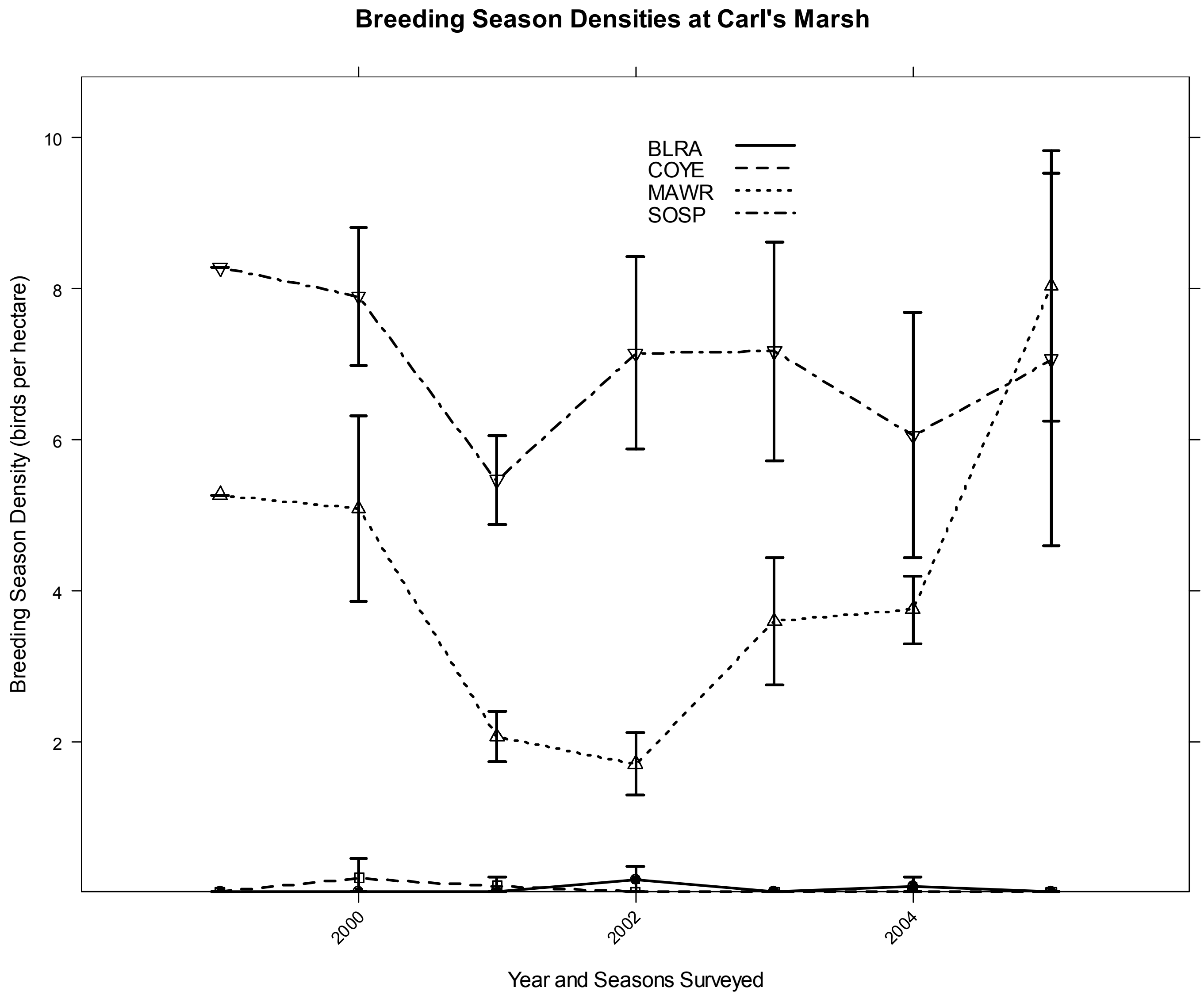

Figure 4c. Population trends of focal avian species at Pond 2A.

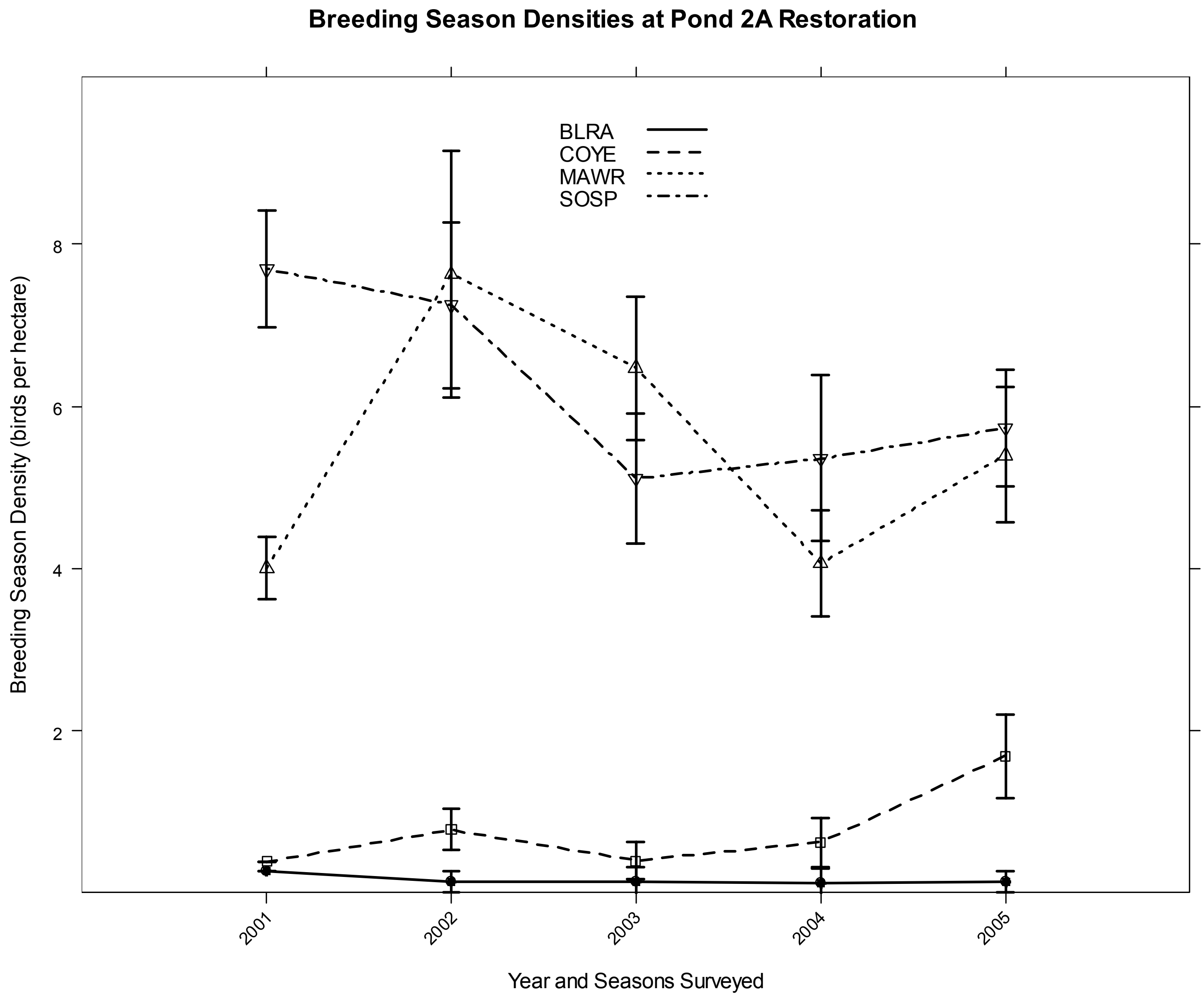

Figure 4d. Population trends of focal avian species at White Slough Marsh.

