Tidal Marsh Birds of the San Francisco Bay Region: Status, Distribution, and Conservation of Five Category 2 Taxa

DRAFT Final Report
to United States Geological Survey-Biological Resources Division
(Formerly National Biological Service)

Prepared by

Nadav Nur, Ph.D.
Steve Zack, Ph.D.
Jules Evens,
and Thomas Gardali

of the Point Reyes Bird Observatory
Stinson Beach, CA 94970

May 1997

PRBO Tidal Marsh Report -- DRAFT

Table of Contents

EXECUTIVE SUMMARY

This project focuses on five species or subspecies recognized as possibly Threatened or Endangered (former Category 2, candidate species, US Fish & Wildlife Service), found entirely or mainly in the salt-water marshes of the San Francisco Bay Area. Four of the taxa comprise morphologically distinct subspecies belonging to one of two passerine species, the Song Sparrow (*Melospiza melodia*) and the Common Yellowthroat (*Geothlypis trichas*). The four passerine subspecies are: Alameda Song Sparrow (*M. m. pusillula*), Samuel's Song Sparrow (*M. m. samuelis*), Suisun Song Sparrow (*M. m. maxillaris*), as well as Salt Marsh Yellowthroat (*G. t. sinuosa*; also referred to as San Francisco Yellowthroat). The final species of interest is the Black Rail *Laterallus jamaicensis*, represented in the San Francisco Bay region by the California subspecies *L. j. coturniculus*. The tidal marsh habitat for each taxon has shrunk dramatically in recent decades such that only 15% of it remains, compared to the historic extent. Loss of habitat has made clarification of population status and trend essential, and placed a high premium on determining the relationship of habitat features to species abundance and distribution, thereby providing information that can help land managers and biologists bring about stabilization of numbers.

Specific objectives of the study were to: (1) assess abundance in relation to habitat and landscape features, especially those affected by management action, (2) obtain population size estimates for each of the five taxa, (3) determine productivity of Song Sparrow populations using monitoring of nesting attempts, and (4) compare and contrast phenotypic characteristics of the three tidal marsh Song Sparrow subspecies.

For both Song Sparrows and Common Yellowthroats, degree of channelization appeared to be an important influence on abundance: abundance was significantly greater in marshes with greater (rather than fewer) channels. The effect was similar in all bay regions. Whether or not the channels were artificial or natural did not appear to be critical. The overall importance of marsh area itself in influencing abundance could not be confirmed, perhaps because the current study focused more on mid-sized and large marshes. Instead, the effect of marsh area was shown to be dependent on degree of isolation of the marsh: for isolated marshes (those more than 1 km distant from the next closest tidal marsh), the effect of marsh area was significantly stronger than for non-isolated marshes. These results suggest that marsh area is important--but only for isolated marshes.

We were able to identify several vegetation/habitat correlates of Common Yellowthroat abundance; future work can be directed at confirming whether or not they causally influence abundance. For yellowthroats, there was a positive correlation with percent cover of *Scirpus* (the genus including Bulrush and Tule), Peppergrass, and Common Cat-tail; and a negative correlation with Pickleweed. This last relationship was of interest, because Pickleweed is the overwhelmingly dominant plant species in most (but not all) tidal marshes in the entire bay region. Also, yellowthroat abundance increased as percent cover by channels increased. For Song Sparrows, there was a positive correlation with *Scirpus* and Peppergrass but a negative correlation with Cord Grass. However, once percent cover of *Scirpus* and Peppergrass was controlled for, the effect of Cord Grass was significantly positive not negative. Thus the importance of Cord Grass is ambiguous. No one plant species appeared to be important in explaining variation in Song Sparrow abundance.

We estimate that 27-30% of Song Sparrow nests successfully produce fledged young; this is a figure similar to other studies of this species. However, at one site (Southampton Bay) nesting success was only a little more than half of this value. With such low nesting success it is not likely that the Southampton Bay population is self-sustaining.

Calculated densities of Song Sparrows appeared to be lower in Central/South San Francisco Bay (median = 3.7 birds per hectare; densities reported include breeders as well as nonbreeders), compared to San Pablo Bay (median = 18 birds per hectare) or Suisun Bay (26 birds per hectare). We estimate the number of breeding Alameda Song Sparrows at 4,000 to 9,700; the number of breeding Samuel's Song Sparrow (San Pablo Bay) at 25,000 to 60,000 birds; and the number of breeding Suisun Song Sparrows at 22,000 to 53,000 birds. In contrast, Marshall and Dedrick (1994) estimated 14,800 breeding Alameda Song Sparrows, 19,100 breeding Suisun Song Sparrows and 31,200 breeding Samuel's Song Sparrows. Thus we estimate fewer than 10,000 breeding Alameda Song Sparrows, with a best estimate 45% less than that of the previous estimate by Marshall & Dedrick (1994). Not only do breeding populations appear to be low, but habitat for this subspecies is the most compromised of the three: the total area of tidal marsh is low, and it consists mainly of small (to medium-sized) marshes that are often isolated from each other. On these bases we recommend that the Alameda Song Sparrow be classified as a Threatened species. As for the other two subspecies, we believe there is still cause for concern.

It was even more difficult to derive total population estimates for the Salt Marsh Yellowthroat. At about 50% of marshes, no yellowthroats or nearly no yellowthroats were detected. Whereas, marshes with yellowthroats were to be found in all regions of the San Francisco Bay Estuary system, the converse was also true: in all three regions of the Bay system, there were marshes in which no Salt Marsh Yellowthroats were detected; this was in contrast to Song Sparrows, for which individuals were detected at all marshes investigated. In general, yellowthroats were uncommon at all marshes except those in Suisun Bay. We estimate 0.7 yellowthroats per hectare of marsh studied; if extrapolated to all available tidal marsh habitat in the San Francisco Bay system, this implies 5,700 to 10,600 breeding Salt Marsh Yellowthroats; additional numbers are found in brackish and freshwater marshes. Further study of Salt Marsh Yellowthroats is urgently called for.

For Black Rails, there appeared to no overall trend for numbers to decrease, comparing 1986 and 1996 censuses. Estimates of total abundance are subject to many sources of error, especially because Black Rails are extremely inconspicuous and could only be detected vocally. We estimate number of Black Rails as roughly between 3900 and 7700 in San Pablo Bay and roughly between 4100 and 8000 in San Pablo Bay; there are apparently no Black Rails in Central and South San Francisco Bay. In addition, we estimate 160 to 250 Black Rails in the Outer Coast region of Marin county. Whereas, individual marsh area was not significantly related to overall Black Rail density (though a non-significant trend was evident for density to increase with marsh area), there was a significant tendency for Black Rails to be absent from small marshes. There was no evidence of extirpation of Black Rails populations or recolonization at individual marshes between 1986 and 1996. Whereas numbers of Black Rails in San Pablo and Suisun Bays appear relatively stable, there is great cause for concern for Outer Coast Black Rails: numbers are low, numbers appear to be decreasing over the past decade, and the birds are found in small, isolated marshes. These populations are in danger of extinction in the short term.

SECTION ONE
INTRODUCTION AND OVERVIEW

The San Francisco Bay region has been dramatically altered in the past century and a half. The bay region, starting in the 19th century, experienced dramatic alterations in size and in function, as did the adjoining estuary draining the great Central Valley (Cohen 1991). Gold mining, water diversion systems, agricultural transformation, creation of salt ponds, and urbanization have dramatically affected all natural habitats in this region, perhaps none more significantly than the tidal salt marshes. It is estimated that only 15% of original tidal marsh habitat remains (Marshall and Dedrick 1994).

Among the wildlife affected by the reduction of tidal salt marshes of the San Francisco Bay region are morphologically distinct subspecies of the Song Sparrow *Melospiza melodia* and the Common Yellowthroat *Geothlypis trichas.* In the San Francisco Bay region, these species are represented by resident subspecies entirely or mainly restricted to tidal marsh habitat. The subspecies of Song Sparrow are the Alameda Song Sparrow *Melospiza melodia pusillula*, Samuel's Song Sparrow *M. m. samuelis*, and the Suisun Song Sparrow *M. m. maxillaris*. These Song Sparrow taxa are restricted to, respectively, the San Francisco Bay (Central and South Bays; Alameda Song Sparrow), San Pablo Bay (Samuel's Song Sparrow), and Suisun Bay (Suisun Song Sparrow; see Figure 1). The subspecies of Common Yellowthroat, found throughout the San Francisco Bay region, is the Salt Marsh Yellowthroat *Geothlypis trichas sinuosa*, also referred to as the San Francisco Yellowthroat. Another bird affected by the tidal marsh reduction in the San Francisco Bay region, and subject of the current study, is the California Black Rail *Laterallus jamaicensis coturniculus* (Evens et al. 1991).

Each of these five bird taxa has been considered "Category 2 Candidate Species" and "Species at Risk." The Black Rail is considered both "California-listed Threatened species" and "California Fully Protected Species," while each of the endemic Song Sparrow subspecies are "California Species of Special Concern" (Laudenslayer, Grenfell, and Zeiner 1991). In 1996, The *Point Reyes Bird Observatory* was awarded funding by the (then) National Biological Survey's Success with Species at Risk Initiative. This report summarizes and completes the NBS-funded project.

Our first objective was to obtain population size estimates for each of the five taxa (three Song Sparrow subspecies, the Common Yellowthroat subspecies, and the California Black Rail in the San Francisco Bay region). Our principal estimation technique was the variable distance point count census method (Reynolds et al. 1980). A second objective was to compare population estimates or indices for 1996 with earlier estimates or indices in order to infer population trend. Our third objective was to assess abundance in relation to habitat and landscape features. Habitat and landscape features that were examined included, the presence of levees--which act to impede tidal flow; degree of channelization; natural vs. artificial channels; size of marsh; and connection vs. isolation of each marsh. In addition, we examined the importance of plant composition (particularly *Salicornia* vs. *Scirpus*).

The fourth objective was to determine productivity (the production of young) for Song Sparrow populations. Identification of Black Rail nests is very difficult, and too few Common Yellowthroat nests were discovered, hence we focus only on the Song Sparrows. We evaluated productivity using standard nest monitoring protocol (Martin and Geupel 1993), comparing results within this study (assessing variation among marshes) as well as comparing results with other studies. Our final objective was to collect auxiliary information on phenotypic characteristics for the four passerines (particularly Song Sparrows) and compare them to the more widespread, less localized taxa around the Bay area. This would allow us an opportunity to assess the phenotypic variation within and between subspecies, and provide the basis for subsequent research (not part of this study) to evaluate whether these subspecies are genetically distinct or not.

We divide the report into two separate sections, one for the four passerine taxa, and one for the California Black Rail, because methodology, geographic scope, and historical information differ substantially for these two groups of birds.

SECTION TWO - SONG SPARROW AND COMMON YELLOWTHROATS IN THE SAN FRANCISCO BAY REGION: ABUNDANCE, PRODUCTIVITY, AND FACTORS INFLUENCING ABUNDANCE

METHODS

Choice of Study Sites

Study sites were chosen as those representative marshes of each bay with sufficient contiguous marsh to support the establishment of multiple point count points (see Figure 2, Table 1, and Appendix 1). Our choices reflected a combination of: an attempt to sample broadly from regions discussed in Marshall and Dedrick (1994), maximize accessibility, and the desire to repeat sampling at sites of previous assessments of Black Rail densities (Evens et al. 1991; discussed in detail in section three). Accessibility was of great importance; we had no boat to use (several marsh fragments, particularly in the Grizzly Island region and in the San Francisco Bay, could only be reached by boat) and so had to depend on road or trail access to marshes. We concentrated attention on those marshes that were under tidal influence and so ignored marshes that were historically tidal, but today are either dry or are so levied as to be standing ponds of extensive Tule vegetation. We attempted to choose sites that were broadly distributed across each bay. These strict criteria had to be modified, however, particularly for sites in San Francisco Bay proper (Central and South Bay), as tidal marsh fragments are often very small and widely dispersed. For San Pablo and Suisun Bays we established study sites at 7 locations, with 70 point count stations in each Bay; however, because of logistical constraints (accessible marshes were small and far apart) we were only be able to establish 47 point count stations at 5 sites in Central and South San Francisco Bay.

Establishing Point-Count Survey Stations

Point count stations were situated 200 m apart, following methodology outlined in Ralph et al. (1993). The configuration of marshes dictated the placement of point count stations. Large marshes (e.g., Petaluma Marsh), afforded point counts set as two parallel lines of five points each. Smaller marshes (e.g., Southhampton Bay Marsh) required a disconnected series of point count stations. We avoided patches of Tule (*Scirpus acutus*) vegetation as much as possible, because such sites reflect standing-water sites and rarely contained subject species of interest. Instead, such sites are characterized by Long-billed Marsh Wrens *Cistothorus palustris* and Redwinged Blackbirds *Agelaius phoeniceus*. Nevertheless, some point count stations with Tule-dominated vegetation were included in the study. Point count stations were set-up so as to include as much tidal marsh habitat as possible. At most sites, all points were established in the middle of tidal marshes – marsh habitat completely covered the domain (a 100 m radius centered on the point count site) of the variable circular plot (VCP). At some sites (e.g., Goodyear Slough B, Pt. Edith Marsh, Dumbarton Marsh), the majority of point count stations had to be established on levees in the middle of marshes. The Dumbarton site is in the San Francisco National Wildlife Refuge and personnel there required that we avoid walking on the marsh owing to their concerns for the Federally-Endangered California Clapper Rail (*Rallus longirostris obsoletus)*.

Point-Count Methodology

The Variable Circular Plot method, first described by Reynolds et al. (1980), is a census technique that can estimate the absolute number of birds per area (density). We established a total of 187 permanent stations (points) at 200 meter intervals (avoiding edges whenever possible) minimizing the probability of encountering the same bird at several stations. The duration of time spent counting at each station was 5 minutes, consistent with published recommendations (Ralph et al. 1995). Each bird heard or seen within our fixed time period from each station was counted and the horizontal distance to its location when first encountered was estimated (in 10 m intervals, up to 100 m). The structural nature of marsh habitats censused as well as previous work to estimate detection probability of our study species influenced our decisions on plot radius (Savard and Hooper 1995, Reynolds et al. 1980, Dawson et al. 1995). The type of encounter was recorded as V = Visual, C = Call, and S = Song; however, analyses presented here pooled all detections regardless of type.

Each station was surveyed on two different mornings beginning 15 March and ending 28 April. Approximately 20 days separated the first and second censuses (labeled here "March" and "April" censuses, respectively). Censuses began 15 minutes after local sunrise and ended before 1030. Although we recorded all bird species detected in a given census, we report here only those data pertaining to our target species. All Song Sparrows detected in a given Bay were assumed to be the representative subspecies of that bay (following Marshall and Dedrick 1994).

We analyze abundance in two ways: first, we use detections of each species (Song Sparrow or Common Yellowthroat) as an **index** of abundance. In these analyses, all detections (within 100 m radius) were used. Second, we estimated **absolute density** (birds per hectare), using the program DISTANCE (Buckland et al. 1993, Laake et al. 1993). The variable circular plot (VCP) method was used, i.e., we recorded distance at which each bird was detected, within a 100 m radius of the observer. In these analyses we used all detections, whether visual or auditory, and whether the bird was singing, calling, or silent. For analyses of Common Yellowthroat density we used detections obtained from both censuses (March census, April census). It is possible that some yellowthroats detected in the April census were recently fledged individuals. Absolute density was estimated only for marshes at which yellowthroats were detected in reasonable numbers (minimum of 8 detections per marsh; n = 8 marshes meeting this criterion). Since 70 yellowthroats were detected in the first census at these 8 marshes, and 103 yellowthroats were detected in the second census, then a rough estimate of the number of fledged young in the second census is 33 individuals. This would imply that 33/173 yellowthroats detected were juveniles, i.e., 19%.

For Song Sparrows, absolute density was analyzed using the first (March) census only. Inclusion of data from the second census would have led to exceeding the program DISTANCE's capabilities, which is a maximum of 1000 observations. We consider all individuals detected in the March census to have been adults. In addition, observations beyond 80 m were not used in the analyses of absolute density, in order to keep the number of observations to 1000 or fewer, i.e., data were truncated at 80 m. In general, truncation is considered to improve parameter estimates (Buckland et al. 1993), both because it is difficult to estimate distance precisely and because observations at large distances have a disproportionate influence on overall parameter estimates. We did not truncate the yellowthroat data because of the small number of detections at individual marshes.

DISTANCE evaluates different functional relationships for detection probability, and chooses the best model using the Akaike Information Criterion (AIC; Buckland et al. 1993); the AIC is analogous to using "adjusted R^2" as a criterion for model selection. DISTANCE also allows one to evaluate models according to whether they show significant lack-of-fit; here, observed values are compared to expected values and a Goodness-of-fit statistic developed (distributed as a chi-squared statistic). Density was estimated for each marsh, using the best-fitting model (out of 9 possible models). For Song Sparrows, density could be estimated for each marsh separately, i.e., a detection probability function was developed for each marsh. The density estimate reflects the product of the encounter rate and the detection probability. For yellowthroats, it was not possible to estimate detection probability for each marsh (owing to the small number of detections) and a pooled detection probability was used.

Nest Monitoring

Nest finding and monitoring followed guidelines outlined in Martin and Geupel (1993). Nest monitoring occurred at four sites (China Camp, Petaluma Marsh, Southampton Bay, and Rush Ranch; see Table 1). Nest monitoring was conducted at two subplots per site. The dimensions of each subplot were, at minimum, 300 m x 300 m (= 9 ha). At Southampton Bay the entire marsh area (54 ha) was monitored (i.e., the two subplots = 54 ha). Two trained field biologists were responsible for a single plot at Petaluma Marsh, Southampton Bay, and Rush Ranch. Each field biologist was responsible for the same plots during the entire season. Owing to logistical difficulties (difficulty obtaining permits in time, etc.), nest searching at China Camp was more sporadic and was conducted by various PRBO staff and field interns. All nest monitoring at China Camp was done by Thomas Gardali, a well-experienced field biologist.

