DISTRIBUTION AND ABUNDANCE IN RELATION TO HABITAT AND LANDSCAPE FEATURES AND NEST SITE CHARACTERISTICS OF CALIFORNIA BLACK RAIL *(Laterallus jamaicensis coturniculus)* IN THE SAN FRANCISCO BAY ESTUARY

FINAL REPORT
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EXECUTIVE SUMMARY

We conducted surveys for California Black Rails (*Laterallus jamaicensis coturniculus*) at 34 tidal salt marshes in San Pablo Bay, Suisun Bay, northern San Francisco Bay and western Marin County in 2000 and 2001 with the aims of: 1) providing the best current information on distribution and abundance of Black Rails, marsh by marsh, and total population size per bay region, 2) identifying vegetation, habitat, and landscape features that predict the presence of black rails, and 3) summarizing information on nesting and nest site characteristics. Abundance indices were higher at 8 marshes than in 1996 and earlier surveys, and lower in 4 others; with two showing no overall change. Of 13 marshes surveyed for the first time, Black Rails were detected at 7 sites. The absolute density calculated using the program DISTANCE averaged 2.63 (± 1.05 [S.E.]) birds/ha in San Pablo Bay and 3.44 birds/ha (± 0.73) in Suisun Bay. At each survey point we collected information on vegetation cover and structure, and calculated landscape metrics using ArcView GIS.

We analyzed Black Rail presence or absence by first analyzing differences among marshes, and then by analyzing factors that influence detection of rails at each survey station. Comparing marshes, the two most important factors were area of the marsh (positively associated with Black Rails) and the proportion of surrounding land that was urban (negative association). To analyze presence or absence of rails at the level of the individual survey station, we developed logistic regression models for Black Rail presence considering only local habitat variables (vegetation composition and structure) and only landscape variables, as well as a combined model. Among all points and marshes, rails responded positively to the density of vegetation below 10 cm in height and positively to the proportion of pickleweed (*Salicornia virginica)*, rushes (*Juncus* spp.) peppergrass (*Lepidium latifolium*), alkali bulrush (*Scirpus maritimus*) and cattails (*Typha* spp) within 50 m of each survey point; they responded negatively to the average vegetation height. At the landscape scale they responded positively to the amount of marsh in the surrounding 250 m, the size of the core area of the marsh (interior area of a marsh more than 50 m from a marsh edge), and negatively to the distance to the nearest large (100 ha) marsh and to distance to water. Black Rails responded both to local vegetation characteristics and to broader landscape features, but presence or absence at

the local scale was better predicted by vegetation characteristics than by landscape characteristics. Our data indicate that Black Rails prefer marshes that are close to water (bay or river), large, away from urban areas, and saline to brackish with a high proportion of *Salicornia, Scirpus maritimus, Juncus* and *Typha*.

We found 26 Black Rail nests at 5 study sites between 1998 and 2001, more nests than have been documented in previous studies. We estimate that at least 23% fledged young. Nests were found in a variety of substrates: pickleweed, alkali bulrush, salt grass (*Distichlis spicata)* and gumplant (*Grindelia stricta)*. Preliminary analyses suggest that Black Rails nest preferentially in pickleweed over other short species, and tall vegetation such as alkali bulrush, over pickleweed, when available. Vegetation density around nests was higher than that in random plots. The period of greatest nesting activity was from early April to May, although active nests were observed in mid-March and mid-July in 2001.

We recommend that nest monitoring of Black Rails continue in order to better estimate nesting success and the factors that influence it. In particular, information is required to establish whether the type of marsh preferred by Black Rails is one that promotes successful reproduction and survival. Land managers seeking to acquire existing tidal marsh habitat, or to improve or restore habitat for Black Rails should consider that: (1) Large marshes in areas with less urban development are more likely to benefit Black Rail populations than smaller marsh fragments in urban areas. (2) Management practices that promote dense vegetation, especially that of *Salicornia* and *Scirpus maritimus*, or, in more brackish areas, *Juncus* and *Typha*, should be encouraged, as should assessment of tidal marsh vegetation itself.

INTRODUCTION

The majority of California Black Rails (>90%) are found in the tidal salt marshes of the northern San Francisco Bay region, primarily in San Pablo and Suisun Bays (Manolis 1977, Evens et al. 1991). Smaller populations occur in San Francisco Bay, the Outer Coast of Marin County, freshwater marshes in the foothills of the Sierra Nevada and in the Colorado River Area (Trulio & Evens 2000). Loss of greater than 80% of historic tidal marsh habitat, and habitat fragmentation and degradation have directly and indirectly impacted this and other tidal marsh breeding species (Goals Report 1999). Although there are few historic records of Black Rail presence and abundance in the Bay, recent survey efforts indicate that the species is absent from some marshes in the northern Bay region and that population sizes may be low enough to cause concern (Evens et al. 1991, Nur et al. 1997). The California Black Rail is a State of California Threatened Species and a Federal Species of Management Concern.