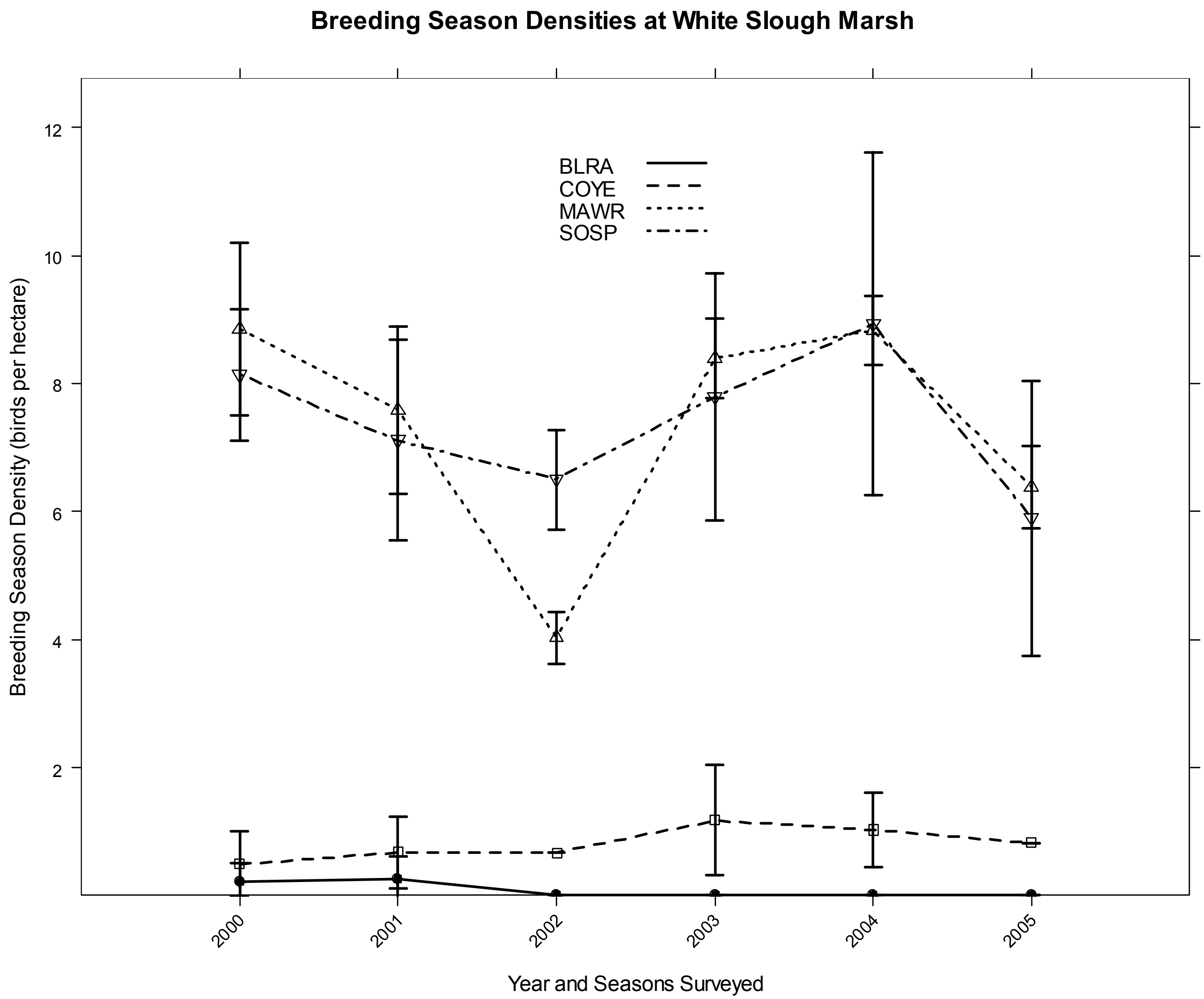

Figure 4e. Population trends of focal avian species at China Camp State Park.

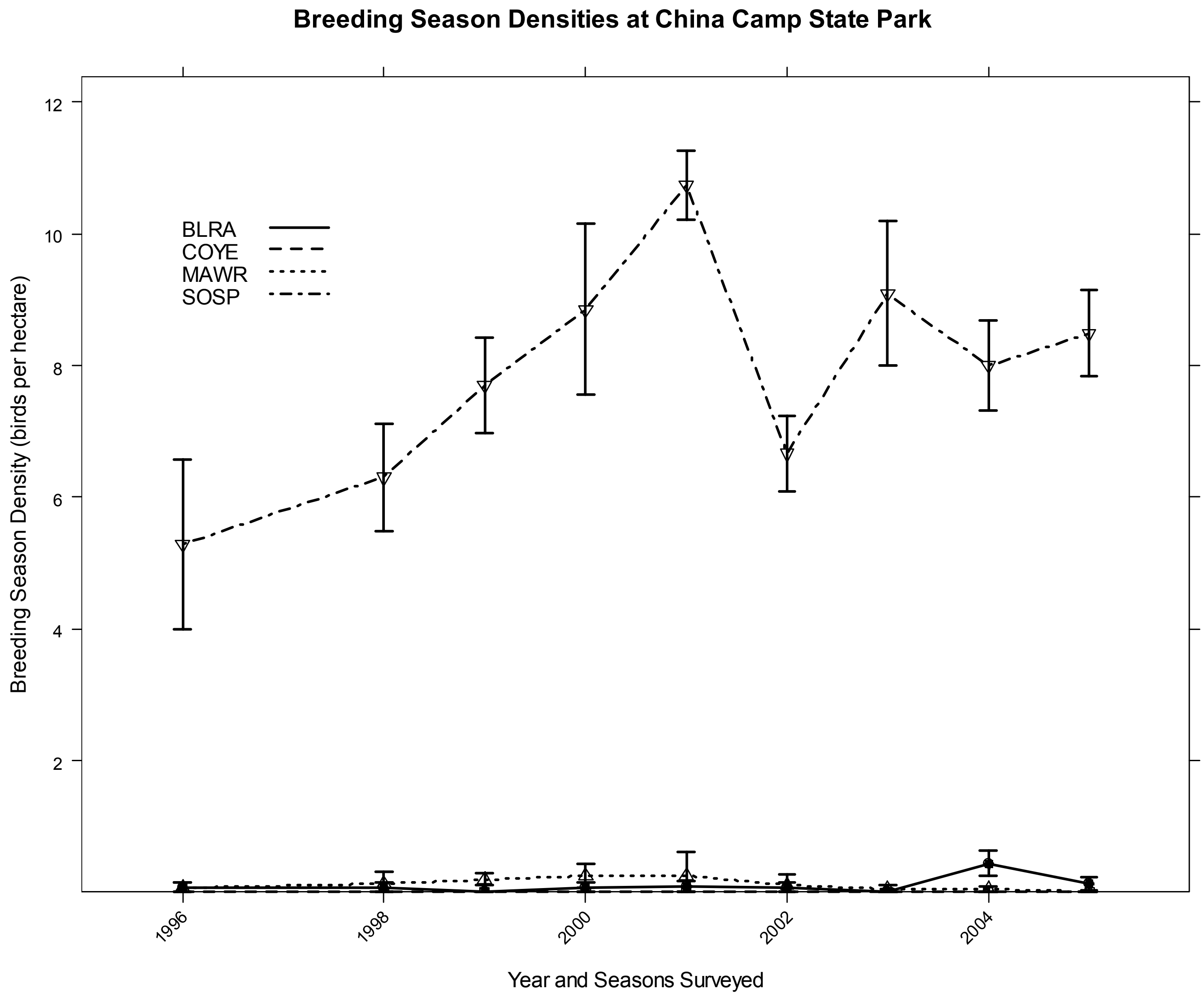

Figure 4f. Population trends of focal avian species at Benicia State Park.