Nest finding began in early March and lasted until breeding activity sharply declined in mid-July. Plots were searched every four days, and individual nests were checked every four days until outcome (success vs. failure) could be determined. Outcome could usually be determined by conditions at the nest or by observing fledglings near the nest. Nests were located at all stages of the reproductive cycle (construction, egg-laying, incubation, and nestling stages). The majority of nests were located by cueing into parental behavior (n = 180, out of 288 nests). Upon finding a nest, data were recorded directly onto a "nest record sheet." Examples include: number of eggs or young, nest attempt (first, second, etc.), and cue used to find nest. Basic measurements of the nest and nest substrate were also recorded on the "Nest Record Sheet" after outcome was determined. Examples include: nest height, plant height, plant species, and number of supporting branches. For a complete list of data variables see Martin and Conway (1995). Nests were checked with careful and conscientious attention to minimize human-induced mortality. These precautionary measures included keeping visits brief, minimizing disturbance to the area around the nest (for example, avoiding creation of a dead end trail to nest), and staying clear of nest sites when predators were nearby. Nesting success (probability an initiated nest succeeds in producing one or more fledged young) was determined using the Mayfield method (Mayfield 1975), as recommended by Johnson (1979).

All data from nest monitoring were recorded and entered in a compatible format with the "Breeding Biology Research and Monitoring Database (BBIRD)" program run out of the Fish and Wildlife Service Cooperative Unit at the University of Montana (Martin and Conway 1995).

Vegetation sampling: Point-Counts and Nest Plots.

As soon as a nesting attempt terminated (successful or unsuccessful) we measured the vegetation associated with the nest (nest substrate and surrounding patch). We used a slightly modified version of the BBIRD (Martin and Conway 1995, James and Shugart 1970) method for vegetation measurements. The basic unit for vegetation sampling was a five meter radius plot centered on the nest. The plot was divided into four quadrants to facilitate measurement and estimation. Stems of all shrubs were counted by species within each five meter radius plot at 10 cm above the ground. The number of stems of each species was counted for each of two size classes (<2.5 cm diameter or >2.5 cm diameter). For each of the four quadrants in the plot, we made visual estimates of percent vegetation, bare ground, water channel or standing water. Vegetative cover was then estimated by species. Each nest was sampled to derive an index of vegetation structure as follows: samples were taken at five points located at the nest, and one meter from the nest in each cardinal compass direction. A wooden dowel of 1/4 inch (6 mm) diameter was held vertically and the number of contacts the vegetation made with the dowel were counted at four height levels (<10 cm, 10-20 cm, 20-30 cm, >30 cm). The height of the tallest piece of vegetation at each sampling point (for example, 1 m, North) was also recorded. This technique is a modification of that given by Wiens (1969).

Vegetation sampling at point count stations was nearly identical to nest sites. Plot radius for percent ground cover was expanded from 5 to 50 meters. Total percent shrub and herb cover (all shrubs combined, all herbs combined) was estimated in the 50 meter radius plot. The lowest shrub species was recorded along with its height as well as the highest shrub species and its height. The same measurements just described were done for herbs. These additional estimates and measurements were taken from Ralph et al. (1993, pp. 37-39, "Methods of Habitat Assessment: estimation of stand characteristics").

Capture-Measure-Release of Song Sparrows and Common Yellowthroats.

Phenotypic characteristics of the three Song Sparrow subspecies and the Common Yellowthroats in the marshes were determined from birds caught in the field. From May 7-13 and on August 13 of 1996 we visited five marshes in order to capture, measure and release Song Sparrow and Common Yellowthroat adults and fledglings. The sites were China Camp, Petaluma Marsh, Dumbarton Marsh, Southhampton Bay Marsh, and Rush Ranch, i.e., sites at which nest monitoring was conducted plus Dumbarton Marsh in South Francisco Bay. Capture was accomplished by the use of mist-nets. Birds were caught either passively by placing nets between patches of comparatively tall vegetation, or by flushing birds towards a set net.

The objective was to obtain typical linear measurements of these birds from the beak, wings, legs, and tail, and to obtain data on the color patterns of these species. The scoring of Song Sparrow subspecies' color patterns followed Marshall (1948).

RESULTS

Description of Study Sites

We established a total of 19 study sites in remnant tidal marsh habitat in the three bays of the San Francisco Bay Estuary region. The site locations are depicted in Figure 2, listed in Table 1, with main features summarized in Table 2, and with additional detail in Appendix 1. In some cases two locations were studied in the same marsh; for the most part, we present results marsh by marsh (i.e., averaging results from the two sites at the same marsh; this was the case for Rush Ranch, Mare Island and Black Johns Slough). The exception were the two sites at Goodyear Slough; here the two sites were so different (see below, Table 2, Table 3B), we treat them as different marshes. Thus, we present data from 16 marshes.

Study sites included sites representing all of the most important areas of remaining tidal marsh in the San Francisco Bay Estuary region. For example, the major marsh regions include, in the San Pablo Bay, marshes extending from China Camp through the marshes surrounding the Petaluma River Region; in the Suisun Bay, the large region of marshes in the Grizzly Island area (our sites were at Rush Ranch), and, in South San Francisco Bay, at the San Francisco National Wildlife Refuge (Dumbarton Bay site).

Study sites differed with respect to presence and placement of levees and degree of channelization (Table 2) and we analyze abundance with respect to these features. Levees act to either retain or divert water: the former causes Tule vegetation to dominate, the latter acts to dry up marshes. Levee placement (parallel to tidal flow, or perpendicular; placement at the face of the bay, or at the land-side of a marsh) also affects water flow and so vegetation. Channelization varies in proportion to age of marsh. For example, China Camp State Park has marshes that are heavily channelized, whereas Mare Island marshes have developed since the cessation of World War II dockyard activities and have few channels. The vegetation in both sites is dominated by Pickleweed, but the abundance of channels in China Camp marshes means vastly more feeding sites for Song Sparrows, who forage heavily in channels at low tide (pers. observ.).

Marsh vegetation is almost always dominated by Common Pickleweed *Salicornia virginica* (Table 3A, 3B, and 3C; botanical classification in Appendix II). The exception to this rule was Suisun Bay. Here, only two out of six marshes showed overwhelming dominance by pickleweed (Southampton Bay, Goodyear Slough A); the other four marshes had little pickleweed (13% or less; i.e., Bullhead Marsh, Goodyear Slough B, Point Edith Marsh, Rush Ranch). Differences in vegetation composition reflects physical differences of the bays. Salinity in Suisun Bay strongly varies seasonally: it is more saline in summer and less in winter; overall, it is less saline than San Pablo and San Francisco Bays. At the same time, Suisun Bay marshes, particularly sites at Rush Ranch, demonstrated the greatest vegetation diversity. San Francisco Bay is the least subject to fresh water inundation and so the salinity regime is more uniform (Cohen 1991).

Densities and Abundance of Song Sparrows

The program DISTANCE uses information on detections of individuals in relation to distance at which they are detected to estimate detection-probability in relation to distance. For Song Sparrows, the optimal detection-probability model was the negative-exponential model with simple polynomial adjustment (see Laake et al. 1993 for further details). This was the only one of 9 models that did not display significant lack-of-fit (P=0.15 for this model). This model was also superior according to the AIC. To estimate density on individual marshes (and from that derive an overall estimate of density) we fit a model in which a separate detection probability-function is calculated for each marsh, and used that to estimate density on each marsh. Density estimates are presented in Table 4, using the negative-exponential model with simple polynomial adjustments. Excluding Hoffman Marsh (only 3 Song Sparrows detected there during two censuses), densities ranged from 3.3 individuals per hectare (Hayward Marsh) to 141 individuals per hectare (Dumbarton Marsh). Both these marshes were in the South/Central Bay, for which median density = 3.7 individuals per hectare (data from all marshes; Table 4). In San Pablo Bay densities ranged from 3.7 individuals per hectare (Mare Island, A site) to 94 individuals per hectare (Black Johns Slough, B site); median density = 18 individuals per hectare. In Suisun Bay, densities ranged from 7.6 individuals per hectare (Goodyear Slough, A site) to 46 individuals per hectare (Goodyear Slough, B site); median density = 26 individuals per hectare.

For Suisun Bay and San Pablo Bay, the median densities probably provide the best overall measure of "average density." An advantage of the median is that it is not unduly influenced by one or two very large or very small (outlier) values. But the strong skew in the South/Central Bay distribution of densities (reflecting low densities at all marshes except Dumbarton, for which density was very high) leads us to prefer the geometric mean as the best measure of average density (note that the geometric mean is the arithmetic mean of the log values, back-transformed; Sokal and Rohlf 1981). The geometric mean for the South/Central Bay is 6.13 individuals per hectare; 67% greater than the median value. In essence, the median is too little influenced by the actual value obtained at the marsh with the highest density; e.g., the median remains at 3.67 whether Dumbarton Marsh had a density of 6 individuals per hectare or 60 individuals or even 141 (as was actually obtained). For San Pablo Bay, the geometric mean was 20.9 individuals/ha (vs. 18.2 for the median); for Suisun Bay the geometric mean was 21.3 individuals/ha (vs. 26.4 for the median).

Median density for all 19 marshes was 18.2 individuals per hectare. We consider this to provide the best estimate of overall density, **for the marshes that were studied**. Our main goal in this study was to develop relative measures of abundance and compare them with respect to habitat and geographic variation. It would be risky indeed to use data on 5 to 7 marshes per bay region, obtained from only 47 to 70 census stations per bay, to extrapolate to the entire population size. Nevertheless, conservation and management needs may dictate some sort of best estimate, no matter how crude. If we utilize Dedrick's (1993) assessment of total tidal marsh habitat available per bay region (see below), median densities per bay region reported above (except geometric mean for the South/Central Bay) and make the further assumptions that: (1) The three subspecies of Song Sparrow are confined to tidal marsh habitat (see Marshall & Dedrick 1994 for discussion on this point), and (2) only 65% of tidal marsh habitat tallied by Dedrick (1993) is actually of sufficient quality to support Song Sparrows (see below for justification of the assumption that some enumerated tidal marsh habitat is of quality too poor to sustain bird populations), we arrive at the following estimated population sizes: approximately 58,800 Suisun Song Sparrows, 66,600 Samuel's Song Sparrows and 8,250 Alameda Song Sparrows. If 25% of adults are non-territorial ("floaters"; based on mist-net data from Song Sparrows at the Palomarin Field Station, N. Nur and G. Geupel, unpublished), this would yield 44,100 breeding Suisun Song Sparrows, 49,900 breeding Samuel's Song Sparrows and 6,200 breeding Alameda Song Sparrows.

Table 5 lists our best estimates of breeding numbers for each subspecies, and compares these estimates with the previously published estimates by Marshall and Dedrick (1994). We also include "lower" estimates for each subspecies, which are one-half of our "best" estimates. We present "upper" estimates that assume only 10% of individuals are non-breeders (instead of 25%). There is, obviously, uncertainty in our estimates reflecting many factors including: (1) uncertainty attached to the density estimates at the censused sites, (2) the assumption that 25% (or 10%) of individuals are non-breeders, (3) the assumption that censused areas are representative of the entire censused marshes, (4) the assumption that censused marshes are representative of all marshes, and (5) uncertainty regarding the number of hectares of suitable tidal marsh habitat in each entire bay region.

Densities and Abundance of Common Yellowthroats

We did not attempt to estimate density for marshes in which yellowthroats were absent (i.e., no detections during either of the two censuses, n=9 sites) or very scarce (fewer than seven individuals detected, over the two censuses, combined, n=2 sites, Dumbarton Marsh and Palo Alto Baylands). For the remaining 8 sites, we used the program DISTANCE, and obtained a pooled density estimate of 1.39 individuals/ha. Number of individuals detected (per point count station, both censuses combined) per site are shown in Table 6. It was not possible to obtain satisfactory marsh-by-marsh estimates of density; no models passed the goodness of fit test (i.e., all models showed significant lack of fit). If indeed yellowthroats are absent from half of all tidal marsh sites in the bay region, as our sample of 19 studied sites suggests, than an overall estimate of density for the Salt Marsh Yellowthroat is about 0.7 individuals/ha. Estimating the number of available hectares of tidal marsh habitat at between 16,808 ha (if 100% of identified habitat is suitable; Marshall & Dedrick 1994) and 10,925 ha (if 65% of the tidal marsh habitat is suitable, see above), and assuming that 10% to 25% of detected birds are non-breeders (see above) yields a total **breeding** population size of between 5,700 and 10,600. These numbers do not take into account that Salt Marsh Yellowthroats (despite their name) are **not** confined to tidal marsh habitat; but are also found in freshwater and brackish marshes (Hobson et al. 1986, Shuford 1993).

Whereas, Song Sparrows were detected at all sites censused, this was not the case with Common Yellowthroats (Table 6). In the South/Central Bay there were three sites without yellowthroats, in San Pablo Bay there were five such sites (out of seven) and in Suisun Bay there was one site (out of seven) without detected yellowthroats. In short, Common Yellowthroats were much more likely to be present at Suisun Bay sites than at other sites surveyed.

Patterns of Abundance in Relation to Habitat and Landscape Features:

Differences Between Marshes

For each species, we present two types of analyses: in the first, we compared measures of abundance with vegetation characteristics at each point count surveyed. In the second analysis, we compared marshes with respect to abundance and habitat/landscape features of the marsh. The second type of analysis allows us to examine between-marsh differences, whereas the first type of analysis can incorporate within-marsh differences.

To examine between-marsh differences in abundance patterns, we analyzed number of Common Yellowthroats detected per point count station (log-transformed) in relation to: 1) Channelization (many vs. few channels), 2) artificial vs. natural channels, 3) isolation of marsh (>1 km from the next closest tidal marsh, or <1 km), 4) number of levees per marsh (categorized as none, one, or many), 5) distance to closest water (from the point-count center, averaged over all point counts for that marsh), 6) width of channel (averaged over all point counts for that marsh), and 7) size of marsh. Note that the first 3 variables were dichotomous (i.e., took on only two states); the fourth was a categorical, trichotomous variable, and the last 3 variables were treated as continuous, quantitative variables.

For yellowthroats, none of the 7 marsh variables were significantly correlated with the abundance index, except degree of channelization (Table 7A; see also Figure 3). Consistently more Common Yellowthroats were detected at marshes with many vs. few channels. Whether or not the channels were artificial was not apparently relevant. The effect of channelization appeared statistically similar across the three bay regions (Table 7A).

For Song Sparrows, marsh channelization was also significantly related to density (Table 7B), analyzing marshes from all regions. In San Francisco and San Pablo Bays, density was higher where channels were many, whereas in Suisun Bay density was similar for the two types of marshes. However, we lacked evidence that, statistically, the effect of channelization was different among the three bay regions ($P>0.26$, for test of heterogeneity of channelization effect among the three bay regions). With only two Suisun marshes showing "many channels," it would be premature to draw conclusions about differences among bay regions with respect to channelization. As with yellowthroats, the effect of natural vs. artificial channels was suggestive but did not appear statistically compelling ($P=0.076$ for difference between the two types of marshes).

For the other five variables, there was no overall correlation with Song Sparrow density in each marsh. Nevertheless, marsh area and marsh isolation did prove significant in a more subtle way: The effect of marsh area on Song Sparrow density was statistically stronger for isolated marshes than for connected marshes (Fig. 3A). For the six isolated marshes there appeared to be an increase in density with increasing area (estimated effect was an increase in density of 23% (standard error of the estimate = c. 8%) with an increase in area of 10 ha; for the connected marshes, there was no relationship (estimated effect was a decrease of 0.0% ± 2.0% (=S.E.)%). Thus, the estimated effect of marsh area was significantly stronger for isolated than for connected marshes. For Common Yellowthroats, there was no statistically significant interaction between marsh area and marsh isolation (Fig. 3B).

Patterns of Abundance in Relation to Habitat Features: Differences Within and Between Marshes

Analysis of point-count-to-point-count variation in the index of Song Sparrow abundance failed to reveal any single plant species or habitat feature of importance. Simple correlations between abundance and each of the eight major plant species revealed that Cord Grass was significantly negatively correlated with Song Sparrow abundance, while *Scirpus* and Peppergrass were both positively, significantly correlated. However, in a stepwise multiple regression, seven plant species were all significantly and positively correlated with Song Sparrow abundance (Saltgrass, Pickleweed, Peppergrass, *Juncus*, Common Cat-tail, and Gum Plant). Only Cord Grass was not significantly correlated with Song Sparrow abundance.

These results indicate ambiguity with regard to the significance of Cord Grass, and raise doubts about a causal effect of this species on Song Sparrow abundance. Instead, they indicate that the more vegetation cover (of most any species) the greater is Song Sparrow abundance. We confirmed this by regressing Song Sparrow abundance on vegetation cover. There was a highly significant effect ($P < 0.0001$; Table 8). However, once vegetation cover was included in a multiple regression model, none of the other habitat variables were significant, those being: Width of Channel, Herb Cover, Shrub Cover, Shrub Height, Litter Cover, Distance to Water, Ground Cover, or Channel Cover (percent total cover that was channel). The importance of vegetation cover was confirmed, even while controlling for marsh-to-marsh differences in vegetation cover and/or Song Sparrow abundance. That is, even within a marsh, there was a significant tendency for Song Sparrow abundance to increase with increasing vegetation cover ($P=0.003$).