Our objectives were to:

- Determine the presence or absence of Black Rails at a comprehensive array of marsh sites with and without previous survey efforts
- Estimate abundance and absolute density at these sites
- Estimate average abundance indices and average densities for the three regions studied: San Pablo Bay, Suisun Bay and the Outer Coast.
- Estimate population sizes for these regions
- Develop regression models relating Black Rail presence during the breeding season to a series of variables at multiple spatial scales, including vegetation structure and composition, distance to tidal channels and various types of habitat edge, marsh patch size and configuration and surrounding land use characteristics.
- Determine the timing of nesting and the proportion of nests that were successful
- Describe nest and nest site characteristics

We confined these surveys to the northern part of the San Francisco Estuary and the Outer Coast, due to the lack of documented breeding in south San Francisco Bay (Trulio and Evens 2000).

STUDY SITES

We surveyed 31 tidal marshes in San Pablo Bay, Suisun Bay, northern San Francisco Bay and western Marin County in 2001 and 14 in 2000 (Fig. 1, Table 1). Many sites had been surveyed previously by Evens (Evens et al. 1991, Nur et al. 1997, Evens and Nur in press), but there are no available records of surveys at 13 sites, including several restoration sites and smaller tidal marsh fragments in eastern Marin County and in northern Alameda County (i.e. Hoffman and Emeryville Crescent). Most sites were mature tidal marsh, but we also included several restoration sites: Petaluma River Marsh ("Carl's marsh," Sonoma County), Greenpoint ("Toy property" across the river from Petaluma River Marsh, in Marin County) and Pond 2A in the Napa-Sonoma marsh complex. We surveyed one muted marsh at Lower Tubbs Island and a diked marsh at Goodyear Slough.

We searched for Black Rail nests at the following sites in San Pablo Bay: China Camp State Park, Black John Slough on the Petaluma R., and Petaluma Rivermouth (outboard of the Sonoma Baylands restoration site). In Suisun Bay the nest study plots were: Rush Ranch and Benicia State Park (Figure 1).

METHODS

<u>Population Surveys</u>

Surveys were conducted during the breeding season between May 3-June 15, 2000 and April 18-May 29, 2001. Surveys were conducted following a standardized tape call-back/response protocol (Evens et al. 1991, Nur et al. 1997). The protocol involves listening passively for 1 minute after arriving at the listening station, then broadcasting tape-recorded black rail vocalizations: 1 minute of "grr" calls followed by 0.5 minutes of "ki-ki-krr" calls. The surveyor then listens for another 3.5 minutes for a total of 6 minutes per listening station. At each station, Black rails heard calling <30° apart were considered the same bird, and those >30° apart were considered different birds. We also recorded rails calling spontaneously outside the survey period; these detections were not used to calculate abundance indices at points but were used in some cases to classify a marsh as rail habitat if it would have otherwise have not been considered rail habitat.

We established 1 to 20 survey stations in each marsh, depending on marsh size. In the smallest marsh fragments there was only enough room for one point. In several marshes many of these stations were previously established by Evens et al. (1991), including Petaluma Marsh, China Camp, Benicia, Bolinas, Tomales Bay. In other marshes we surveyed from points we established for landbird point count surveys (Nur et al. 1997). Survey stations were placed at least 100 m apart but in most sites they were 200 apart, as was the case for landbird point count stations.

A black rail abundance index (birds detected/ha) was calculated using all detections within 30 m. Because Black Rails have been estimated to move toward the observer before vocalizing an average of 6.2 m (Evens and Page 1985, Nur et al. 1997, *contra* Legare et al. 1999), it is assumed that the effective survey area is of radius 36.2 m. Thus we calculated the abundance estimate based on a 36.2 m radius, but used detections within 30 m.

We used DISTANCE software v 3.5 (Buckland et al. 1993, Thomas et al. 1998) to determine the probability of detecting vocalizing Black Rails for the 2001 data. The best-fitting detection probability model was used to estimate absolute densities at individual sites and to calculate a regional mean density. We calculated the ratio of abundance index (based on number of rails detected per area) to absolute density as estimated by DISTANCE; this ratio corresponds to the fraction of birds detected in the survey area given that they were present (detectability), p. Note that number of birds detected per area = p x true density of birds per area, where p is the probability of detecting a bird given that it is present. Thus to convert an apparent abundance index to true density one can simply multiply the former by $1/p$. We used this approach (use of correction factor $1/p$) to obtain abundance adjusted for non-detection, as well its associated standard errors; the standard errors were then used to calculate population size ranges.