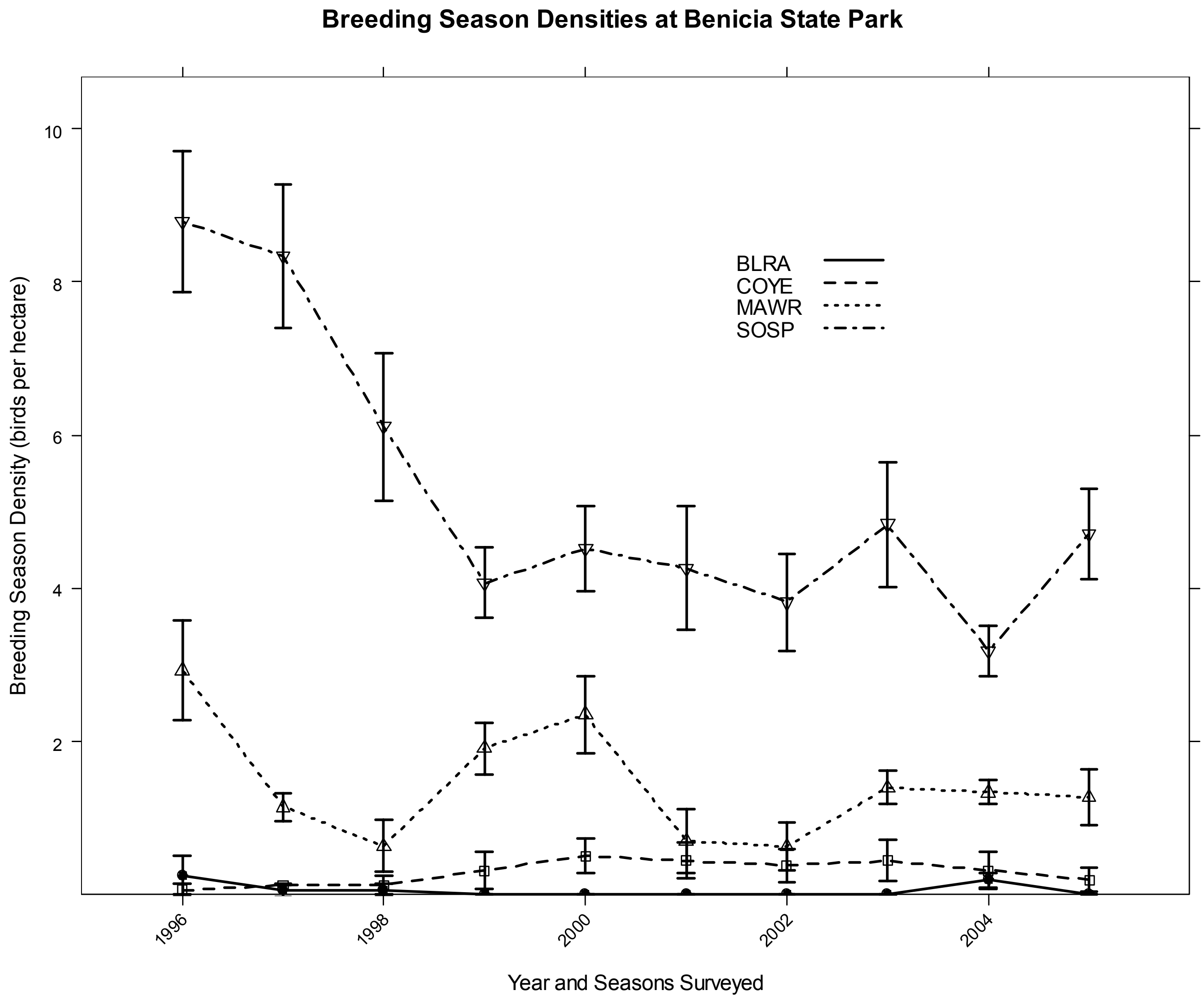

Figure 4g. Population trends of focal avian species at Rush Ranch.