Our conclusion is that Song Sparrows do not respond (i.e., use habitat in a selective manner) to any specific plant species or microhabitat feature except to favor vegetation cover; they may also display aversion to Cord Grass, but this is yet to be confirmed.

For Common Yellowthroats, there appeared to be stronger affinities with specific plant species, than was the case for Song Sparrows. Five of the eight species showed significant ($P<0.01$) simple, pairwise correlations between yellowthroat abundance and vegetation cover: for *Scirpus*, Peppergrass, *Juncus*, and Common Cat-tail, correlations were positive; for Pickleweed, there was a significant negative correlation. In these analyses, we excluded point counts from marshes in which no yellowthroats were ever detected; however, individual point count stations with no detections were included if yellowthroats were detected elsewhere in the marsh. Multiple regression analysis confirmed the importance of four of these species (Table 9A): *Scirpus*, Peppergrass, Common Cat-tail, and Pickleweed all had significant effects, when one controlled for the effects of the other 3 species. The direction of the effects were the same as for the pairwise correlations: positive for all species except for pickleweed (which had a negative effect). Results of the multiple regression analysis are shown in Table 9A; note that R^2 for a model with those 4 plant cover variables was 52%, an impressively high value for a study examining fine-scale differences in abundance. Abundance in relation to pickleweed cover (the strongest correlation involving habitat or vegetation) is shown in Table 9B.

The analysis that we have reported above does not distinguish between two types of effects: between-marsh and within-marsh. It could be that marshes with high pickleweed have low abundance (either because of a causal effect of pickleweed or because of some other confounding factor); alternatively, within a marsh, areas with high pickleweed might have higher abundance of yellowthroats. We could distinguish between these two possibilities by fitting a model which controlled for marsh-to-marsh differences in abundance and pickleweed cover (i.e., controlled for a Marsh "Main Effect."). In that model, there was no significant effect of pickleweed, once between-marsh effects were accounted for. The same was the case when we considered each of the other three plant species (*Scirpus*, Peppergrass and Common Cat-tail) which appeared to be significant in the previous analysis. In other words, within-marsh differences in yellowthroat abundance could not be attributed to differences in abundance of any of the eight main plant species. There appear to be ample between-marsh differences in yellowthroat abundance and these can be accounted for by variation in *Scirpus*, Peppergrass, Common Cat-tail, and Pickleweed.

To confirm that marshes with high abundance of Common Yellowthroats are characterized by high percent cover of *Scirpus*, Peppergrass, and Common Cat-tail, yet low percent cover of Pickleweed, we carried out a correlation analysis in which there was only one observation per marsh (i.e., we used mean values for yellowthroat abundance, and for percent cover of each plant species); in these analyses we did not attempt a multiple regression analysis, but only looked at correlations between yellowthroat abundance and each of the four plant species listed above. Such an analysis confirmed that marshes with low pickleweed, yet high peppergrass, and high Common Cat-tail had high abundance of yellowthroats ($P < 0.002$); there was also a positive correlation between yellowthroat abundance and *Scirpus* cover ($P=0.032$).

We conclude that Common Yellowthroats are most abundant where Pickleweed is least prevalent, and where *Scirpus*, Peppergrass, and Common Cat-tail are most prevalent. These habitat associations suggest that specific plant species can promote (or inhibit) Common Yellowthroat habitat use, but they cannot demonstrate causality.

We also examined Common Yellowthroat abundance in relation to 9 habitat variables: Width of Channel, Herb Cover, Shrub Cover, Vegetation Cover, Shrub Height, Litter Cover, Distance to Water, Ground Cover, and Channel Cover (percent total cover that was channel). Only the correlation with Channel Cover proved significant ($P=0.031$, Table 10).

Reproductive Success of Song Sparrows

Reproductive success (measured as probability an initiated nest produces at least 1 fledged young) was similar for the two marshes in San Pablo Bay (Petaluma Marsh, China Camp), between 28% and 30% (Table 11A). A similar value was obtained at one marsh in Suisun Bay (Rush Ranch, 27%) but nesting success was only 16% at Southampton Bay. Nesting success at Southampton Bay was significantly lower than at Petaluma Marsh ($P<0.05$), and was only marginally insignificantly lower ($0.05 < P < 0.1$) at Southampton Bay than at China Camp.

We compared nesting success obtained in this study with values obtained from another study carried out in 1996, that at Palomarin Field Station, in Western Marin County (Table 11B), conducted on *M. m. gouldii*. Nesting success in that year (24%) was greater than that obtained at Southampton Bay, but somewhat less than that observed at the two San Pablo Bay sites. Thirty percent nesting success is typical of open-cup nesting, multi-brooded species (such as the Song Sparrow; Martin 1992). We possess insufficient information to determine if nesting success of 27 to 30% is indeed adequate to lead to population stability (i.e., if production of young is adequate to balance mortality), but it is unlikely that population stability can be achieved with nesting success of only 16% (Martin 1992).

The number of fledged young produced from each nest monitoring plot is shown in Table

11C. It may appear that the Southampton Bay nest monitoring plot, despite its low nesting success, produced as many fledged young as did the Petaluma Marsh nest monitoring plot, but this is only because the Petaluma nest monitoring plot (two sub-plots) was 18 ha in total area, whereas the Southampton Bay monitoring plot was 54 ha. Table 11C also shows the number of fledged young per nest attempt.

Phenotypic features of the three endemic Song Sparrow subspecies

Among adults, the Suisun Song Sparrow (*Melospiza melodia maxillaris*) is the largest of the three endemic Song Sparrow subspecies in the San Francisco Bay region; the Alameda Song Sparrow (*M. m. pusillula*) is the smallest. Results are summarized in Table 12; we do not present statistical analyses of differences in metric characters due to small sample size. The Suisun Song Sparrow has greatest mass, and, conspicuously, the most robust beak. Suisun Song Sparrows' beaks are larger in all four dimensions measured (two length measurements, bill depth and width; Table 12). Wing lengths (measured as Wing Chord) are the most similar of measurements taken among the three subspecies. Males were larger than females, on the average, for all measurements obtained for all three subspecies.

Hatching year birds (those caught as independent fledglings) reflected the main trends as found in adults, but with considerably more variation (Table 12.B). The greater variation reflects, in part, capturing different-aged young. Nesting commences in March and continues through mid-July, creating the possibility of capturing fledged young of very different ages.

Before discussing the color patterns we assessed from captured adults, it is important to stress the difficulty in attributing a single color when scoring these Song Sparrow subspecies. We obtained our color categories by referring to Marshall (1948) and followed as best we could his system. Prior to going to the field, we examined dozens of his specimens now in the California Academy of Science. There, we found representative specimens for his color categories, particularly important for the "Upperparts" designation. It was clear upon such museum examinations, and more clear in the field, that the attribution of a single color was often difficult. This is because the "Upperparts" are composed of scores of contour feathers, and the colors often vary within a feather, often change in overall hue from the head to the tail, and can vary for other reasons such as feather wear and age. Thus, summing up this ample variation into a single color category was difficult at best, and difficult to insure consistency.

Having stated these important qualifications, we nonetheless attributed a single "Upperparts" and a single "Vent" color for each individual (results in Table 13). Overall, the Suisun Song Sparrows (*M. m. maxillaris*) were the darkest and the least variable, whereas the smaller Alameda Song Sparrows (*M. m. pusillula*) were the lightest and most variably colored. Suisun Song Sparrows are mostly dark olive brown to blackish brown with white to off-white vents. Samuel's Song Sparrows (*M. m. samuelis*) are yellowish-brown (but variable) with the buff-colored vents. Alameda Song Sparrows are variable, but mostly either light olive brown or a red-to-yellow tinge of brown with an off-white vent.

In sum, there are consistent phenotypic (morphometric and plumage) differences among the three subspecies. However, the phenotypic variation between subspecies may or may not reflect underlying genetic differentiation. That each of these endemic Song Sparrow subspecies is year-round resident in tidal marshes (most other Song Sparrow subspecies are migratory) and apparently restricted to them (displaying narrow habitat tolerance), makes it more likely that each subspecies is effectively, genetically isolated from all other subspecies. If so, with sufficient evolutionary time each subspecies is likely to evolve into a full species, if this has not already happened. However, environmental features, particularly those correlated with vegetation cover, are known to strongly affect bird phenotypes. Many studies of Song Sparrows throughout North America have reinforced this point (Zink and Van Remsen 1986). In order to fully understand the species status of these Song Sparrows, a genetic evaluation is required. Towards that end, we took single feather samples from each Song Sparrow caught in the field. This non-invasive procedure provides sufficient tissue to allow the kind of genetic analysis required. We intend to collaborate with researchers from San Francisco State University (led by Prof. Thomas B. Smith) on this important issue.

DISCUSSION

For Song Sparrows, the main impression is that of a locally common to very abundant species, apparently restricted to tidal marsh habitat fragments around the San Francisco Bay region and yet distributed throughout the entire bay region. Populations in San Pablo Bay (*Melospiza melodia samuelis*) and in Suisun Bay (*M. m. maxillaris*) appear relatively abundant, in contrast to those in the South and Central Bay of San Francisco Bay proper (*M. m. pusillula*), which appear to be the least common and are distributed in the most fragmented landscape. Thus populations in Central and South San Francisco Bay are lowest and yet under strongest pressure from habitat loss and fragmentation.

Density estimates

Most of the densities obtained per marsh of the three Song Sparrow subspecies are very high compared to other studies, including those of Song Sparrows. For example, Song Sparrows (the subspecies *M. m. gouldii*) at Palomarin in the Point Reyes National Seashore are estimated at about three to four breeding birds per hectare (G. Geupel and N. Nur, unpublished). This estimate excludes individuals that did not hold territories or who were unmated. Density estimates were similar to this value for the Alameda Song Sparrow at all sites studied except Dumbarton Marsh, considering that floater (non-territorial) individuals were counted in our surveys. In contrast, density estimates for Samuel's and Suisun Song Sparrow were on average much higher, and at three sites were an order of magnitude higher (i.e., density was estimated to be 46 birds per hectare or greater at three sites). Marshall and Dedrick (1994) concluded that 5.49 birds per hectare was a reasonable estimate of **breeding bird** density, based on a mapped census at one marsh (San Pablo marsh in Richmond) by Johnston (1956). If 25% of all adults are non-territorial floaters , this yields 7.3 adult birds per hectare: greater than our estimates for the Alameda Song Sparrow but only 1/3 to 1/2 of what we estimated for Samuel's and Suisun Song Sparrow. However, even Marshall and Dedrick report very high densities in some marshes; e.g., they report 198 breeding birds in 14.6 ha at First Mallard Branch, part of Rush Ranch, i.e., 13.6 breeding birds per hectare.

On Mandarte Island, British Columbia, the well-studied Song Sparrow population has been observed, in some years, to have a density of 20 breeding birds or greater per hectare, with an additional component of floater (non-territorial) birds present (Arcese et al. 1991). Our conclusion is that densities of Song Sparrows observed here are unusually, but not impossibly, high. Thus, the main impression is of a locally abundant sparrow residing in patches of suitable habitat that are potentially isolated.

The highest density obtained in this study was that of 141 birds per hectare at Dumbarton Marsh. Whereas, density at this marsh was undoubtedly high (Marshall & Dedrick 1994 call this an "exemplary population" of Alameda Song Sparrows), we consider our stated value to be unreliable because we were not permitted to census in the midst of the habitat, but rather had to confine our censusing to the boardwalk (due to concern about disturbance to Clapper Rail nests). Song Sparrows might be congregating near the boardwalks which provide shelter and cover.

Many factors act to limit the reliability of our population estimates, including: (1) whether sites (i.e., marshes) studied are representative of the entire habitat, (2) whether the surveyed area in each marsh is representative of the entire marsh, (3) quality of the habitat enumerated and quantified by Dedrick (1993), (4) reliability of distances recorded by the observer, (5) behavior of birds (e.g., density estimates assume that birds are neither attracted nor repelled by the observer), and (6) errors associated with estimating the functional form of the detection-probability function. In general, these factors may affect **absolute** density estimates but would not affect **relative** estimates to any great degree.

We estimated approximately 49,900 breeding San Pablo Song Sparrows (range 25,000 to 60,000), a result comparable to, but somewhat greater than Marshall & Dedrick's (1994) estimate (i.e., 31,200, Table 4). However, for Suisun Song Sparrows we estimated 44,000 breeding birds (range 22,000 - 53,000) whereas Marshall & Dedrick (1994) estimated only 19,100 birds. For the Alameda Song Sparrow, the difference is greater still but in the opposite direction: we estimated only 8,100 breeding birds, whereas Marshall & Dedrick (1994) estimated 14,800 birds. The difference between our estimates and theirs is that they assumed the same density of breeding birds for each subspecies, i.e., 5.49 birds per hectare, whereas we used a density estimate specific to each bay region (and thus specific to that subspecies). Marshall & Dedrick present no density estimates obtained from field work in the Central and South San Francisco Bay. In contrast, we estimated 6.13 birds (breeders and non-breeders) per hectare in the South/Central bay, a value that was 1/3 to 1/4 that obtained in San Pablo and Suisun Bays. If density in the South/Central Bay is indeed lower than elsewhere in the Bay region, as our field work indicates, this implies that total population size of the Alameda Song Sparrow is correspondingly lower than previously believed.

Distribution and Influences on Abundance

Song Sparrows were detected at every marsh included in this study; in San Pablo and Suisun Bays, densities were consistently moderate to high. For example, in Suisun Bay, densities varied from 8 birds per hectare to 46 birds per hectare. In contrast, distribution of the Common Yellowthroat appeared much less regular. At about half of all marshes, no yellowthroats were detected. The exception to this was Suisun Bay: here most sites had reasonable number of yellowthroats. Reasons for the spotty distribution remain to be identified: they may represent recent extirpation, or they may reflect a failure to recolonize certain areas. Hobson et al. (1986), who surveyed the entire bay region for Salt Marsh Yellowthroats, catalog numerous sites where Salt Marsh Yellowthroats had been observed before 1970, yet were absent in 1985.

We were able to identify several marsh features that characterized areas with relatively high abundance of yellowthroats: (1) Presence of channels, (2) greater amount of cover comprised of channels, (3) greater amount of Peppergrass, Cord Grass, and *Scirpus* (bulrush and Tule), and (4) lesser amount of Pickleweed. For Common Yellowthroats and Song Sparrows, there was no overall effect of marsh area or of marsh isolation. However, for Song Sparrows, but not for Common Yellowthroats, the effect of marsh area was shown to depend on whether or not a marsh was isolated: the effect of area was stronger in isolated marshes than in connected marshes. Among Song Sparrows, channelization was associated with greater abundance, just as we observed for Common Yellowthroats. For Song Sparrows, greater vegetation cover was associated with greater abundance, but we did not find that any one or several species had a marked negative or positive correlation with Song Sparrow abundance. We recommend that future management and conservation programs take into account these landscape, habitat, and vegetation features which appear to promote abundance of these two tidal-marsh species.

It would be premature, however, to conclude that marsh area was unimportant for non-isolated marshes, for either species. In fact, our study in 1996 included few small, non-isolated marshes and included few small marshes of any kind from San Pablo Bay or Suisun Bay. To address this gap we are now, in 1997, surveying small marshes in San Pablo Bay and Suisun Bay, both isolated and connected. Results of such surveys will better allow us to address the importance of marsh area and marsh isolation.

We evaluated marsh isolation using an arbitrary threshold: 1 km. A better approach would be to use a bird's view of isolation. This would require information about dispersal distances for Song Sparrows and yellowthroats. We are now conducting studies of dispersing color-banded juvenile Song Sparrows in order to empirically determine dispersal distances and probabilities.

CONCLUSION AND PROSPECTUS

Our conclusion is that Alameda Song Sparrow is the most threatened of the three subspecies and therefore especially deserving of classification as a Federally-listed Threatened species. Future conservation and research efforts should be especially focused on this subspecies. Threats to this subspecies arise because: (1) Its population size is apparently low (and lower than previously thought), (2) much of its habitat is highly fragmented and consists of small, isolated marshes (the exception is Dumbarton Marsh), and (3) our results to date indicate that small, isolated marshes support low Song Sparrow densities. Nest-monitoring is needed to determine nesting success at these small, isolated marshes which may be especially vulnerable to nest predators. Restoration at Bair Island provides a good opportunity to improve the outlook for this subspecies.

There remains ample cause for concern for Samuel's Song Sparrow and for the Suisun Song Sparrow and we would support their listing as State Species of Concern, or similar designation. For these two subspecies, population sizes appear to be adequate (for the time being) but, for both subspecies, their habitat is threatened, and many individuals are found in isolated and/or small marshes. For the San Pablo Song Sparrows, nesting success appears reasonably good (at the two sites studied), but this was not the case for the Southampton Bay population, which had a particularly low rate of nest success.

The conservation and management status of the Salt Marsh Yellowthroat remains to be clarified. Our best estimate of population size is somewhere between 6,000 and 11,000 breeding birds, in tidal marsh habitat alone. The best previous region-wide estimate for this subspecies was obtained by Hobson et al. (1986). Surveys that they conducted in 1985 yielded 428 breeding pairs (i.e., 856 breeding birds) in the bay area, and an additional 282 breeding birds in Western Marin county (mostly in the Point Reyes area). Clearly there is a big discrepancy between our estimates (6,000 to 11,000 breeding birds in tidal marsh habitat) and Hobson et al.'s (1986) estimate (less than 900 breeding birds in all habitat). At minimum there were Saltmarsh Yellowthroats present in 1996 that were not tallied in 1985. For example, Hobson et al. state that there are no breeding Saltmarsh Yellowthroats in Contra Costa County. Yet when we surveyed only two marshes in this county (Bullhead and Point Edith) we found yellowthroats at both marshes, and detected 28 individuals per census (both marshes combined). We surveyed five marsh sites in Solano County, a far from comprehensive survey, and detected 55 individuals per census (all five sites combined); yet Hobson et al. report a total of 62 breeding individuals in that county. Either Saltmarsh Yellowthroat numbers have increased substantially between 1985 and 1996, or Hobson et al. missed detecting individuals, or both may be the case.

Information Needs

Future surveys need to specifically target Common Yellowthroats, in order to derive reliable estimates of population density (which currently are unavailable). What is needed are surveys at more marshes, and an attempt to cover more area (a greater diversity of potential habitat) at each marsh than our own surveys did.

For Song Sparrows, more information is needed regarding Alameda Song Sparrows. Within our budget constraints, we were only able to survey five marshes; that sample needs to be increased. We also recommend nest-monitoring for this subspecies, to determine if reproductive success is adequate to sustain populations in the long-run. Given that the only isolated marsh (and one surrounded by suburbs) for which nest-monitoring was carried out (Southampton Bay) was also the site with the lowest nesting success, gives us cause for concern, since marshes in the Central and South Bay are generally isolated and next to suburbs.

For Samuel's and Suisun Song Sparrows, the additional field work being carried out in 1997 to survey small marshes will help give a more complete picture of Song Sparrow distribution and density than is currently available. The 16% nesting success obtained at the Southampton Bay population is unlikely to lead to a self-sustaining population. What we don't know is whether the 26-28% nesting success obtained at Rush Ranch and Petaluma Marsh is sufficient to produce self-sustaining (i.e., "source") populations. We believe that population viability analyses (Burgmann et al. 1993) are required for all four subspecies. However, population viability analyses will require field work in order to estimate adult survival, juvenile survival, and dispersal for each subspecies. Only then will we be able to project future trends for each subspecies and consider the beneficial or detrimental effects of management action.

The last area of recommended work for the future concerns studies of genetic differentiation among the three Song Sparrow subspecies, and comparison of the tidal marsh subspecies with other Song Sparrow subspecies. Studies need to evaluate whether the peculiar habitat requirements of these Song Sparrows, given sufficient time and isolation, has led to genetic differentiation supporting separate, full species designation. Ferrell (1966) did not find evidence for genetic differentiation using ABO blood-type groups, but this work needs to be repeated using modern highly sensitive molecular genetic techniques. Similarly, work is needed to study genetic differentiation between the San Francisco Common Yellowthroat (*Geothlypis trichas sinuosa*) and the neighboring *G. t. occidentalis*. It was beyond the scope of this project to carry out such work, but samples have already been collected by us, which could be used for such purposes.

Support from the former National Biological Service was critical for our establishing a research program in the San Francisco bay region and enabled us to provide the first region-wide density estimates on these habitat-restricted avian subspecies. We are now actively involved with state, federal, and private agencies in discussing how our results can assist management of remaining marshes and marsh fragments, and how to use our information on vegetation and habitat correlates of Song Sparrow and Common Yellowthroat densities to guide marsh restoration activities.

SECTION THREE: CALIFORNIA BLACK RAIL (*LATERALLUS JAMAICENSIS COTURNICULUS*) IN THE SAN FRANCISCO BAY REGION: DENSITY INDICES AND THE INFLUENCE OF HABITAT VARIABLES.

INTRODUCTION

Prior surveys have determined that tidal marshlands of the San Francisco Bay region support the preponderance of the California Black Rail population in the western United States (Manolis 1978, Evens et al. 1991). Small populations occur also on the Outer Coast tidal marshes (Bodega Bay, Tomales Bay, Bolinas Lagoon, and Morro Bay) and in freshwater marshes and swales associated with the Colorado River and the Salton Sea. However, it has been estimated that these sites support less than 10% of the total population, and, because of fragmentation and small sizes of these populations, they are susceptible to stochastic extinctions (Evens et al. 1991). Former breeding populations in Central and South San Francisco Bay and the coastal marshes of southern California are apparently extirpated (Evens et al. 1991, Eddleman and Evens 1994). The historic and ongoing pressures of agriculture, salt production, and urbanization have reduced tidal marshlands of San Francisco Bay by an estimated 85% (Dedrick 1993), and there has been a concomitant reduction in Black Rail populations supported by that habitat (Evens et al. 1991).

In the San Francisco Bay estuary, Black Rails are now confined to the most pristine remnants of historical tidal marshlands in the northern reaches of the system, primarily those associated with the San Pablo and Suisun bays (Manolis 1978, Evens et al. 1989, Evens et al. 1991). In this study we selected 20 marshes within the estuary and three embayments on the outer coast to determine abundance, stability, and current status of the population. The data derived from censuses of these study sites were used to compare with earlier studies, to estimate total population size, and to evaluate the status of those populations, especially in smaller marshes that may suffer extinction and recolonization in a larger metapopulation context.

METHODS

Earlier studies (Manolis 1978, Evens et al. 1989) determined that in the San Francisco Bay area Black Rails occur almost exclusively in tidally influenced marshes, in particular, those with unrestricted tidal flow (classified as "estuarine, intertidal, emergent, regularly flooded"—Cowardin et al. 1979, USFWS 1991). In this study, therefore, we restricted our coverage to study sites with characteristics of tidally influenced marshes.

A total of 26 marsh parcels ranging in size from 9.1 to 149.3 hectares (x = 68.2 ± 8.35 ha) were surveyed during the period April 9-June 28, 1996 to estimate abundances of California Black Rails at sites that had been previously surveyed in a larger, synoptic survey effort in 1986-1988 (Evens et al. 1989); sites are depicted in Figure 4. Of all sites surveyed, 85% are fully tidal, and 15% are influenced by muted tidal flow. Excluding those sites with muted tidal flow, of those marsh parcels surveyed in 1996, 14 (53.9%) were associated with San Pablo Bay or its major tributaries (mean size 73.7 ha ±11.02), five (19.2%) were in the Suisun Bay and the Carquinez Strait (mean size 87.7 ha ± 22.87), and seven (26.9%) were associated with the outer coast (mean size 43.29 ha ±12.02). South and central bay sites were not surveyed because, as noted above, no Black Rails were observed in these marshes in 1986-1988 (Evens et al. 1989).

Listening stations (aural sampling stations) were located along transects selected to sample elevational change within each marsh and were distributed throughout the length and breadth of the marsh at or above Mean High Water. Census stations were distributed at 100 meter intervals through each marsh parcel and, where possible, each station was a minimum of 50 m from upland habitat. As much as possible, censusing (listening) station were located at the same sites as the 1986-1988 surveys.

A total of 352 listening stations were surveyed for six minutes each. Of these, 296 (84.1%) were located in the San Francisco Estuary, and 56 (15.9%) were located in outer coast marshes. Of the total stations surveyed, 9.1% were in marshes with muted tidal flow. All censuses were conducted between dawn and 0930 hrs Pacific Standard Time. Census efforts were canceled when wind exceeded approximately 25 km/hr or when the observer determined that background noise was interfering with the ability to detect rail vocalizations. After arriving at a listening station, the observer waited silently for one minute then broadcast a tape recording of California Black Rail vocalizations at moderate volume in each ordinal direction for a total of 1.5 minutes. The tape recording consisted of a repetitive series of "grr" calls followed by 0.5 min of "kic-kic-kerr" calls (Repking and Ohmart 1977). Maximum sound pressure 1 m from the source was approximately 90 db.

For each rail response heard within 5 minutes of initiating the broadcast, the observer recorded the time, the call type, and estimated the distance and direction from the center of the station. An effective 30 m census radius was chosen after field testing found that the observer's ability to estimate distance accurately, or hear low range vocalizations consistently, declined beyond that distance, and to conform with earlier studies (Evens et al. 1986, Evens et al. 1989). All calls coming from one compass direction during the six minute listening period were considered to represent only one rail unless two calls were heard simultaneously. Calls from different compass directions (i.e., > 30 degrees apart) were considered to represent different rails. In an earlier study it was estimated that Black Rails move toward the source of a broadcast tape an average of 6.2 m (Evens and Page 1985); therefore, although we counted birds only within 30 m of the observer, we calculated densities assuming sampling stations had a radius of 36.2 m, covering an area of 0.4115 ha (Column D; Table 14). The values derived from the average number of detections in each marsh parcel were used to calculate density indices for each region and to extrapolate abundance estimates. Because of the grave conservation status of the California Black Rail (designated a category 1 candidate species for listing as threatened or endangered by USFWS [1991]), and because abundance estimates rely on extrapolated data, these calculated values should be considered density indices rather than absolute densities. Furthermore, the extrapolation of densities is potentially confounded by several variables, some of which may lead toward overestimates, some toward underestimates; these are discussed below.

Generally, sites were sampled only once, but two sites were sampled twice in 1996: Dutchman's Slough (Site # 13) on the Napa River and Southhampton Marsh (Site # 19) in the Carquinez Straight.

Abundance rankings were assigned to each site based on the density index calculated from the 36.2 m radius circular plot as follows: <0.6 rail/ha (low); 0.6-2.12 rails/ha (moderate); >2.12 rails/ha (high). This scale conforms to earlier analyses (Evens et al. 1989).

RESULTS AND DISCUSSION

Density indices and population estimates

Results of the 1996 censuses including date, parcel number (after Dedrick 1993), parcel size (hectares), number of survey stations, fraction of stations at which rails were detected, number of rails detected per station, and density index (average number of birds per station x effective census area) are provided in Table 14.

Density indices at those sites that were surveyed in 1988 and 1996 are listed in Table 15. For comparison, two sites surveyed in 1988 but not replicated in 1996 (Petaluma River marsh and Coon Island) are included. Abundance estimates (density index x marsh size) and abundance rankings for each study site are also provided in Table 15.

From our 1996 census results, based on a 36.2 m effective radius and excluding those study plots with muted tidal influence, we estimated mean density indices for each subregion as follows ("Abundance Index," in Table 16.A). We also extrapolate to each region based on tidal marsh area (from Dedrick 1993). Note that these estimates assume complete detectability within 36.2 m of the observer (see below), and thus provide a lower-bound estimate of abundance.

The above "abundance estimates" include two San Pablo Bay sites and four outer coast sites with no detections (Table 15); however, they do not include sites with muted flow. The arithmetic mean is particularly sensitive to especially high or especially low values. By basing our estimates on the median density indices (Table 16.B), we derive a more robust and more conservative estimate for each subregion.

These results indicate similar densities in San Pablo Bay as compared to Suisun Bay and Carquinez. It may seem that Suisun Bay densities were somewhat higher (1.08 vs. 0.71 for median values), but any such difference is unreliable for two reasons. First, only a few marshes were surveyed in Suisun Bay (compared to San Pablo Bay), and sampled marshes may not be representative of the Bay as a whole. Second, marshes in Suisun Bay were selected because we knew or expected rails to occur there; in contrast, marshes in San Pablo Bay were not selected *a priori* with respect to their containing rails. Thus, average density indices cannot be validly compared between the two Bay regions. The primary objectives of the rail surveys were to compare densities in the 1996 with the 1980's and to compare marshes within a Bay region, not to compare Bay regions. Also, we sampled only large, broad marshes in Suisun Bay, although an unknown proportion of the Suisun marshland is comprised of linear strip marsh along sloughs. The extent of truly suitable habitat within the nominally-designated tidal marsh habitat in the whole region (San Pablo Bay, Suisun Bay, and Outer Coast) is likely to fall between 50% and 85% of the acreage represented by Dedrick's published value (3780 ha). For San Pablo Bay and Suisun Bay we have picked 65% to represent our best guess at truly suitable habitat; for the Outer Coast we estimate that percentage at only 50% (due to vegetational differences, e.g., more sparse coverage, compared to San Francisco Bay itself).

The abundance estimates discussed so far assume complete detectability of rails within 36.2 m of the observer. To assess this assumption, we analyzed distances at which rails were detected using the program DISTANCE (Buckland et al. 1993; see above) for observations of individuals within 30 m of the observer. Using a uniform density function with polynomial adjustment, detection probabilities were estimated to be 100% at 3 meters; 75% at 5 m; 25% at 10 m; and 5%

at 30 m. From this we conclude that substantial numbers of rails were being missed in our surveys. It was not possible to estimate detection probabilities on a per-marsh basis. Instead, we assumed the same detection probability function at all marshes and estimated absolute density in each marsh. For San Pablo Bay, median density for 14 marshes was 3.105 birds per hectare, which converted to 2.13 birds per hectare after adjusting for bird movement (i.e., a circular plot with 36.2 m radius was sampled instead of 30 m radius). This turned out to be 3.0 times the median density assuming complete detectability. In other words, observers were detecting only 33% of rails within 36.2 m of the observers. We therefore adjusted "abundance estimate" values (using complete detectability) by a factor of 3.0 for all three Bay regions (there were too few data from the other two regions to calculate separate detectability functions).

Finally, we incorporate fraction of truly suitable habitat within the nominally-designated tidal marshland (50% for Outer Coast; 65% for San Pablo and Suisun Bays; compare columns 2 and 3 in Table 16.B). These results imply perhaps as many as 7700 Black Rails in San Pablo Bay and 8000 in Suisun Bay and Carquinez Straights. At the same time there are several other sources of bias that might reduce or inflate our estimates by an as yet undetermined factor. They include the following:

Factors that may bias estimates

(1) Black Rails tend to be occur in the larger undiked marshes associated with larger rivers and in some bayshore parcels, particularly those associated with the mouths of rivers of creeks (Evens et al. 1989). Dedrick's (1993) estimates of areal extent of marshland habitat includes an unknown proportion of narrow strip marshes, bayfront marshes not associated with tributary mouths, and low *Spartina* or *Scirpus robustus* beds, none of which support Black Rails. We estimate those habitats may account for 35% of the tidal marshlands of San Francisco Bay (except 50% in the Outer Coast); but these estimates are very rough.

(2) We have accounted for the movement of birds toward the observer based on observed movement after a Black Rail's first call; however, we have no way of knowing whether birds move prior to their initial call, but suspect they do. In effect the tape may be acting to lure birds in from a large area. If so, then a much larger area was being sampled (hence true densities are lower than reported).

(3) The age at which calling begins is unknown. It is possible that detections after mid-May include juvenal birds and not just adults.

(4) Little is known regarding the vocalizations of this species, therefore, our abundance estimates may or may not include females. It is presumed that the *ki-kik-kerr* call is given by the male (Eddleman et al. 1994), however less than 10% of our detections within 30 m of the observer were of this type. Approximately 90% of the detections in this and previous studies of the species were "growl calls" in response to broadcast tapes, and it is not clear that these agitated "scolding" vocalizations represent only territorial males (Evens and Page 1985, Eddleman et al. 1994); the broadcasts may well elicit responses from nesting females. Indeed, Flores and Eddleman (1991) state that "scolding occurs in response to disturbance while female is displaying near nest site." Because of these uncertainties we cannot say whether our density indices represent just territorial males or some fraction of the total number of breeding adults.

(5) Finally, we wish to point out that this study was a synoptic survey with study sites chosen to

represent the geographic breadth of tidal marshlands in the San Francisco Bay area. Therefore, sites were fairly well distributed along varying reaches of watercourses and at representative marsh types (bayshore, river or slough shore, river mouth); however, there was probably some bias introduced by access to sites. Higher marshes are more easily accessed by observers and a higher proportion of stations occurred at or above Mean High Water than below. Although we attempted to use straight transects, observers often had to modify their route because large sloughs impeded movement toward the lower marsh plain.

Keeping in mind the caveats above, it is clear that no precise estimate of Black Rail abundance can be made at this time. Our best lower-bound estimate is 8,000 adult Black Rails in the entire the San Francisco Bay system; however, the true number may be twice as great, depending on the factors listed above.

Between Year and Between Decade Variation.

We selected 16 study sites where rails were present and for which data were available from 1988 and 1996 and compared density indices to determine whether there was interannual variation. The mean 1988 abundance index was 1.08 (± 0.165); the 1996 mean was 1.46 (± 0.294), suggesting a population increase of 35% within these 16 sites. Indeed, if we consider only the largest six marshes (> 100 ha) with full tidal influence, we find a mean density index of 1.71 (±0.646) rails/ha in 1996 as compared to 0.99 (±0.374) rails/ha in 1988, an increase of 73%.

Another measure of interannual variation is available in the detection fraction, i.e., the percentage of stations at which rails are detected within a marsh. In an earlier survey of San Pablo Bay marshes, Black Rails were detected at only 0.240 of the 338 stations sampled (Evens et al. 1989) whereas in this study we detected rails at 0.470 of 212.5 stations sampled. In Suisun and Carquinez we detected birds at 0.254 of 114 stations in 1988; in 1996 we detected birds at 0.568 of 56 stations. On the Outer Coast, the rate is not available for the 1988 surveys, but in 1996 the response rate was 0.146 at 56 stations.

The apparent increase observed in this survey is perhaps related to variation in the hydrologic cycle. The 1988 surveys followed two relatively dry seasons. In contrast, 1994-95 experienced high rainfall and 1995-96 was also an above normal rain year. Perhaps more importantly, both years preceding this study experienced anomalous spring precipitation (18.1% of the annual rainfall in 1995-96 fell in April and May). It is well-known that rails favor marshes where the substrate is saturated (Eddleman et al. 1994) and the results of this study suggest that marshes that are isolated from tidal influence, or that receive muted tidal flow, may provide Black Rail habitat only in years of high rainfall. This suggests that marshlands with muted tidal influence may provide habitat only of secondary value.