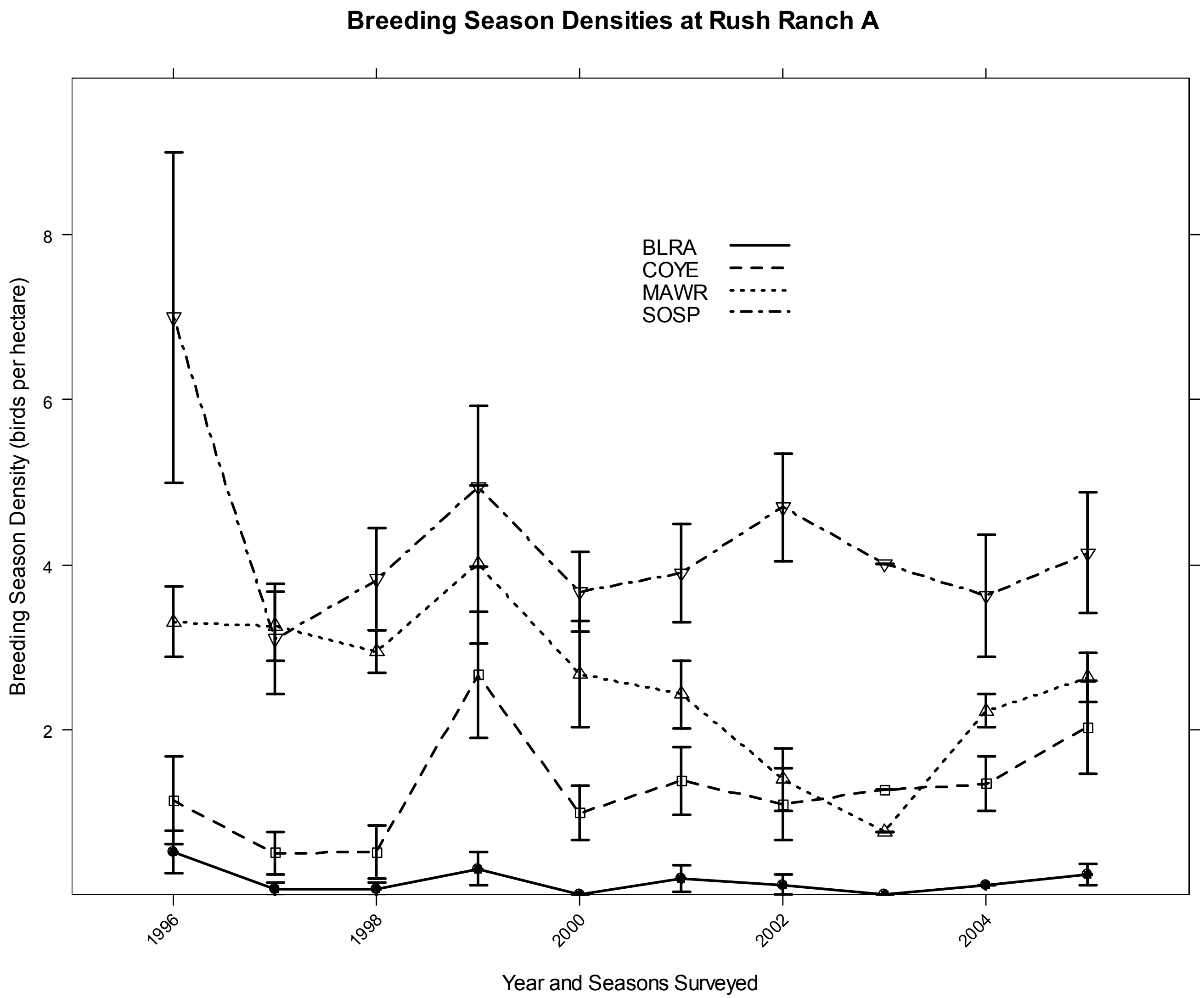

Figure 5. Clapper Rail densities (breeding birds/ha of suitable habitat) based on detections during 1992, 1993, and 2005 surveys. Densities at Coon Is. (1992, 1993), China Camp (1993), and Corte Madera (1992) based on a single survey.

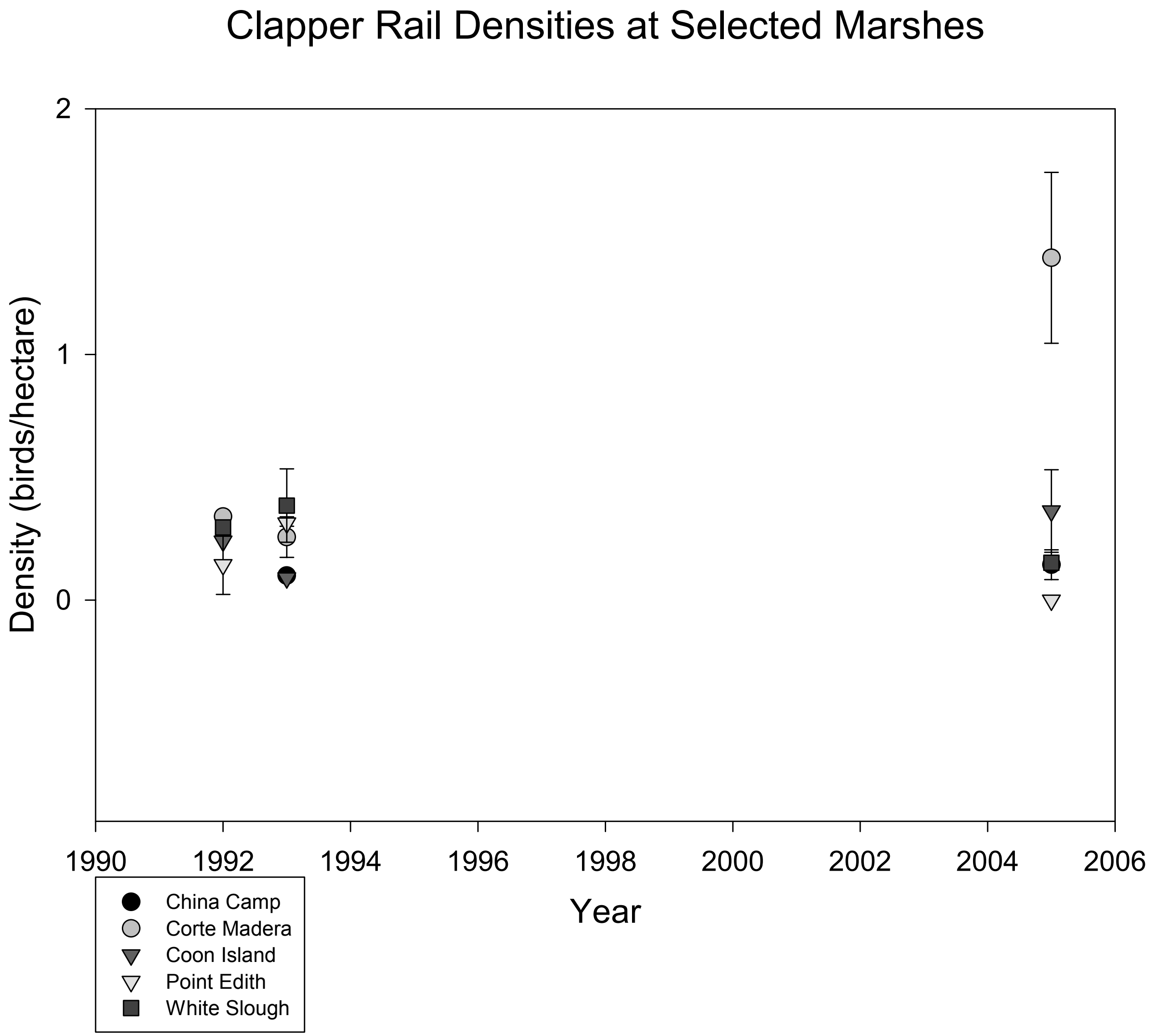

Figure 6. Proportion of Song Sparrow nests surviving to fledging (25 days), ±1 S.E., in relation to nest height from ground, grouped by 0.1 m bins.

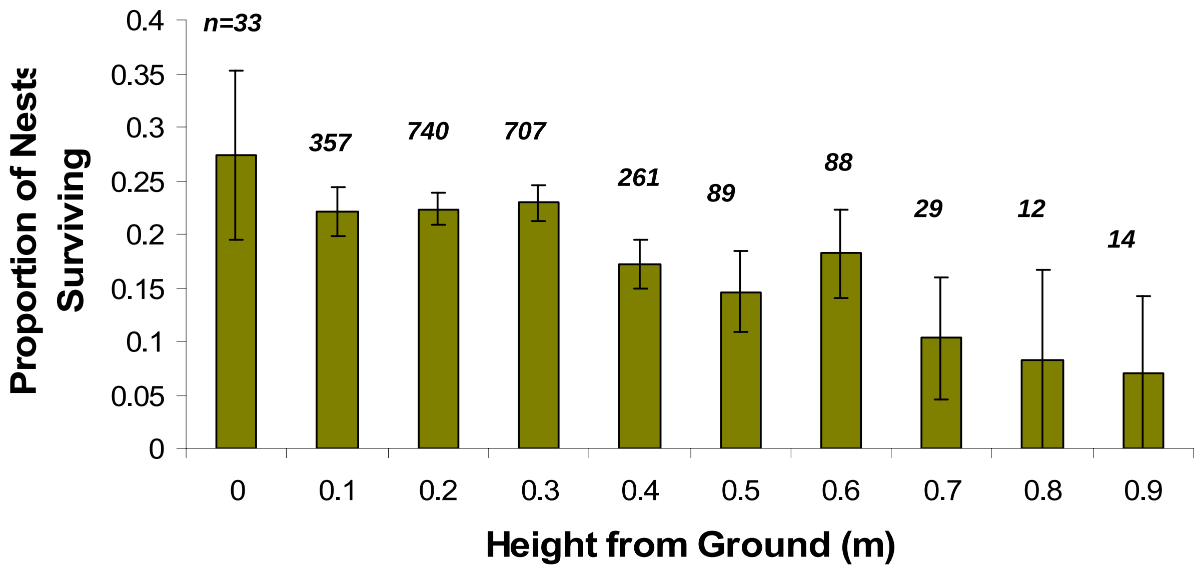

Figure 7. Estimated nest survival rate to day 25 after controlling for site effects in relation to nest height, as determined by Cox model.

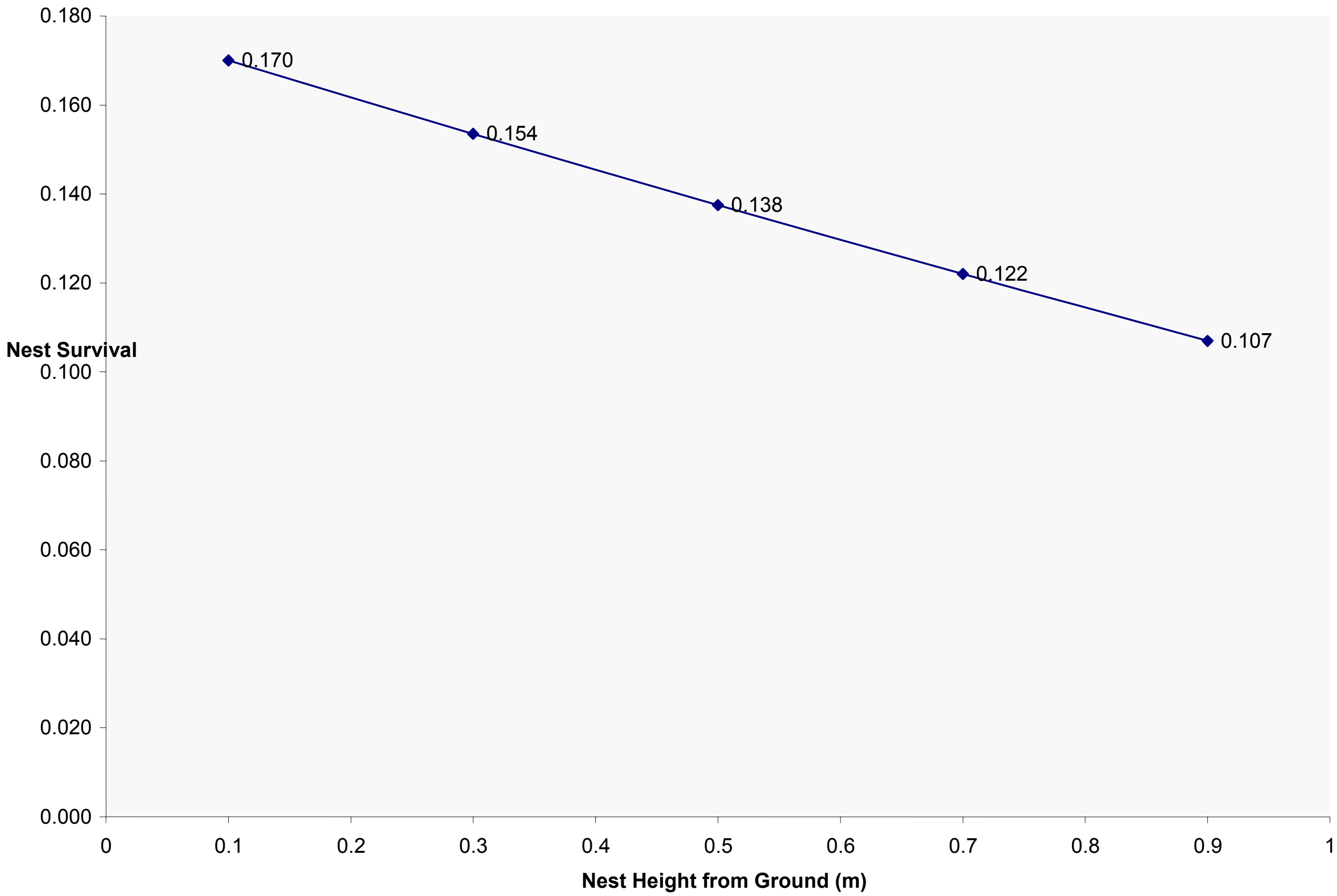

Figure 8. Proportion of nests surviving in the egg stage (from day 0 to hatching) versus nestling stage (from hatching to day 25).

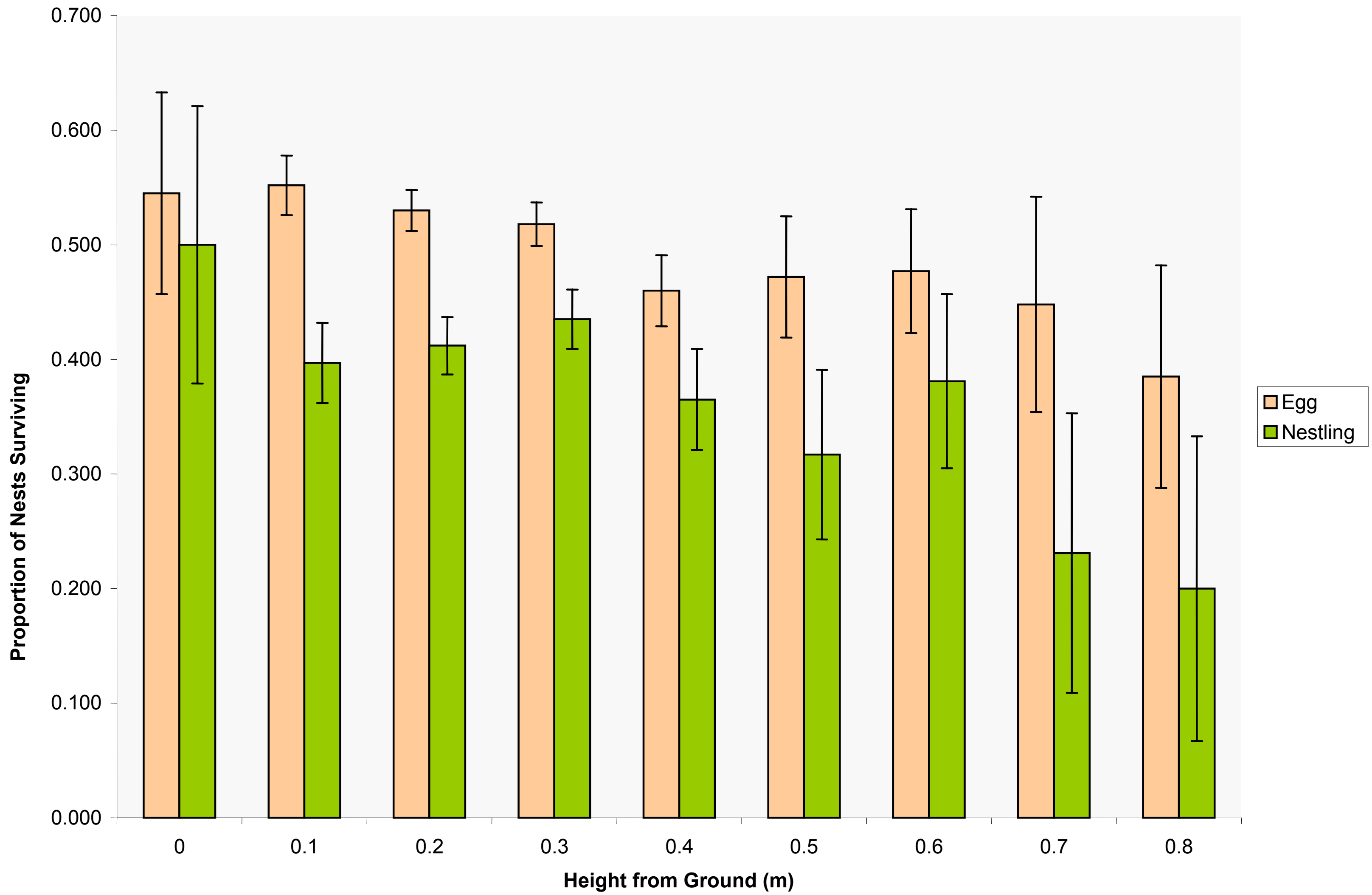

Table 1. List of marsh sites and number of points surveyed during the 2005 breeding season.