Although temporal variation in abundance was suggested from the change in mean number of responses per station from 1988 to 1996, the difference was not significant. A matched pairs t-test, using logs of density indices at all sites where rails were detected in at least one of the census years indicated no significant difference between years ($P>0.3$). When the outer coast sites were excluded, the tendency toward increase from 1988 to 1996 was slightly more pronounced ($P>0.15$), although still not significant.

There was a suggestion that between-decade differences in detection differed among the three regions. In Suisun Bay all three marshes that were covered in both years showed higher density indices. In San Pablo Bay, five increased, two decreased and the remainder were virtually unchanged (Table 15). On the outer coast, all three sites at which rails were present in 1988 showed a decrease in 1996. Marshes which declined from 1988 to 1996 were small, relatively isolated from one another, and isolated form large Black-rail population centers.

A comparison of density indices in Table 15 also reveals that no marsh that had zero detections in 1988 was observed to have rails in 1996. Marshes without Black Rails in 1988 still had no rails in 1996. Thus there was no indication that "empty" marshes were being colonized in the intervening years. Conversely, no marsh with rails in 1988 was observed to have no rails in 1996. Thus, there was no observed re-colonization nor any observed local extinctions comparing the two time periods.

Outer Coast marshes showed the strongest tendency to decline, which is of great concern since abundances are already lowest in these marshes. The long-term outlook for these marshes is bleak.

It would not be surprising if abundance patterns (overall difference and differences in time trends) differed between Suisun and San Pablo Bays, because these bay regions are somewhat dissimilar. Suisun tends to be less saline than San Pablo and Black Rails prefer fresh water (Eddleman et al. 1994). In addition, predator pressure likely differs as well, with more predators (such as fox and coyote) present in the less urbanized Suisun Bay. Another factor influencing Black-rail abundance (for which we have little information) is elevation of habitat relative to tidal level. Low-elevation areas are susceptible to inundation; this is especially a problem for Black-rail nests (Eddleman et al. 1994).

Relationship between marsh size and density indices

We examined Black Rail density in relation to marsh size, but found no significant relationship, though the tendency was positive in each Bay region (results of regression analysis). In subsequent analyses we excluded the one diked marsh which was surveyed (at Hill Slough) because diked marshland appears unsuitable habitat for Black Rails (Eddleman et al. 1994). Excluding the diked marsh, there was a nearly significant effect of marsh area (in ha) on the density estimate of Black Rails (log-transformed; $P=0.054$, regression analysis). To clarify whether or not abundance was or was not related to marsh area, we partitioned Black Rail density into two components: (1) presence of rails at the marsh (i.e., density > 0), and (2) abundance of rails, given that some were present. For the latter component, there was a positive trend for density to increase with increasing marsh size (bay by bay and overall) but was nowhere near significant ($P>0.3$ for all analyses).

To examine the first component, we examined marshes with respect to presence or absence of rails, using logistic regression, classifying each marsh with respect to presence (score = 1) or absence (score = 0) of rails. Combining results from all regions, there was a significant positive relationship between presence of rails and size of the marsh (Likelihood Ratio Statistic = 4.38, df=1, $P=0.036$). When San Pablo Bay, the region with the greatest number and size-diversity of marsh-study sites was analyzed by itself, marsh size was also significant ($P=0.034$) with respect to presence or absence of rails.

We conclude that marsh size influences the likelihood a marsh will contain rails; but it is unclear whether further gradation in Black Rail density is influenced by marsh size.

Correlations between abundance values and habitat variables

In an earlier study, vegetation height, presence of *Frankenia* (as an indicator of upland marsh habitat), presence of terrestrial insects (upland marsh indicator), and absence of amphipods (indicators of lower marsh elevations) were identified as key predictive factors in Black Rail distribution (Evens et al. 1986). Subsequent field work, including this study, have suggested other variables help explain the patchy distribution of Black Rails among San Francisco Bay region tidal marshes (Evens et al. 1989, Flores and Eddleman 1991, Evens et al. 1991).

The relationship between patch size and abundance of a species is an important consideration in conservation biology. We did not examine contiguity of marshes as a determinant of Black Rail density (this lying outside the scope of this study), but this, too is likely an important factor. Moreover, area effects may be expected to be more intense depending on degree of isolation of a marsh, as we have shown for Song Sparrows (see above). Whether or not two marshes are considered isolated from each other or connected, depends on dispersal characteristics specific to a species.

The Rallidae in general disperse themselves effectively (del Hoyo et al. 1996) and the apparent colonization of several disparate and isolated sites in California in recent years (Evens et al. 1991, Aigner et al. 1995) suggests that this is the case for Black Rails as well. In addition, the most isolated marsh within the San Francisco Bay system-—Southhampton Marsh in the Carquinez Strait—-supports an apparently stable population (at least since 1988; JE, pers. obs.). The marshes of San Francisco Bay are perhaps all contiguous, from a rail's perspective; absence at some marshes is more likely the result of proximate habitat characteristics (small size, low elevation relative to tide, lack of transitional upland vegetation, presence of predators, etc.) specific to that site. For example, the marshes of Central and South San Francisco Bay do not support breeding Black Rails, probably because of the low elevations of those sites relative to tidal inundation (Evens et al. 1991). The outer coast marshes, however, do seem to show the patterns of distribution and abundance expected for fragmented habitat. At those sites, apparently appropriate habitat is unoccupied, and at those sites that are occupied (Tomales Bay, Bolinas Lagoon) abundances are relatively low and show a decrease since 1988.

Acknowledgments

Work reported here was carried out under Contract 1445-CA09-95-0267 between the Point Reyes Bird Observatory and the National Biological Service (now United State Geological Survey, Biological Resources Division). We are grateful to the NBS for making this study possible. We thank the following agencies and individuals for providing permission for us to work on lands they manage and/or providing logistical help: US Fish & Wildlife Service (San Francisco Bay National Wildlife Refuge, San Pablo Bay National Wildlife Refuge, with special thanks to Joy Albertson and Marge Kolar), California Department of Fish & Game (especially David Feliz at Grizzly Island), California Department of Parks and Recreation (China Camp State Park and Benecia State Park), Hayward Regional Shoreline (thanks to Mark Taylor), Solano County Open Space, in particular Tom Klimowski (Rush Ranch), Wickland Oil Martinez (Bullhead Marsh), and Marin County Parks (McInnis Marsh). California Academy of Sciences provided access to study skins. We thank Emilie Strauss and Wally Neville for conducting point counts; Rich Stallcup, Geoff Grace, David Wimpfheimer, Terry Nordbye, and Nate Christy for Black Rail surveys; and Robin Leong for point counts and black rail surveys. We thank Geoff Geupel for his help in keeping this project running and for insightful comments and thank intern biologists Tonya Haff and Ryan DiGaudio for their dedication to nest monitoring and vegetation sampling. This is PRBO Contribution Number 773.

Literature Cited.

Aigner, P.A., J. Tecklin, and C.E. Koehler. 1995. Probable breeding population of the Black Rail in Yuba County, California. Western Birds 26:157-160.

Arcese, P., J.N.M. Smith, W.M. Hochachka, C.M. Rogers, and D. Ludwig. 1992. Stability, regulation, and the determination of abundance in an insular Song Sparrow population. Ecology 73:805-832.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. London: Chapman & Hall.

Burgman, M.A., S. Ferson, and H.R. Akcakaya. 1993. Risk Assessment in Conservation Biology. Chapman Hall, London.

Cohen, A.N. 1991. An Introduction to the Ecology of the San Francisco Estuary. 2nd Ed. San Francisco Estuary Project, Oakland.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Dawson, D. K., D. R. Smith, C. S. Robbins. 1995. Point Count Length and Detection of Forest Birds. pp. 35-43 in C. John Ralph, J. R. Sauer, and S. Droege (editors) Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U. S. Dept. of Agriculture.

Dedrick, K. 1993. Atlas of the present tidal marshlands, San Francisco Bay, California. Proceedings of the Eighth Symposium on Coastal and Ocean Management (Coastal Zone-93). July 19-93, 1993.

Desante, D.F. 1981. A field test of the variable circular-plot censusing technique in a California coastal scrub breeding bird community. In Estimating Numbers of Terrestrial Birds. Studies in Avian Biology, No. 6. (C. J. Ralph and J. M. Scott editors). Cooper Ornithological Society.

de Hoyo, J., A. Elliot, and J. Sargatal, eds. 1996. Handbook of Birds of the World. Vol 3. Hoatzin to Auks. Lynx Edicions, Barcelona.

Eddleman, W. and J. Evens. 1994. California Black Rail *in* Life on the Edge: a guide to California's Endangered Natural Resources: Wildlife. (Ed. by Thelander, K.G. and Crabtree, M.). Biosystems Books; Santa Cruz, CA.

Eddleman, W.R., R.E. Flores, and M.L. Legare. 1994. Black Rail *(Laterallus jamaicensis) In* The Birds of North America, No. 123 (A.Poole and F. Gillis, eds) Philadelphia: The Academy of

Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Evens, J.G. and G.W. Page. 1985. Quantifying Black Rail abundance in San Francisco Bay salt marshes. Scientific Report of the Point Reyes Bird Observatory to the Hood Harris Foundation Fund for Conservation grants, Marin Audubon Society.

Evens, J.G., G.W. Page, L.E. Stenzel, and N.D. Warnock. 1986. Distribution, abundance, and habitat of California Black Rails in tidal marshes of Marin and Sonoma Counties, California. Scientific Report of the Point Reyes Bird Observatory. Dec. 1986.

Evens, J.G., G.W. Page, L.E. Stenzel, R.W. Stallcup and R.P. Henderson. 1989. Distribution and relative abundance of the California black rail (Laterallus jamaicensis coturniculus) in tidal marshes of the San Francisco estuary. Report to California Department of Fish and Game from Point Reyes Bird Observatory.

Evens, J.G., G.W. Page, S.A. Laymon, and R.W. Stallcup. 1991. Distribution, relative abundance and status of the California Black Rail in western North America. Condor 93:952-966.

Faber, P.M. 1993. Common Wetland Plants of Coastal California. 4th Edn. Pickleweed Press, Mill Valley, CA.

Ferrell, G.T. 1966. Variation in blood group frequencies in populations of Song Sparrows of the San Francisco Bay region. Evolution 20:369-382.

Flores, R.E. and W.R. Eddleman. 1993. Nesting biology of the California Black Rail in southwestern Arizona. Western Birds 24:81-88.

Hickman, J.C. (Ed.). 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley and Los Angeles.

Hobson, K., P. Perrine, E.B. Roberts, M.L. Foster, and P. Woodin. 1985. A Breeding Season Survey of Salt Marsh Yellowthroats (*Geothlypis trichas sinuosa*) in the San Francisco Bay Region. Report of the San Francisco Bay Observatory to U.S. Fish & Wildlife Service.

James, F. C., And H. H. Shugart, Jr. 1970. A quantitative method of habitat description. Aud. Field Notes. 24:727-736.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Johnston, R.F. 1956. Population structure in salt marsh Song Sparrows. Condor 58:24-44, 254-272.

Laake, J.L., S.T. Buckland, D.R. Anderson, and K.P. Burnham. 1993. DISTANCE User's Guide, Version 2.0. Colorado Cooperative Fish and Wildlife Research Unit, Col. State Univ., Fort Collins, CO.

Laudenslayer, W.F., Jr., W.E. Grenfell, Jr. and D.C. Zeiner. 1991. A Check-list of the Amphibians, Reptiles, Birds, and Mammals of California. Calif. Fish and Game 77:109-141.

Manolis, T. 1978. Status of the Black Rail in Central California. West. Birds 9:151-158.

Marshall, J.T. 1948. Ecologic races of Song Sparrows in the San Francisco Bay region. Condor 50:193-215, 233-256.

Marshall, J.T. and K.G. Dedrick. 1994. Endemic Song Sparrows and Yellowthroats of San Francisco Bay. Pp. 316-327 **in** N. K. Johnson & J. Jehl (Eds.), A Century of Avifaunal Change in Western North America. Studies in Avian Biology 15.

Martin, T. E. 1992. Breeding productivity considerations: What are the appropriate habitat features for management? in J. M. Hagan and D. W. Johnston (editors) Ecology and Conservation of Neotropical Migrant Birds. Smithson. Inst. Press, Washington, D.C.

Martin, T. E. and C. Conway. 1995. The Breeding Biology Research and Monitoring Database (BBIRD) Field Protocol. University of Montana Coop. Unit, Unpublished manual.

Martin, T. E. and G. R. Geupel. 1993. Nest-monitoring plots: Methods for locating nests and monitoring success. Journal of Field Ornithology 64:507-519.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin. 87:456-466.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. Desante. 1993. Field Methods for Monitoring Landbirds. USDA Forest Service Publication, PSW-GTR 144, Albany, CA.

Ralph, C.J., J. R. Sauer, and S. Droege (Editors). 1993 Monitoring Bird Populations by Point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U. S. Dept. of Agriculture.

Repking, C.F. and R.D. Ohmart. 1977. Distribution and density of Black Rail populations along the lower Colorado River. Condor 79:486-453.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Savard, J. L. and T. D. Hooper. 1995. Influence of Survey Length and Radius Size on

Grassland Bird Surveys by Point Counts at Williams Lake, British Columbia. pp. 57-62 **in** C. John Ralph, J. R. Sauer, and S. Droege (editors) Monitoring Bird Populations by Point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U. S. Dept. of Agriculture.

Shuford, W.D. 1993. The Marin County Breeding Bird Atlas. Bushtit Books, Bolinas, CA.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry: the principles and practice of statistics in biological research, 2nd edition. San Francisco: W. H. Freeman

United States Fish and Wildlife Service. 1991. Federal Register Vol. 56, No. 225, Nov. 21, 1991. Proposed Rules.

Wiens, J.A. 1969. An approach to the study of ecological relationships among grassland birds. Ornith. Monographs 8:1-93.

Zink, R.M., and J. Van Remsen, Jr. 1986. Evolutionary process and patterns of geographical variation in birds. Current Ornithology 4:1-69.

Table 1. Bay and County location of study sites, with study site codes, and number of point-count points established. Sites where nest monitoring were conducted are indicated by an asterisk, *. Refer to Figure 1 for location of each site in the San Francisco Bay region. For more detail, refer to Appendix 1.

Bay	County	Site	Code	Pts
Suisun	Solano	Goodyear Slough A	GSA	10
Suisun	Solano	Goodyear Slough B	GSB	10
Suisun	Contra Costa	Pt. Edith Marsh	PEM	10
Suisun	Contra Costa	Bullhead Marsh	BHM	10
Suisun	Solano	Southhampton Bay Marsh*	SBM	10
Suisun	Solano	Rush Ranch A*	RRA	10
Suisun	Solano	Rush Ranch B*	RRB	10
San Pablo	Sonoma	Petaluma Marsh*	PM	10
San Pablo	Solano	Mare Island A	MIA	10
San Pablo	Solano	Mare Island B	MIB	10
San Pablo	Marin	Black Johns Slough A	BJA	10
San Pablo	Marin	Black Johns Slough B	BJB	10
San Pablo	Marin	McInnis Marsh	MIM	10
San Pablo	Marin	China Camp*	CCM	10
San Francisco	Alameda	Dumbarton Marsh	DM	14
San Francisco	Alameda	Hayward Marsh	HM	11
San Francisco	San Mateo	Palo Alto Baylands	PAB	12
San Francisco	Alameda	Emeryville Crescent	EC	5
San Francisco	Contra Costa	Hoffman Marsh	HOM	5

Table 2. General physical and vegetation features of study sites. For more detail, refer to Appendix 1. "S.F." refers to Central and South San Francisco Bay. "Primary Vegetation" refers to species comprising 50% or more of total cover.

Bay	**Site Name**	**Levees**	**Channelization**	**Primary Vegetation**
San Pablo	China Camp	None	Many large and small, natural	*Salicornia*
San Pablo	McInnis Marsh	Inland	Many large and small, natural	*Salicornia*
San Pablo	Black Johns Slough A&B	Inland	Many large and small, natural	*Salicornia*
San Pablo	Petaluma	Inland	Few, natural	*Salicornia*
San Pablo	Mare Island A&B	Perpendicular	Few, natural	*Salicornia*
Suisun	Southhampton Bay	None	One large, few small, natural	*Salicornia*
Suisun	Pt. Edith	Several	Few large, very few small	Cat-tail, Saltgrass
Suisun	Bullhead Marsh	Inland	Few large and small	Cat-tail, Bulrush, Tule
Suisun	Goodyear Slough A	Seaward	Few, mostly small	decadent *Salicornia*
Suisun	Goodyear Slough B	Multiple	Parallel to levees only	Wild Radish, Cat-tail, *Salicornia*
Suisun	Rush Ranch A&B	None	Many large and small, natural	Rushes, Saltgrass
S.F.	Hoffman Marsh	Inland	Few, mostly small	*Salicornia*
S.F.	Emeryville Crescent	Multiple	Few, mostly small	*Salicornia*
S.F.	Hayward Marsh	Inland	Few	*Salicornia*
S.F.	Dumbarton Marsh	Perpendicular	Many large and small, natural	*Salicornia*
S.F.	Palo Alto Baylands	Multiple	Many large and small, natural	*Salicornia*

Table 3A. Vegetative characteristics (percent cover shown) of all study sites along San Pablo Bay, 1996. Site codes from Table 1. See Appendix 2 for plant nomenclature.