# on map	Site name	# of stations point count surveys performed	# of stations vegetation surveys performed	# of nest plots	# of line transects
	San Pablo Bay				
1	Petaluma Dog Park		2		
2	Petaluma Marsh-Mira Monte Slough	11	12		
3	Black John Slough B	10			
4	Black John Slough A	10			
5	Bahia Peninsula	11	1		
6	Green Pt. Restoration	6	6		
7	Carl's Marsh	10	7	2	1
8	Petaluma River Mouth	9	8		
9	China Camp SP	15	9	2	
10	Corte Madera Eco. Reserve-Heerdt Marsh/Muzzi Marsh	10	4		
11	Sears Point		11		
12	Tubbs Island Levee Setback	6	6		2
13	Lower Tubbs Island	8	2		2
14	Pond 2A Restoration	11	11	2	8
15	Coon Island	10			3
16	Bull Island	10			5
17	White Slough Marsh	6	1		
18	Mare Island A	10	7		
19	Mare Island B	10	5		
	Suisun Bay				
20	Benicia SRA	10		2	
21	Goodyear B	10	10		
22	Shelldrake House Pond	10			4
23	Grey Goose	7			
24	Hill Slough West Restoration	10			4
25	Rush Ranch A	10		2	
26	Delta King	12			3
27	Overlook	9			
28	Blacklock	15	7		3

Table 1 (continued). List of marsh sites surveyed during the 2005 breeding season.

# on map	Site name	# of stations used in point counts	# of stations used in vegetation surveys	# of nest plots	# of line transects
	Suisun Bay				
29	Bullhead Marsh	10	10		
30	Pt. Edith	10	4		
31	Pt Edith Restoration		5		
	Delta				
32	Brown's Island	10			4
33	Sherman Island	9	2		6
	San Francisco Bay				
34	Hayward Regional Shoreline	11	7		
35	Whaletail	6	6		
36	Alameda Creek	6	6		
37	Mowry Slough		9		
38	Dumbarton West	14			
39	Newark Slough	7			
40	Palo Alto Baylands	9			
41	East Palo Alto-Faber tract/Laumeister tract	11	7		
42	Cooley Landing	11			
43	Ravenswood Slough	8			
44	Greco Island North		14		
45	Middle Bair West		5		
46	Outer Bair East	11	17		

Table 2. 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
	San Pablo Bay							
2	Petaluma Marsh-Mira Monte Slough	0	0	28	46	6	168	33
3	Black John Slough B	5	0	20	2	37	156	14
4	Black John Slough A	2	0	29	28	9	145	16
5	Bahia Peninsula	0	0	0	0	39	2	18
6	Green Pt. Restoration	2	0	7	67	0	56	15
7	Carl's Marsh	0	1	2	109	36	90	21
8	Petaluma River Mouth	4	0	0	0	0	204	11
9	China Camp SP	11	4	0	0	0	335	18
10	Corte Madera Eco. Reserve-Heerdt Marsh/Muzzi Marsh	1	3	0	3	34	136	15
12	Tubbs Island Levee Setback	0	0	7	12	2	17	15
13	Lower Tubbs Island	2	0	10	72	0	99	19
14	Pond 2A Restoration	1	0	12	60	1	53	12
15	Coon Island	10	0	24	164	0	252	14
16	Bull Island	2	0	12	104	2	64	11
17	White Slough Marsh	0	0	4	62	1	44	17
18	Mare Island A	10	0	0	0	0	57	11
19	Mare Island B	1	0	0	0	0	93	10
	Suisun Bay							
20	Benicia SRA	0	0	21	38	23	129	19
21	Goodyear B	0	0	57	87	58	125	15
22	Shelldrake House Pond	0	0	28	65	1	56	29
23	Grey Goose	3	0	42	45	2	55	15
24	Hill Slough West Restoration	0	0	21	53	2	57	16
25	Rush Ranch A	7	0	60	77	96	114	12
26	Delta King	0	0	27	65	55	27	30
27	Overlook	0	0	31	75	0	79	18
28	Blacklock	0	0	12	98	0	58	12
29	Bullhead Marsh	1	0	63	73	0	178	14
30	Pt. Edith	9	0	47	131	10	133	14

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
	Delta							
32	Brown's Island	8	0	33	91	0	63	15
33	Sherman Island	13	0	59	83	1	114	17
	San Francisco Bay							
34	Hayward Regional Shoreline	0	0	0	42	9	39	37
35	Whaletail	0	0	0	22	0	144	16
36	Alameda Creek	0	0	1	43	0	50	20
38	Dumbarton West	0	0	4	10	0	163	18
39	Newark Slough	0	0	1	0	0	44	10
40	Palo Alto Baylands	0	4	19	14	1	104	22
41	East Palo Alto-Faber tract/Laumeister tract	0	6	0	5	11	66	21
42	Cooley Landing	0	0	0	0	9	32	21
43	Ravenswood Slough	0	0	0	8	0	56	18
46	Outer Bair East	0	0	1	14	0	133	25

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) ↑ ↓ indicates trend compared with 2004 for Song Sparrows.

# on map	Site name	Black Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Savannah Sparrow	Song Sparrow
	San Pablo Bay						
2	Petaluma Marsh-Mira Monte Slough	0	0.58(0.72)	0.52(0.80)	0	0.46(1.54)	3.70(1.99) ↓
3	Black John Slough B	0.20(0.32)	0.58(0.56)	0.06(0.20)	0.57(1.10)	0.32(1.01)	6.73(2.17) ↑
4	Black John Slough A	0.06(0.20)	1.11(0.92)	1.32(1.29)	0.07(0.24)	0.46(0.68)	6.28(1.66) ↑
5	Bahia Peninsula	0	0	0	1.85(3.24)	0	0 ↓
6	Green Pt. Restoration	0.22(0.34)	0.66(0.60)	4.93(3.07)	0	0	3.95(0.55) ↓
7	Carl's Marsh	0	0	8.03(5.50)	1.81(3.07)	0.75(1.71)	7.06(4.49) ↑
8	Petaluma River Mouth	0.21(0.32)	0	0	0	0	8.29(2.38) ↑
9	China Camp SP	0.13(0.26)	0	0	0	0	8.49(2.12) ↑
10	Corte Madera Eco. Reserve-Heerdt Marsh/Muzzi Marsh	0.06(0.20)	0	0.13(0.42)	0.13(0.42)	0	5.76(2.01) ↑
12	Tubbs Island Levee Setback	0	0.53(0.74)	0.85(0.96)	0.21(0.52)	1.49(0.96)	1.49(1.19)
13	Lower Tubbs Island	0.08(0.23)	0.40(0.58)	3.30(2.25)	0	0.08(0.23)	6.00(3.45) ↓
14	Pond 2A Restoration	0.13(0.30)	1.69(1.07)	5.40(0.81)	0.06(0.19)	0	5.73(1.66) ↑
15	Coon Island	0.57(0.47)	0.76(0.59)	3.88(2.48)	0	0	7.45(1.85) ↓
16	Bull Island	0.11(0.34)	0.89(0.90)	7.45(1.89)	0.20(0.42)	0	4.79(1.76) ↓
17	White Slough Marsh	0	0.83(1.30)	6.38(2.04)	0.21(0.52)	0	5.90(2.96) ↓
18	Mare Island A	0.57(1.02)	0	0	0	0.13(0.27)	2.16(1.59) ↓
19	Mare Island B	0.06(0.20)	0	0	0	0.25(0.62)	3.91(2.71) ↓
	Suisun Bay						
20	Benicia SRA	0	0.19(0.31)	1.27(1.34)	0.45(0.80)	0	4.71(1.93) ↑
21	Goodyear B	0	2.61(0.70)	4.14(1.21)	0	0.64(1.20)	5.73(2.04) ↓
22	Shelldrake House Pond	0	1.31(0.78)	4.40(2.70)	0	0.07(0.21)	3.50(1.97) ↓
23	Grey Goose	0	2.58(1.35)	2.84(0.79)	0.37(0.63)	0	3.30(1.34) ↓
24	Hill Slough West Restoration	0	0.57(0.82)	2.10(2.56)	0	1.46(1.73)	2.16(1.70) ↓
25	Rush Ranch A	0.25(0.45)	2.03(0.92)	2.63(1.99)	3.25(2.39)	0	4.14(1.13) ↑
26	Delta King	0	0.65(1.02)	2.89(3.59)	2.13(1.99)	0.36(0.56)	0.67(1.09) ↓
27	Overlook	0	1.67(0.97)	4.50(1.52)	0	0	3.91(1.28) ↓
28	Blacklock	0	0.94(0.86)	6.55(3.66)	0	0.13(0.36)	4.47(2.80) ↑
29	Bullhead Marsh	0.08(0.27)	3.16(2.58)	3.88(1.35)	0	0	8.58(4.43) ↑
30	Pt. Edith	0.46(0.63)	1.65(0.97)	6.91(1.87)	0.26(0.34)	0	6.01(1.47) ↓

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) ↑ ↓ indicates trend compared with 2004 for Song Sparrows.

# on map	Site name	Black Rail	Common Yellowthroat	Marsh Wren	Red-winged Blackbird	Savannah Sparrow	Song Sparrow
	Delta						
32	Brown's Island	0.32(0.54)	1.34(0.87)	5.41(1.42)	0	0	3.31(1.46) ↑
33	Sherman Island	0.29(0.60)	2.03(1.03)	3.71(1.68)	0.06(0.19)	0	4.70(1.43) ↓
	San Francisco Bay						
34	Hayward Regional Shoreline	0	0	1.67(1.62)	0.29(0.69)	1.98(1.44)	1.53(0.82) ↓
35	Whaletail	0	0	0.42(0.52)	0	0.53(0.48)	4.99(1.68) ↓
36	Alameda Creek	0	0	3.22(2.13)	0	0.32(0.53)	4.10(1.93)
38	Dumbarton West	0	0	0.25(0.61)	0	0.25(0.53)	5.70(1.95)↑
39	Newark Slough	0	0.18(0.48)	0	0	0.33(0.87)	4.24(1.87) ↓
40	Palo Alto Baylands	0	1.59(2.48)	1.11(2.26)	0	0	7.10(3.43)↑
41	East Palo Alto-Faber tract/Laumeister tract	0.12(0.38)	0.17(0.41)	0.58(1.04)	1.04(3.06)	0	7.39(4.82)↑
42	Cooley Landing	0	0	0	0.12(0.26)	0	1.16(1.06)
43	Ravenswood Slough	0	0	0.08(0.23)	0	0	3.58(2.22)
46	Outer Bair East	0	0.06(0.19)	0.58(1.15)	0	0.23(0.59)	4.75(1.92)↑

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 2005 field season. Overall nest survival rate for entire nesting period is also shown in Figure 3. ↑ ↓ indicates trend compared with 2004.

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	149	0.912	0.008	**0.123** ↓	0.083	0.182	0.207
	Laying / Incubation	147	0.923	0.009	0.335 ↓	0.102	0.252	
	Nestling	82	0.893	0.014	0.355 ↑	0.036	0.155	
Carl's Marsh	Overall	97	0.914	0.010	**0.130** ↑	0.080	0209	0.211
	Laying / Incubation	95	0.911	0.011	0.281 ↑	0.067	0.211	
	Nestling	39	0.923	0.017	0.481 ↑	0.067	0.375	
Pond 2A	Overall	65	0.950	0.008	**0.312** ↑	0.207	0.466	0.484
	Laying / Incubation	64	0.959	0.011	0.564 ↓	0.229	0.637	
	Nestling	50	0.944	0.013	0.590 ↑	0.143	0.495	
Suisun Bay								
Benicia	Overall	131	0.924	0.007	**0.166** ↓	0.116	0.236	0.209
	Laying / Incubation	129	0.942	0.008	0.442 ↓	0.177	0.367	
	Nestling	73	0.879	0.017	0.308 ↑	0.022	0.124	
Rush Ranch	Overall	44	0.936	0.012	**0.219** ↑	0.121	0.391	0.386
	Laying / Incubation	44	0.953	0.014	0.517 ↑	0.170	0.640	
	Nestling	33	0.914	0.021	0.439 ↑	0.045	0.351	

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. The arrows represent change in rate from 2004.

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 2005 breeding season at tidal marsh study sites in China Camp State Park, Carl's Marsh, Pond 2A, Benicia State Park, and Rush Ranch.

Species	China Camp [1]	Carl's Marsh [1]	Pond 2A [1]	Benicia [1]	Rush Ranch [1]	Total nests found	Total nests of known fate	Successful nests	% Successful
American Goldfinch [2]	1:1(1)	0	0	3:2(1)	0	4	3	2	67
Anna's Hummingbird[3]	0	0	0	1:1(1)	0	1	1	1	100
Black Rail	1:1(0)	0	1:0(0)	2:1(1)	3:1(1)	7	3	2	66.7
Clapper Rail	2:2(1)	1:0(0)	0	0	0	3	2	1	50
Common Yellowthroat	0	0	4:3(1)	2:2(2)	1:1(1)	7	6	4	67
Gadwall[4]	0	1:1(1)	0	0	1:1(1)	2	2	2	100
Loggerhead Shrike[5]	0	0	0	0	1:1(1)	1	1	1	100
Mallard [6]	0	0	0	1:1(1)	1:1(0)	2	2	1	50
Marsh Wren	0	46:14(2)	17:10(5)	3:0(0)	10:4(2)	76	28	9	32
Mourning Dove[7]	1:1(0)	0	0	0	0	1	1	0	0
Red-winged Blackbird[8]	0	4:4(4)	0	2:2(1)	11:9(3)	17	15	8	53
Song Sparrow	214:149(31)	131:97(20)	90:65(31)	186:131(27)	52:44(17)	673	482	126	26
Virginia Rail	0	0	1:1(1)	0	0	1	1	1	100