	Sites				
Species	**China Camp**	**McInnis**	**Black John Slough**	**Petaluma River Mouth**	**Mare Island**
Alkali Heath	1.12	-	-	-	-
Common Cat-Tail	-	-	-	1.12	-
Common Pickleweed	69.65	91.37	58.94	93.97	99.37
Coyote Bush	-	-	.19	-	-
Cord Grass	2.95	-	.56	-	-
Gum-Plant	5.1	2.25	4	.22	-
Jaumea	.75	.37	1.06	-	.06
Peppergrass	-	-	.06	.82	-
Bulrush	3.05	1.5	25.44	-	.44
Sea Arrowgrass	.25	-	-	-	-
Saltgrass	16.2	5.5	9.37	-	-
Wild Buckwheat	-	-	-	.02	-
Wild Radish	-	-	-	.05	-
Unknown Grass	-	-	.31	-	-
Unknown Herb	-	-	.25	.60	-

Table 3B. Vegetative characteristics (percent cover shown) of study sites along Suisun Bay, 1996. Site codes as in Table 1. See Appendix 2 for plant nomenclature.

	Sites					
Species	**Southampton Bay**	**Bullhead Marsh**	**Point Edith**	**Goodyear Slough A**	**Good Year Sl. B**	**Rush Ranch**
Brass Buttons	-	-	4.5	1.25	-	.12
Common Cat-Tail	-	33.5	36.75	-	20.37	-
Common Reed	-	-	1.12	3.87	1.87	-
Common Pickleweed	54.45	7.37	6.87	79.37	13.37	.56
Common Tule	-	11.37	-	-	-	-
Coyote Bush	-	3.5	3.37	-	3	-
Fennel	-	-	.5	-	.25	-
Gum-Plant	5.87	-	1.0	.12	3.37	-
Rushes	4.45	4.62	.62	1	4.37	37.32
Meadow Foxtail	-	-	-	2.12	.25	-
Mustard	-	.12	-	-	-	-
Ox Tongue	-	-	-	-	1.37	-
Peppergrass	10.75	.37	12.75	.05	4.75	15.01
Poison Hemlock	-	-	-	-	.25	-
Poison Oak	-	.25	-	-	-	-
Ragwort	.75	-	-	-	-	-
Saltgrass	12.45	3.75	17.0	9.87	8.37	16.76
Bulrush	3.05	13.5	6.25	-	7.25	13.05
Seaside Arrow-Grass	1.62	.12	-	-	.5	.59
Silverweed	2.25	-	-	-	-	9.26
Suisun Thistle	-	-	-	-	-	.11
White Sweetclover	-	-	.12	-	-	-
Water Parsley	-	2	-	-	-	.94
Wild Buckwheat	2.3	-	-	1.45	1.87	.1
Wild Radish	-	-	-	-	28.75	-
Unknown Grass	1.75	-	-	-	-	-
Unknown Herb	.65	.25	1.5	-	-	-
Unknown Thistle	.05	-	.25	-	-	-

Table 3C. Vegetative characteristics (percent cover) of all study sites along Central and South San Francisco Bay, 1996. Site codes as in Table 1. See Appendix 2 for plant nomenclature.

	Sites				
Species	**HOM**	**EC**	**PAB**	**HM**	**DM**
Alkali Heath	-	-	3.02	1.81	5.54
Common Pickleweed	85.75	73.5	50.94	55.11	55.71
California Cord Grass	7.5	6.25	17.61	15.79	5.45
Coyote Bush	-	-	.83	.45	8.03
Dodder	-	.25	-	-	.62
Elderberry	-	-	-	-	.09
Fennel	-	-	-	-	2.95
Gum-Plant	1.75	8	4.27	3.07	5.09
Crystalline Iceplant	-	1.5	-	-	1.07
Jaumea	.75	-	-	.45	-
Mustard	-	-	4.68	3.98	1.43
Peppergrass	-	-	.1	-	3.12
Saltgrass	4.25	10	.31	-	5.53
Bulrush	-	-	1.56	-	-
Unknown. Grass	-	-	12.92	15.57	5.89
Unknown Shrub	-	-	-	-	.09
Unknown Thistle	-	-	3.54	1.02	-

Table 4. Density estimates of Song Sparrows in the three bay regions of the San Francisco bay area; based on first census only. Site codes as in Table 1. See text.

San Pablo Bay Site	**Density (per ha)**	**Suisun Bay Site**	**Density (per ha)**	**San Francisco Bay Site**	**Density (per ha)**
BJA	47.6	BHM	8.71	HM	3.24
BJB	93.8	GSA	7.63	HOM	0.89
CCM	18.2	GSB	45.9	DM	141
MIA	5.08	PEM	30.0	EC	3.67
MIB	3.69	RRA	26.4	PAB	5.82
MIM	16.5	RRB	22.8		
PM	68.7	SBM	36.1		
Median	**18.2**		**22.8**		**3.67**

Table 5. Estimates of breeding population size for tidal marsh Song Sparrows, by region. San Pablo Bay = *Melospiza melodia samuelis*; Suisun Bay = *M. m. maxillaris*; South and Central Bay corresponds to *M. m. pusillula*. All estimates have been rounded to the closest hundred for this Table. See text.

REGION	Best estimate	Lower estimate	Upper estimate	Marshall & Dedrick (1994) estimate
SAN PABLO BAY	49,900	25,000	59,900	31,200
SUISUN BAY	44,100	22,100	52,900	19,100
SOUTH & CENTRAL S.F. BAY	8,100	4,000	9,700	14,800

Table 6. Abundance indices for Common Yellowthroats. Shown are the mean (+ S.E.) of number of individuals detected per point count station (both censuses combined).

Site	Mean number of individuals per point count station	Standard Error
South, E. SF Bay		
Dumbarton Marsh	0.21	0.15
Emeryville Crescent	0.0	--
Hayward Marsh	0.0	--
Hoffman Marsh	0.0	--
Palo Alto Baylands	0.50	0.29
San Pablo Bay		
Black Johns Slough A	0.90	0.31
Black Johns Slough B	1.00	0.37
China Camp Marsh	0.0	--
Mare Island A	0.0	--
Mare Island B	0.0	--
McInnes Marsh	0.0	--
Petaluma Marsh	0.0	--
Suisun Bay		
Bullhead Marsh	2.90	0.46
Goodyear Slough A	0.0	--
Goodyear Slough B	3.30	1.04
Point Edith Marsh	2.60	0.72
Rush Ranch A	3.30	0.70
Rush Ranch B	2.10	0.55
Southampton Bay Marsh	1.20	0.29

Table 7A. Index of Common Yellowthroats abundance (birds detected per point count station, 2 censuses combined) in relation to Marsh Characteristics. Effect of Channelization (Few vs. Many Channels) is significant ($P = 0.044$), while controlling for a "Bay" Main Effect (Overall Model incorporating Bay and Channelization Main Effects: $P = 0.0011$, $R^2=0.658$). Effect of Channelization is similar among the three Bay regions ($P > 0.8$ for test of heterogeneity among Bay Regions with respect to Channelization).

	Few Channels	Many Channels
San Franc. Bay	0.0 ± 0.0 N = 3 Marshes	0.36 ± 0.14 N = 2 Marshes
San Pablo Bay	0.0 ± 0.0 N = 3 Marshes	0.48 ± 0.28 N = 4 Marshes
Suisun Bay	2.00 ± 0.61 N = 5 Marshes	2.70 ± 0.60 N = 2 Marshes

Table 7B. Estimated density of Song Sparrows (birds per hectare) in relation to Marsh Characteristics. Effect of Channelization (Few vs. Many Channels) is significant ($P = 0.043$), while controlling for a "Bay" Main Effect (Overall Model incorporating Bay and Channelization Main Effects: $P = 0.0063$, $R^2=0.376$). Effect of Channelization is not statistically different among the three Bay regions ($P > 0.2$ for test of heterogeneity).

	Few Channels	Many Channels
San Franc. Bay	2.63 ± 0.89 N = 3 Marshes	73.4 ± 67.6 N = 2 Marshes
San Pablo Bay	25.8 ± 21.4 N = 3 Marshes	44.0 ± 18.1 N = 4 Marshes
Suisun Bay	25.7 ± 7.6 N = 5 Marshes	24.6 ± 1.8 N = 2 Marshes

Table 8. Relationship of Song Sparrow abundance (number of individuals detected during two censuses) in relation to Total vegetation cover, N = 167 Point count stations (vegetation data unavailable for 20 point count stations). The relationship of increased abundance with increasing vegetation cover is significant ($P<0.0001$); the relationship is significant even after controlling for a "site" Main Effect ($P=0.003$), indicating that, **even within a marsh**, areas with higher vegetation cover had significantly higher numbers of Song Sparrows.

Total Vegetation Cover (%)	Number of Song Sparrows Detected (Mean)	Sample Size (Number Point Count Stations)
39-60	5.20	10
60-70	7.17	6
70-80	11.57	14
80-90	11.24	34
90-95	13.97	33
95-100	13.96	70

Table 9A. Vegetational Correlates of Common Yellowthroat Abundance. Results of a Multiple Regression Analysis for the Four Vegetation Variables listed, while controlling for the effects of the other 3 Vegetation Variables. At each of 105 point count stations yellowthroat abundance was assessed as was percent cover by plant species. There was no significant effect of cover by Saltgrass, *Juncus*, Gum Plant, or Cord Grass, once the listed 4 Vegetation Variables were included in the model. Analysis carried out on log-transformed yellowthroat abundance (the dependent variable).

Model statistics: $R^2 = 0.518$, $P < 0.0001$, $n = 105$

Independent Variable:
(all four considered simultaneously)

Pickleweed cover (Percent of total cover)	$ß = -0.0073 \pm .0013$, $P < 0.001$
Peppergrass cover (Percent of total cover)	$ß = +0.0159 \pm .0043$, $P < 0.001$
Common Cat-tail cover (Percent of total cover)	$ß = +0.0119 \pm .0029$, $P < 0.001$
Scirpus cover (Percent of total cover)	$ß = +0.0064 \pm .0027$, $P = 0.018$

Table 9B. Relationship of Common Yellowthroat abundance (number of individuals detected during two censuses) in relation to Percent cover comprised of Pickleweed. Point count stations in marshes with no detected Common Yellowthroats are omitted; N = 105 Point count stations. The relationship of increasing abundance with increasing Pickleweed is significant (P < 0.0001).

Percent cover, Pickleweed	Number of Common Yellowthroats Detected (Mean)	Sample Size (Number Point Count Stations)
0-10	2.73	40
11-20	2.73	11
21-30	1.80	5
31-40	1.00	7
41-50	0.67	12
51-60	0.17	6
61-70	0.77	13
71-90	0.88	8
91-100	0.25	4

Table 10. Relationship of Common Yellowthroat abundance (number of individuals detected during two censuses) in relation to Percent cover comprised of channels. Point count stations in marshes with no detected Common Yellowthroats are omitted; N = 105 Point count stations. The relationship of increasing abundance with increasing channel cover is significant (P = 0.031).

Percent cover, channel	Number of Common Yellowthroats Detected (Mean)	Sample Size (Number Point Count Stations)
0-1	1.78	32
1-5	1.57	44
5-10	0.80	15
10-15	2.86	7
15-20	2.50	2
20-25	3.00	3
25-30	5.00	2

Table 11A. Mayfield estimates of nest survival for Suisun and Samuel's Song Sparrows at nest monitoring sites. Site codes as in Table 1.

Bay	Site	Subspecies	N[1]	total[2]	Estimated Daily Survival (S.E.)	total incubation	total nestling
San Pablo	CC	Samuel's	27	.302	.953(.012)	.625	.757
San Pablo	PM	Samuel's	60	.282	.950(.008)	.699	.480
Suisun	SB	Suisun	102	.156	.928(.007)	.464	.412
Suisun	RR	Suisun	34	.267	.948(.011)	.477	.695

Table 11B. Reproductive success of Song Sparrows in Coastal scrub habitat at Palomarin Field Station, Point Reyes National Seashore, 1996.

Location	County	Subspecies	N[1]	total[2]	Estimated Daily Survival (S.E.)	total incubation period survival	total nestling period survival
Palomarin	Marin	*gouldii*	34	.244	.945(.011)	.599	.504

Table 11C. Number of young produced for Suisun and Samuel's Song Sparrows at all nest monitoring sites. Site codes as in Table 1.

Bay	Site	Subspecies	Number of Nests	Number of Fledglings	Fledglings Per Nest Attempt
San Pablo	CC	Samuel's	29	40	1.38
San Pablo	PM	Samuel's	66	64	0.97
Suisun	SB	Suisun	147	63	0.43
Suisun	RR	Suisun	46	38	0.83

[1] - Number of nests that could be used in Mayfield nest success analysis.

[2] - Calculated survival probability for entire nesting period (laying, incubation, and nestling)

Table 12. Measurements of Song Sparrow subspecies obtained from mist-net captured (and subsequently released) birds. All linear measurements are in millimeters. The "±" indicates the standard deviation.

A) Adults

Subspecies	**Sex**	**N**	**Mass (g)**	**Wing Chord**	**Tarsus**	**Nostril-Culmen**	**Exposed Culmen**	**Bill Depth**	**Bill Width**
samuelis	F	5	17.64 ± 1.79	53.20 ± 0.45	20.35 ± 0.37	8.00 ± 0.62	10.37 ± 0.61	5.53 ± 0.32	4.86 ± 0.46
	M	7	17.81 ± 1.51	58.00 ± 0.98	20.40 ± 0.86	8.82 ± 0.48	10.67 ± 0.59	5.70 ± 0.14	4.88 ± 0.43
maxillaris	F	5	21.07 ± 1.34	57.20 ± 2.39	20.82 ± 1.31	9.06 ± 0.85	11.59 ± 1.08	6.31 ± 0.44	5.47 ± 0.39
	M	9	19.10 ± 1.43	58.60 ± 1.85	21.28 ± 1.25	8.84 ± 0.60	11.56 ± 0.87	6.03 ± 0.69	5.39 ± 0.47
pusillula	F	6	19.05 ± 1.65	55.83 ± 1.17	20.32 ± 0.83	8.68 ± 0.94	11.01 ± 0.97	6.18 ± 0.83	5.26 ± 0.80
	M	6	18.92 ± 0.64	58.00 ± 1.67	20.47 ± 0.89	8.42 ± 0.39	10.71 ± 0.60	5.49 ± 0.16	4.66 ± 0.35

B) Hatch-year birds (sexes combined)

Subspecies	**N**	**Mass (g)**	**Wing Chord**	**Tarsus**	**Nostril-Culmen**	**Exposed Culmen**	**Bill Depth**	**Bill Width**
samuelis	6	17.93 ± 1.52	59.50 ± 1.38	18.09 ± 1.12	8.65 ± 0.45	10.75 ± 0.55	5.73 ± 0.43	4.89 ± 0.29
maxillaris	12	18.41 ± 2.21	58.41 ± 2.27	18.52 ± 5.97	9.39 ± 0.71	11.88 ± 1.01	6.50 ± 0.60	6.51 ± 0.60
pusillula	7	16.31 ± 1.85	55.00 ± 1.63	19.36 ± 1.16	7.83 ± 0.49	10.15 ± 0.34	5.48 ± 0.27	5.50 ± 0.27

Table 13. Distribution of color patterns for upperparts and for vent color of the three resident subspecies of Song Sparrow in the San Francisco Bay Region. The sample sizes come from adults caught in the field by mist-net, and then scored as per the color code categories developed by Marshall (1948). Sexes combined. See text for discussion.

	Melospiza melodia:		
Color Code	***pusillula***	***samuelis***	***maxillaris***
Upperparts:			
1-dark olive brown	**0**	**2**	**7**
2-light olive brown	**4**	**1**	**1**
3-blackish olive	**0**	**0**	**1**
4-blackish brown	**2**	**1**	**5**
5-reddish brown	**0**	**0**	**0**
6-reddish brown with light gray edges	**3**	**1**	**0**
7-yellowish brown	**2**	**5**	**0**
8-yellowish gray	**1**	**1**	**0**
Vent :			
1-white	**1**	**0**	**6**
2-off white	**3**	**2**	**2**
3-yellowish wash	**6**	**4**	**2**
4-buff	**2**	**6**	**2**

Table 14. Black Rail fraction of detections, "minimum density," and marsh characteristics, 1996. Sites are mapped in Figure 4.

Site #	**Location**	date '96	parcel # *	size* (ha)	Sta. #	fraction of detections @	bird/ sta'n '96 ≤30 m	D	obs
	San Pablo Bay								
1.,2	China Camp	5-1	139	103	24	0.04	0.04	0.09	je,gg
3.	Gallinas Creek mouth (N)	5-9	143	130.4	24	0.16	0.36	0.88	gg dw
4.	Hamilton Shore	5-7	145	39.7	10	0.00	0.00	0.00	rs
5.	Sonoma Baylands	6-7	107	100.6	16	0.75	1.19	2.89	je,gg
6.	Sonoma Creek mouth	5-3	73	72.3	13	0.23	0.23	0.56	je
7	Napa Slough	5-3	74	54.6	17	0.29	0.29	0.71	gg
8a	Mare Island Point (E)	5-20	1	144.2	17	0.29	0.35	0.85	rs
8b	Mare Island Point (NW)	5-24	2	36.6	11	0.08	0.08	0.19	rl,nc
9, 10	Black John Slough	5-10	127	55.1	21	0.57	1.19	2.89	je,gg
11	White Slough, Napa R.	5-13	5	63.9	10	0.10	0.10	0.24	dw
12	Wilson Ave, Napa R.	5-13	4	28.6	07	0.00	0.00	0.00	gg
13	Dutchman's Slough, Napa R.	5-13	3	9.1	04	0.00	0.00	0.00	gg
13	" " "	5-27	(3)	(9.1)	04	1.00	1.25	3.04	rs
15	Fagan Slough	6-17	15,49	126.4	20	0.80	1.58	3.84	je,gg
16	Bull Island**	6-17	50	67.5	09	0.00	0.00	0.00	tn

	Suisun Bay & Carquinez								
18a	Southhampton (aka Benecia)	4-9	174	54.2	12	0.48	0.68	1.65	je,rs
18b	Southhampton**	5-26	(174)	(7.5)	03	0.67	0.33	0.80	rs
19a	Cutoff Slough (N)	5-20	410	115.2	22	0.36	0.35	0.85	gg,th
19b	Cutoff Slough (E)	5-21	409	149.3	21	0.57	1.05	2.55	je,gg
20a	Hill Slough	5-22	541	19.6	24	0.50	0.54	1.31	gg
20b	Hill Slough (diked)	5-22	557	100.0	11	0.00	0.00	0.00	je
	Outer Coast								
21a	Tomales Bay (south end)	6-6	na	45.0	18	0.22	0.39	0.95	gg
21b	Tomales Bay (Tomasini Pt.)	6-29	na	~50	06	0.00	0.00	0.00	gg
21c	Tomales Bay (Bivalve)**	6-27	na	~50	03	0.00	0.00	0.00	gg
21d	Tomales Bay (Ocean Roar)	6-27	na	~50	06	0.00	0.00	0.00	gg
22a	Drakes Bay (Johnson's)	6-28	na	~5.0	04	0.25	0.25	0.60	gg
22b	Drakes Bay **	6-28	na	5.0	06	0.00	0.00	0.00	gg
23	Bolinas Lagoon	6-19	na	~98.0	13	0.23	0.31	0.75	gg

@Fraction of detections = fraction of stations at which rails detected

* Sizes and parcel numbers after Dedrick 1993. * * sites with muted tidal flow (as opposed to fully tidal);
nd = no data available; na = not applicable
parentheses indicate sites included as part of another parcel. Estimated size is preceded by tilde (~).

D: density calculated based on a listening station with an effective radius of 36.2 m (4114.8 sq. m).

Observers: je = Jules Evens; rs = Rich Stallcup; gg = Geoff Grace; dw = David Wimpfheimer; tn = Terry Nordbye; rl = Robin Leong; nc = Nate Christy.

Table 15. Comparison of "minimum density" estimates for 1988 and 1996, estimated "minimum abundance" in 1996, and rank of site according to abundance.

Site #	**Location**	D '88	D '96	D '96 x size	abund. rank
	San Pablo Bay				
1,2	China Camp	0.12	0.10	10.3	low
3	Gallinas Creek mouth (N)	0.07	0.88	114.8	mod
4	Hamilton Shore	0.00	0.00	0.0	low
5.	Sonoma Baylands	1.22	2.89	290.7	high
6.	Sonoma Creek mouth	0.58	0.56	40.5	low
7.	Napa Slough	0.95	0.71	38.8	mod
8a	Mare Island Point (E)	0.90	0.85	122.6	mod
8b	Mare Island Point (NW)	nd	0.19	7.0	low
9,10	Black John Slough	1.53	2.89	159.2	high
11	White Slough, Napa R.	0.97	0.24	15.3	low
12	Wilson Ave, Napa R.	0.00	0.00	0.0	low
13	Dutchman's Slough, Napa R.	2.43	3.04	(5)	high
14	Coon Island	1.51	nd	na	mod
15	Fagan Slough	2.06	3.84	485.4	high
16	Bull Island**	0.00	0.00	0.0	low
17	Petaluma R. marsh	2.04	nd	na	high
	Suisun Bay & Carquinez				
18a	Southhampton (Benecia)	0.58	1.65	89.4	mod
18b	Southhampton**	nd	0.80	(5.6)	mod
19a	Cutoff Slough (N)	0.65	0.85	97.9	mod
19b	Cutoff Slough (E)	1.90	2.55	380.7	high

20a	Hill Slough	nd	1.31	25.7	mod
20b	Hill Slough (diked)**	nd	0.00	0.0	—
	Outer Coast				
21a	Tomales Bay (south end)	1.38	0.95	42.8	mod
21b	Tomales Bay (Tomasini Pt.)	0.00	0.00	0.00	—
21c	Tomales Bay (Bivalve)*	0.00	0.00	0.00	—
21d	Tomales Bay (Ocean Roar)	0.00	0.00	0.00	—
22a	Drakes Bay (Johnson's)	0.89	0.60	3.0	low
22b	Drakes Bay **	0.00	0.00	0.0	—
23	Bolinas Lagoon	1.10	0.75	(5)	mod
24	Bodega Bay		nd	na	low

** sites with muted tidal flow (as opposed to fully tidal); nd = no data available

D: density calculated based on a listening station with an effective radius of 36.2m (4114.8 sq. m]

RANK(to conform to Evens et al. 1989): Low = < 0.60 rails per hectare; Moderate = 0.60 - 2.12 rails per hectare; High = > 2.12 rails per hectare .

Table 16. A) POPULATION ESTIMATES BASED ON THE MEAN OF ABUNDANCE INDICES FOR EACH AREA; based on Table 14.

SUBREGION	SIZE (HA)	ABUNDANCE INDEX ± S.E.	# sites	ABUNDANCE ESTIMATE*	RANGE: Mean ± 1 S.E.
SAN PABLO BAY	5,531	1.25 ± 0.345	13	6914	5003-8824
SUISUN & CARQUINEZ	3,780	1.43 ± 0.320	5	5405	4195-6615
OUTER COAST	543	0.46 ± 0.196	5	250	143-356

*Abundance estimate - estimated number of individuals, based on detected individuals only. This provides a lower-bound estimate. See below for a more complete estimate.

B) Median and Quartile Densities (detections per hectare); Estimated abundance per region derived from median density indices and from DISTANCE.

REGION	total area (ha)	suit-able area (ha)	Q_1	M	Q_3	max	"abundance estimate" based on median*	Popult'n Estimate based on DISTANCE@
SAN PABLO BAY	5531	3595	0.22	0.71	2.89	3.84	3927	7658
SUISUN & CARQUINEZ	3780	2457	0.75	1.08	2.25	2.55	4082	7960
OUTER COAST	543	272	0.0	0.30	0.68	0.95	163	245

*Abundance estimate - estimated number of individuals, based on detected individuals only, extrapolated from observed density to total area. This provides a lower-bound estimate. Contrast with next column on right, for more complete estimate.
@Population estimate based on densities estimated using Variable Circular Plot (VCP) data and program DISTANCE. To obtain population totals, calculated density was extrapolated based on best estimate of suitable habitat (65% of total area in San Pablo and Suisun Bays, 50% of total area in Outer Coast).

Figure Legends.

Figure 1. The three Song Sparrow subspecies restricted to tidal marshes and their general distribution in the San Francisco Bay region.

Figure 2. Distribution of study sites in the San Francisco Bay region. Codes for sites are defined in Table 1. See Table 2 and Appendix 1 for more details of sites.

Figure 3. Relationship of density in each marsh (birds per hectare, log-transformed) in relation to area of marsh (hectares) and isolation of marsh (I = Isolated, i.e., > 1 km to nearest adjacent marsh; otherwise, C = Connected). Each symbol (I or C) indicates one marsh. Note log-scale for Area. A) Song Sparrows. Effect of Marsh Area, NS; Effect of Marsh Isolation, NS; Interaction of Isolation and Area, P = 0.013. That is, effect of Area is stronger in Isolated than in Connected Marshes. Line of best fit (density vs. area) is shown for Isolated Marshes only (P = 0.061, for regression coefficient). B) Common Yellowthroats. Effect of Marsh Area, NS; Effect of Marsh Isolation, NS; No significant interaction between Marsh Area and Marsh Isolation, i.e., effect of marsh area is statistically similar in isolated as in connected marshes.

Figure 4. California Black Rail Survey: distribution of study sites. Numbers correspond to sites listed in Table 14.

Appendix 1. Description and location of study sites.

Site Name: China Camp
Bay: San Pablo Bay
County: Marin
Location: At China Camp State Park, off San Pedro Rd., east of San Rafael. Gallinas Creek to the north, and the isolated oak hill (surrounded by marsh) served as boundaries.
Marsh History: Established as State Park.
Logistics: Points were all established within the marsh. Several points were only accessed by returning to park road and walking around channels to adjacent point.
Levees: None.
Channelization: Heavily channelized with very curved and winding channels.
Vegetation: Dominated heavily by Pickleweed, with Gum Plant on the channel fringes. *Scirpus* only appears near the bay shore.

Site Name: McInnis Marsh
Bay: San Pablo Bay
County: Marin
Location: Gallinas Creek separates this marsh from the southerly China Camp marsh. Access is by walking past the McInnis Park Golf Center, northeast of San Rafael, to the east and following the north-south levee to Miller Creek to the power line boardwalk.
Marsh History:
Logistics: Point counts were established on and near the PG&E power lines. All but three points were along the boardwalk, and all points were well beyond the levees to the west.
Levees: Inland levees have acted to dry up old marsh fields.
Channelization: Similar to the degree at China Camp. The boardwalk seemed to have an effect similar to channels in directing water flow and concentrating Song Sparrow activity.
Vegetation:

Site Name: Black Johns Slough
Bay: San Pablo
County: Marin
Location: From Hwy 101, near the northern end of Novato, turn on Atherton Ave. to the east then take a left on Bugia Ln. and follow it to the Petaluma River. The sites for the point count are east and north east. The east point counts begin at the PG&E powerline and head to the north. The northeast points were situated beginning north of the water building where the marsh constricted to a small size.
Marsh History:
Logistics: All but three points were established within the marshes. The three other

points were placed on the PG&E boardwalk leading up to the Petaluma River to the east.
Levees: Inland levees have isolated marsh fragments and dried them.
Channelization: Naturally and extensively channeled.
Vegetation: Dominated, again, by Pickleweed, with Gum Plants on channel edges. Patches of *Scirpus* are common throughout.

Site Name: Petaluma Marsh
Bay: San Pablo
County: Sonoma
Location: Take the Port Sonoma Marina exit off Hwy 37 east of Novato. Drive past the marina and park near the patch of Eucalyptus trees and walk along the levee to the extensive east-west marsh fringing the northern edge of San Pablo Bay. (Also known as Sonoma Baylands.)
Marsh History:
Logistics: All points were established within the marsh.
Levees: Main levee protects Hwy 37 inland. A smaller levee on the west end splits off a small marsh fragment..
Channelization: Comparatively minor to virtually non-existent.
Vegetation: Virtually all Pickleweed.

Site Name: Mare Island
Bay: San Pablo
County: Solano
Location: Southwest margin of island.
Marsh History: Old diagrams indicate that present marsh built up extensively through both reclamation and natural activities after 1925.
Logistics: All twenty points established within marsh.
Levees: One levee partially bisects marsh.
Channelization: Few channels; none large.
Vegetation: Dominated by Pickleweed. The Pickleweed adjacent to the island seemed dry and sparse.

Site Name: Southampton Bay (as per Marshall 1994).
Bay: Suisun
County: Solano
Location: At Benicia State Recreation Area, off Interstate 780 in Benicia.
Marsh History: Surrounded by suburbia
Logistics: All points were established in the marsh; six points on the east side of main channel, one point in the center of the marsh fragment split by park road, and three points on the west side of the main channel.

Levees: No levees.
Channelization: One large channel with a few lateral ones. Very few small channels.
Vegetation: Again dominated by Pickleweed, but with patches of Tule throughout and on the marsh fringes.

Site Name: Pt. Edith.
Bay: Suisun.
County: Contra Costa
Location: On south side of Suisun Bay. Crossing the Interstate 780 bridge to south after Benicia, turn on first exit and head east on Waterfront Road. Obtain permission to bird watch at the entrance kiosk at the site of the Port of Chicago. Park at the small parking lot created for Pt. Edith. The marsh we censused was to the east of the main north-south levee.
Marsh History: The marsh was affected by the Shell Oil spill of 1988. Abundance oil residue remains today.
Logistics: All points were accessed from the main levee, with one point on an old levee. Most all points were within 200 m of main levee.
Levees: Many perpendicular levees come off main levee.
Channelization: Some large channels exist, but much channelization occurs adjacent to levees.
Vegetation: Tule vegetation and common cattail vegetation dominates. Patches of Pickleweed and Saltgrass are common as well.

Site Name: Bullhead Marsh
Bay: Suisun.
County: Contra Costa
Location: On south side of Suisun Bay. Crossing the Interstate 780 bridge to south after Benicia, turn on first exit and head east on Waterfront Road. Access is through Wickland Oil Martinez land.
Marsh History: The marsh was affected by the Shell Oil spill of 1988.
Logistics: All points are accessed from or on the levee. None are greater than 200 m from the levee. Five points are on the levee.
Levees: Levees fringe all but bayside portion of marsh.
Channelization: Moderately so.
Vegetation: Tule vegetation and common cattail vegetation dominates. Patches of Pickleweed (more than Pt. Edith) and Saltgrass are common as well.

Site Name: Goodyear Slough A.
Bay: Suisun.
County: Solano.

Location: East of Benicia on 680, on west side of Suisun Bay. Exit on Lake Hermann Rd. and park at designated parking area for Goodyear Slough. The site is the marsh to the southwest.
Marsh History:
Logistics: All points were located in marsh.
Levees: Entire marsh is boxed in by levees.
Channelization: Absent or nearly so.
Vegetation: Pickleweed dominated, but vegetation in poor shape. Many plants appear brown-orange. Standing, stagnant water is common.

Site Name: Goodyear Slough B.
Bay: Suisun.
County: Solano.
Location: East of Benicia on 680, on west side of Suisun Bay. Exit on Lake Hermann Rd. and park at designated parking area for Goodyear Slough.
Marsh History:
Logistics: All points were established along the levees (deep water marshes predominate).
Levees: Extensive grid of levees.
Channelization: Natural channels occur among extensive channels adjacent to levees.
Vegetation: A mix of Tule and Cat-tail with small patches of Pickleweed (often in poor shape).

Site Name: Rush Ranch
Bay: Suisun.
County: Solano.
Location: Hwy 12 to Suisun City, and then south on Grizzly Island Rd. Rush Ranch is prominently indicated a few miles down the road. Points were established in extensive marsh past the ranch.
Marsh History:
Logistics: All 20 points were established within the marsh.
Levees: None near study site.
Channelization: Heavily channelized with very curved and winding channels.
Vegetation: Mix of Saltgrass and Pickleweed with non-native Pepper Grass and patches of Tule. This site has many endemic plant species.

Site Name: Hoffman Marsh
Bay: San Francisco Bay
County: Contra Costa
Location: Travelling Interstate 580 south past near a dog park

PRBO Tidal Marsh Report -- DRAFT

Marsh History:
Logistics: All points are located in the marsh.
Levees: None, roads surround marsh except for bay side.
Channelization: Fairly well developed.
Vegetation: Dominated by Pickleweed, with small amounts of Gum Plant.

Site Name: Emeryville Crescent.
Bay: San Francisco.
County: Alameda
Location: Travelling south on Interstate 580 around Emeryville, turn west on the Powell Street exit. Private parking is difficult in this area.
Marsh History:
Logistics: All points are within the marsh.
Levees: None, roads fringe marsh borders.
Channelization: Minimal, but natural. Some standing water.
Vegetation: Pickleweed.

Site Name: Hayward Marsh.
Bay: San Francisco.
County: Alameda.
Location: Travelling south on Interstate 880, passing Hayward, turn west on Hwy 92 towards the San Mateo-Hayward Bridge and exit to Breakwater Avenue for the Hayward Regional Shoreline which is just north of where Hwy 92 meets the bay. Park at the Visitor's Center.
Marsh History:
Logistics: All points are on levees. Points 1-4 are in the Salt Marsh Harvest Mouse Preserve, the remaining seven points are on the levee that dissects the restored salt marsh.
Levees: Extensive grid of levees.
Channelization: Poorly channelized.
Vegetation: Pickleweed dominated.

Site Name: Palo Alto Baylands A.
Bay: San Francisco Bay
County: San Mateo.
Location: Travel south on Hwy 101 to East Palo Alto. Main exit is University Avenue, and wind through neighborhood streets and park near San Fransiquito Creek. **Marsh History:** part of the NWR system.
Logistics: All points along the levee separating the marsh from the neighborhood of East Palo Alto. One levee into the marsh had two points.
Levees: Levees fringe the entire marsh away from the bay shore, and one bisects it.

Channelization: Moderate.
Vegetation: Pickleweed with Gum Plant.

Site Name: Palo Alto Baylands B.
Bay: San Francisco Bay
County: Santa Clara.
Location: South on 101, take the Embarcadero exit east, then park at Visitor's Center.
Marsh History: part of the NWR system, co-managed with Palo Alto Open Space.
Logistics: All points are along the PG&E boardwalk.
Levees: Levees fringe the entire marsh away from the bay shore.
Channelization: Heavily so.
Vegetation: Pickleweed with Gum Plant.

Site Name: Dumbarton.
Bay: San Francisco.
County: Alameda.
Location: 101 South to 84 West and cross the Dumbarton Bridge. (with permission and key from USFWS), go to Frontage Rd (paralleling 84) and take dirt road to south and old wharf to Hetch Hetchy Aquaduct and park. Point counts are along old rail road line.
Marsh History:
Logistics: All points were atop rail road line in accordance with wishes of USFWS and their concern for disturbance to potential Clapper Rail nests.
Levees: Railroad line is extensive east-west levee.
Channelization: Heavily and extensively.
Vegetation: Picklweed with Gum Plants on channel edges.

Appendix 2. Plant species encountered in this study in the San Francisco Bay area at our study sites. Plant species common and Latin names are from Faber (1993) and from Hickman (1993); Hickman (1993) is used when the sources differ in Latin name. Code names are our field codes for these species.