1 Total Nests Found : Total Nests of Known Fate (Number of successful nests)
2 *Carduelis tristis*
3 *Calypte anna*
4 *Anas strepera*
5 *Lanius ludovicianus*
6 *Anas platyrhynchos*
7 *Zenaida macroura*
8 *Agelaius phoeniceus*

Table 6. Song Sparrow breeding densities at nest monitoring sites, 2005. For territory mapping method, please see text.

marsh	number of territories (2005)	area (ha)	2005 density (pairs/ha)	2005 density (birds/ha)	2004 density (birds/ha)	2005 density index point count data (birds/ha)
China Camp State Park						
Plot A	76	11.49	6.61	13.23	11.76	n/a
Plot B	70	10.14	6.90	13.81	13.60	n/a
Total	**146**	**21.63**	**6.75**	**13.50**	**12.58**	**8.49±2.12**
Carl's Marsh						
Plot A	48	14.03	3.42	6.84	8.42	n/a
Plot B	41	9.46	4.33	8.67	5.46	n/a
Total	**89**	**23.49**	**3.79**	**7.58**	**6.64**	**7.06±4.49**
Pond 2A						
Plot A	39	5.67	6.88	13.76	10.89	n/a
Plot B	51	5.37	9.50	18.99	16.40	n/a
Total	**90**	**11.04**	**8.15**	**16.30**	**13.40**	**5.73±1.66**
Benicia State Park						
Plot A	67	13.62	4.92	9.84	9.96	n/a
Plot B	48	13.33	3.60	7.20	7.84	n/a
Total	**115**	**26.95**	**4.27**	**8.53**	**8.92**	**4.71±1.93**
Rush Ranch						
Plot A	40	8.05	4.97	9.94	10.18	n/a
Plot B	26	6.02	4.32	8.64	7.03	n/a
Total	**66**	**14.07**	**4.69**	**9.38**	**8.68**	**4.14±1.13**

Table 7. Summary of banding results in 2005 field season for Song Sparrows (*Mature marshes in italics*).

Site	Total Newly Captured	Adults	Juveniles	Nestlings
China Camp State Park	*106*	*2*	*0*	*104*
Carl's Marsh	71	15	4	52
Pond 2A	37	3	0	34
Benicia State Park	*92*	*10*	*1*	*81*
Rush Ranch	*53*	*2*	*0*	*51*
Totals	**359**	**32**	**5**	**322**

Table 8. Song Sparrow nestlings banded 1996-2005.

Year	Nestlings banded
1996	19
1997	368
1998	217
1999	313
2000	368
2001	218
2002	244
2003	162
2004	121
2005	322
Total	2352

Table 9. Clapper Rail densities

2005 Clapper Rail Survey Results				
			Density Range	
#	Survey Sites	Area (ha)	low	high
	Central San Francisco Bay			
1	San Bruno (SamTrans Peninsula)	14	2.0	2.6
1a	San Bruno Point	9	2.3	3.0
2	Bothin Marsh, Richardson Bay	38	0.0	0.0
3	Muzzi Marsh	46	0.7	0.8
4	Heerdt Marsh	24	1.4	1.7
5	Meeker Slough, Inner Richmond Harbor	11	0.1	0.2
	Central San Francisco Bay Total:	142	0.8	1.0
	San Pablo Bay			
6	Gallinas Creek, north fork	11	0.6	0.8
7	Gallinas Creek, south fork	13	1.6	1.8
8	Gallinas Creek mouth, south (China Camp State Park)	47	0.2	0.2
9	Gallinas Creek mouth, north	36	1.5	1.8
10	Gallinas Ck. North (Hamilton south)	36	0.8	1.0
11	Hamilton Field	29	0.0	0.1
12	Bahia Lagoon	8	2.0	2.8
13	Bahia channel-Toy marsh	55	0.1	0.1
14	Carl's Marsh	24	0.1	0.2
15	Port Sonoma Marina	4	0.7	0.8
16	Sonoma Creek	27	0.0	0.0
17	Skaggs Is. Bridge	5	0.0	0.0
18	(White Slough N)	99	0.1	0.1
18a	(White Slough S)	45	0.0	0.1
19	Pond 2A	92	0.0	0.0
20	Coon Island	76	0.1	0.2
21	Bull Island	60	0.0	0.0
22	Wildcat Marsh south	34	0.1	0.2
22a	Wildcat Marsh north	40	0.1	0.2
23	Point Pinole North	24	0.0	0.0
24	Pinole Creek mouth	10	0.0	0.0
	San Pablo Bay Total:	775	0.2	0.3
	Suisun Bay			
25	Peyton Slough	50	0.0	0.0
26	Point Edith	150	0.0	0.0
27	Reserve Fleet/Goodyear Slough	60	0.0	0.0
28	Suisun Slough mouth	100	0.0	0.0
29	Cordelia Slough	20	0.0	0.0
30	2nd Mallard Slough	15	0.0	0.0
31	Cutoff Slough	75	0.0	0.0
32	1st Mallard Slough	30	0.0	0.0
33	Hill Slough	23	0.0	0.0
	Suisun Bay Total:	523	0.0	0.0
	South San Francisco Bay			
34	Sanchez Marsh (Burlingame Lagoon)	2	0.0	0.0

35	Coyote Point Marina	4	0.0	0.0
36	Seal Slough, San Mateo	24	0.2	0.3
36a	Joinsville Marsh	6	0.0	0.0
37	Outer Bair East (channels)	100	0.1	0.1
37a	Outer Bair East (levees)	56	0.1	0.1
38	Middle Bair East	41	0.4	0.6
39	Greco Island North	111	0.2	0.3
40	East Palo Alto	33	0.6	1.1
41	Palo Alto Baylands	30	0.2	0.5
42	Dumbarton West	84	0.1	0.1
43	Mowry Slough	34	0.2	0.3
44	Newark Slough	30	0.0	0.1
	South San Francisco Bay Total:	554	0.2	0.3

Table 10. Cox model estimates of effect of nest height on nest survival compared among sites.

Site	Hazard Ratio	Standard Error	P value	N
Black John Slough	1.103	0.105	>0.3	159
China Camp	1.001	0.037	>0.9	961
Petaluma River Marsh	0.713	0.094	0.010	57
Pond 2A	0.929	0.108	>0.5	26
Petaluma River Mouth	0.862	0.210	>0.5	247
Rush Ranch	1.028	0.049	>0.5	168
Benicia State Park	1.060	0.027	0.024	712

Table 11. Comparison of ΔAIC_c and weights for 10 predictive models. nest_ht = nest height; plantsub = plant substrate supporting nest (see Methods). N = 2325 nests.

Model	**Model Name**	***k***	**ΔAICc**	**Weight**
M1	nest_ht + site + nest_ht*site	14	0.00	0.419
M2	nest_ht + site	8	0.78	0.284
M3	site	7	1.15	0.236
M4	nest_ht + site + nest_ht*site + plantsub	18	6.01	0.021
M5	plantsub + site	11	6.09	0.020
M6	nest_ht + site + plantsub	12	6.81	0.014
M7	nest_ht + plantsub	6	9.53	0.004
M8	nest_ht	2	11.28	0.001
M9	plantsub	5	12.02	0.001
M10	null	1	21.96	0.000