Plant Family	**Common Name(s)**	**Latin Name**	**Code**
Anacardiaceae	Western Poison Oak	*Toxicodendron diversilobum*	POOA
Apiaceae	Poison Hemlock	*Conium maculatum*	POHE
Apiaceae	Fennel	*Foeniculum vulgare*	FENN
Apiaceae	Water Parsley	*Oenanthe sarmentosa*	WAPA
Asteraceae	Coyote Bush, Chaparral Broom	*Baccharis pilularis*	COBU
Asteraceae	Suisun Thistle	*Circium fontinale* var. *hydrophilium*	SUTH
Asteraceae	Unknown thistle	*Circium* sp.	THIS
Asteraceae	Brass-Buttons	*Cotula coronopifolia*	BRBU
Asteraceae	Gum-Plant	*Grindelia nana* var. *angulstifolia (humilis)*	GUPL
Asteraceae	Jaumea	*Jaumea carnosa*	JAUM
Asteraceae	Bristly Ox-Tongue	*Picris echioides*	OXTO
Asteraceae	Ragwort	*Senecio hydrophilius*	RAGW
Azioaceae	Crystalline Iceplant	*Mesembryanthemum crystallinum*	ICEP
Brassicaceae	Mustard	*Brassica* spp.	MUST
Brassicaceae	Peppergrass	*Lepidium hydrophilium*	PEPP
Brassicaceae	Wild Radish	*Raphanus sativus*	WIRA
Caprifoliaceae	Elderberry	*Sambucus* spp	ELDE
Chenopodiaceae	Fat Hen, Salt Bush, Spear Oracle	*Atriplex patula* var. *hastata*	FAHE
Chenopodiaceae	Pickleweed, Common Pickleweed	*Salicornia virginica*	PICK
Convolvulaceae	Morning Glory	*Convolvulus* or *Calystegia*	MOGL
Cuscutaceae	Dodder	*Cuscuta salina*	DODD
Cyperaceae	Bulrush	*Scirpus microcarpus*	SCIR
Cyperaceae	Tule, Common Tule	*Scirpus acutus* var. *occidentalis*	COTU
Fabaceae	White Sweetclover	*Melilotus alba*	SWCL
Frankeniaceae	Alkali Heath	*Frankenia salina (grandifolia)*	ALHE
Juncaceae	Rushes	*Juncus* spp.	JUNC
Juncaginaceae	Seaside Arrow-Grass	*Triglochin maritima*	SEAR
Liliaceae	Wild Asparagus	*Asparagus offcinalis*	WIAS
Poaceae	Meadow Foxtail	*Alopecurus* sp.	MEFO
Poaceae	Saltgrass, Salt Grass	*Distichlis spicata*	SAGR
Poaceae	Common Reed	*Phragmites australis*	CORE
Poaceae	California Cord Grass	*Spartina foliosa*	COGR
Polygonaceae	Wild Buckwheat	*Rumex* sp.	WIBU
Rosaceae	Silverweed	*Potentilla anserina*	SILV
Solanaceae	Nightshade	*Solanum* spp.	SOLA
Typhaceae	Narrow-leaved Cattail, Common Cat-Tail	*Typha latifolia*	COCT
	Unknown herb		UNHE
	Unknown shrub		UNSH
	Unknown grass		GRAS

Figure 1. The three Song Sparrow subspecies restricted to tidal marshes and their general distribution in the San Francisco Bay region.

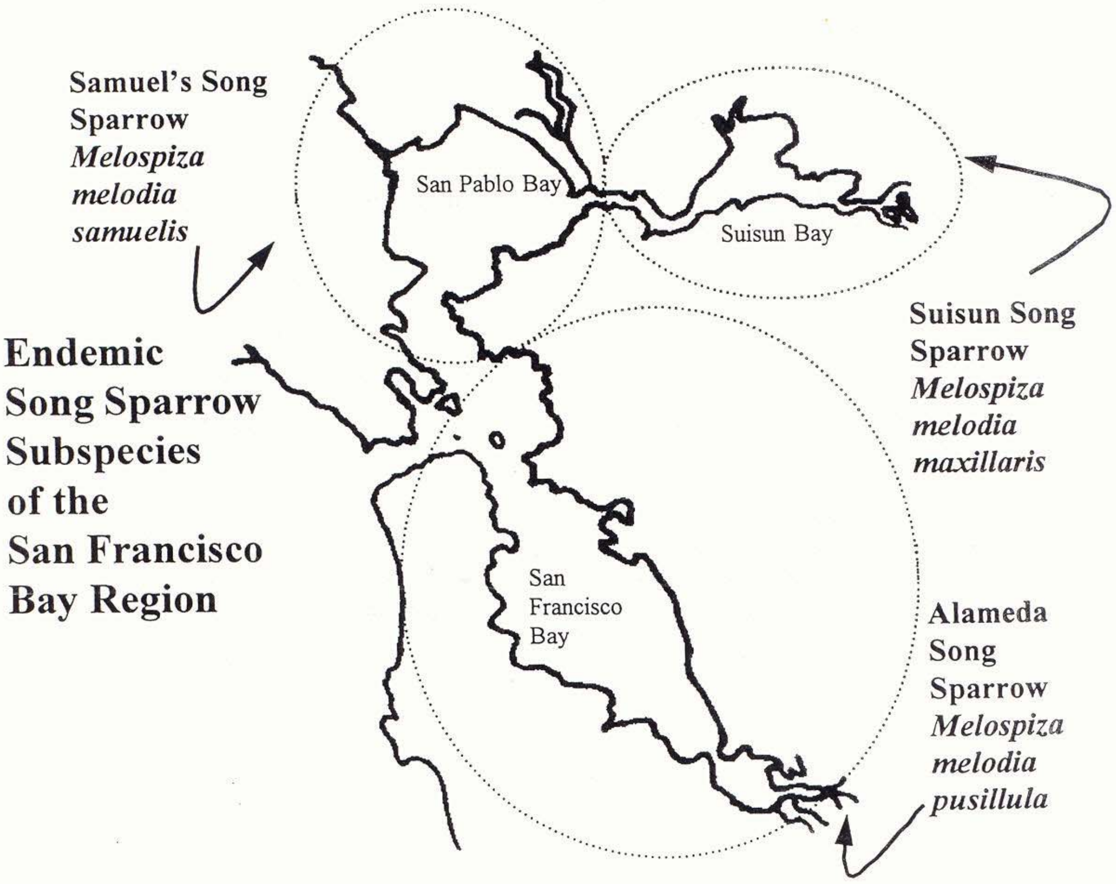
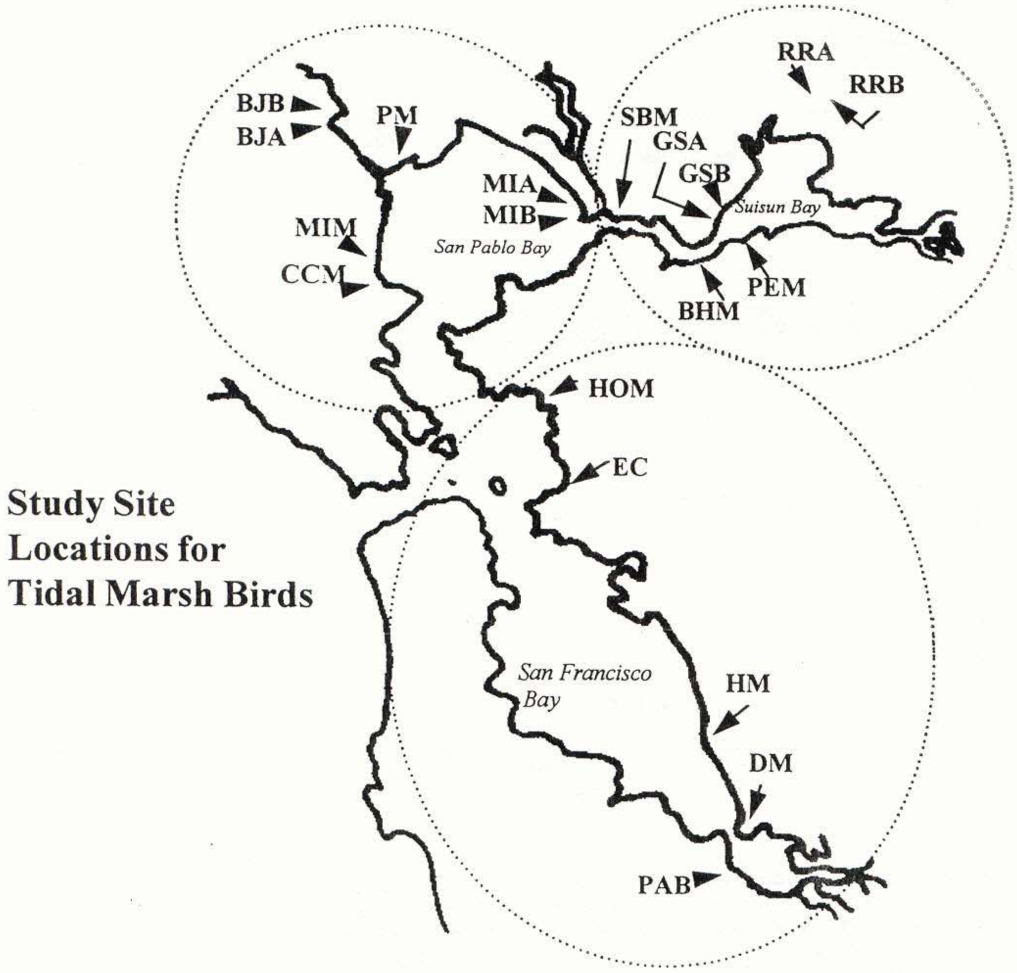


Figure 2. Distribution of study sites in the San Francisco Bay region. Codes for sites are defined in Table 1. See Table 2 and Appendix 1 for more details of sites.



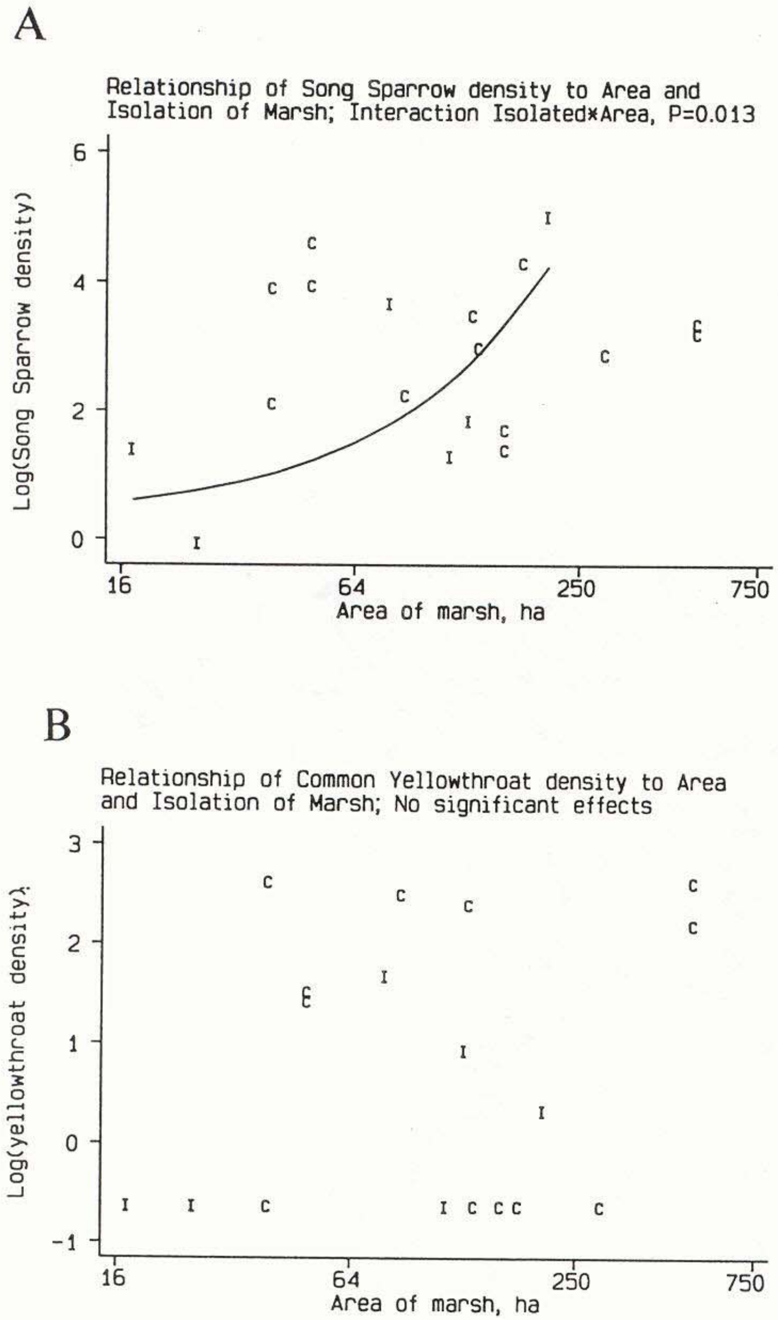


Figure 3. Relationship of density in each marsh (birds per hectare, log-transformed) in relation to area of marsh (hectares) and isolation of marsh (I = Isolated, i.e., > 1 km to nearest adjacent marsh; otherwise, C = Connected). Each symbol (I or C) indicates one marsh. Note log-scale for Area. A) Song Sparrows. Effect of Marsh Area, NS; Effect of Marsh Isolation, NS; Interaction of Isolation and Area, P = 0.013. That is, effect of Area is stronger in Isolated than in Connected Marshes. Line of best fit (density vs. area) is shown for Isolated Marshes only (P = 0.061, for regression coefficient). B) Common Yellowthroats. Effect of Marsh Area, NS; Effect of Marsh Isolation, NS; No significant interaction between Marsh Area and Marsh Isolation, i.e., effect of marsh area is statistically similar in isolated as in connected marshes.

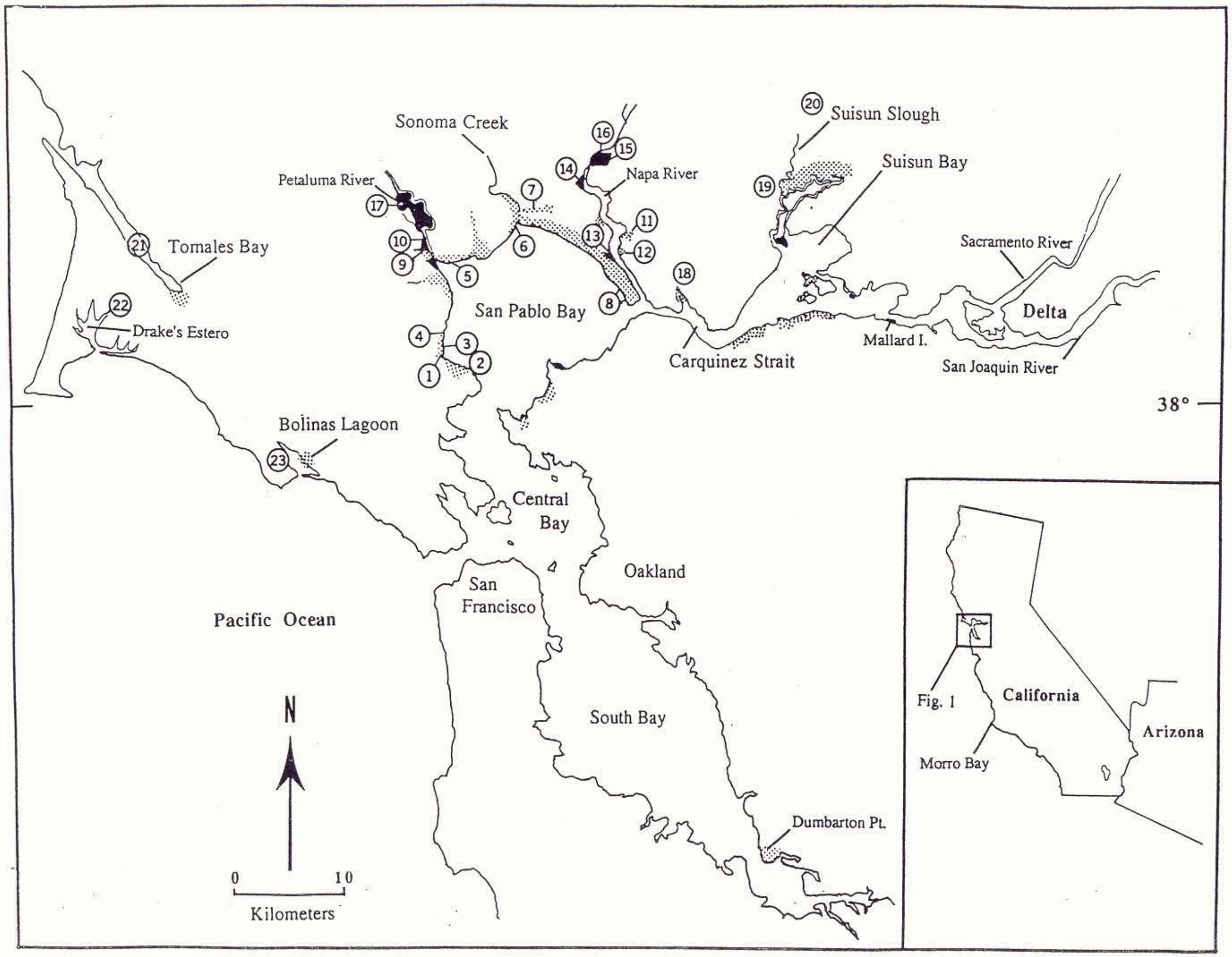


Figure 4. California Black Rail Survey: distribution of study sites. Numbers correspond to sites listed in Table 14.