We calculated regional population sizes as a function of density and the area of tidal and muted marsh (Marshall and Dedrick 1994). We calculated population estimates based on the two-sided 90% confidence interval of the density. Two-sided 90% confidence intervals are especially useful because they can readily be used to establish one-sided 95% intervals. For example, one may be interested in establishing that Black Rail density is at least X birds per ha, with 95% certainty, or that the density is no greater than Y birds per ha, with 95% certainty, depending on management concerns.

We collected the following information in the field at each survey point: UTM coordinates; distance to closest channel and its width; within a 50 m radius plot centered on each survey point: the proportion of marsh vegetation, channels, ponds; distance to the closest tidal channel and its width; the relative proportion of cover for each plant species; the number of times vegetation contacted a ¼" dowel at 5 points within the plot at 10 cm height intervals from the ground (stem counts), and the maximum vegetation height. See Table 5 for a complete list of habitat and vegetation variables analyzed.

For each survey point location, we used ArcView GIS 3.2a and extensions, Spatial Analyst and Patch Analyst (Rempel 2000) to derive a set of landscape parameters characterizing that point and the surrounding marsh. GIS data for bayland habitats were obtained from the San Francisco Estuary Institute's (SFEI) EcoAtlas GIS (version 1.50b4).

For characterizing upland habitats, we derived a composite land use layer for the San Francisco Bay area consisting of the most recent 1:24000 land use maps from the Department of Water Resources (1993-1999) where available, and 1:24000 land use maps from the USGS Midcontinent Ecological Science Center (1985) elsewhere. Landscape parameters analyzed are listed in Table 5.

To identify local habitat and landscape features that may influence the presence of Black Rails, we conducted two types of analyses. In the first group of analyses, we compared presence/absence among marshes, where each marsh was scored 0 or 1 depending on whether Black Rails were detected at any survey station within a marsh. Marshes were then compared with respect to their site-wide characteristics (e.g., average percent pickleweed cover). For this analysis we used logistic regression (Hosmer & Lemeshow 1989) to develop multi-variable models, using Stata 6.0 (StataCorp. 1999).

In the second group of analyses, we analyzed the patterns of presence or absence of Black Rails at individual survey stations in relation to local habitat (including vegetation structure and composition) and landscape features. We also examined each bay separately to determine if the same factors were responsible in San Pablo and Suisun Bays. We also examined patterns associated with within-marsh differences in Black Rail presence. We used forward and backwards stepwise logistic regression to develop the following models with multiple independent variables: 1) a model with vegetation and other local habitat variables (but no landscape metrics), 2) a separate model for landscape metrics only and 3) a combined model. All variables retained in the final models were significant at the level of $P < 0.05$.

Nest finding and monitoring

In 1996, PRBO established 4 plots for monitoring tidal marsh bird nesting behavior in San Pablo Bay and Suisun Bay (Nur et al. 1997), with an additional site added in San Pablo Bay in 1999 (Figure 1). Due to the elusive behavior of Black Rails, nests are extremely difficult to find using parental behavioral cues. Nests are usually very well-concealed beneath marsh vegetation. We found most nests accidentally during the course of looking for other species' nests. Once we found a nest, we noted the contents and placed a flag at least 10 m away to aid in finding the nest again. We checked nest contents every 3 to 7 days. We were concerned that checking nests more often would cause an increase in the chance of predation or abandonment. Black Rails are precocial and the young leave the nest within 24 hours of hatching (Baicich & Harrison 1997), which makes it difficult to determine if eggs hatched. We assumed a nest was successful if it was active for a period of 17-20 days and if the nest was empty and intact on the final visit. We often found eggshell fragments in and near the nest, and if they showed no evidence of yolk (an indication of predation), we assumed the nest was successful. If shells were strewn about near the nest or the nest was otherwise untidy, we assumed the nest had been depredated. If parents gave distress calls near a nest that appeared to have possibly fledged or we heard peeping young, we considered that nest successful.

After the outcome was determined (and after several weeks had passed if a nest was successful, to minimize disturbance to chicks) we collected the following data at the nest site: nest dimensions and height from ground, type of nest support and cover vegetation, height of vegetation and distance to the closest tidal channel and its width. At a subset of nests and at randomly chosen points (in 1999: clustered around a randomly placed point in the marsh; in 2000: placed 30 m from the nest in a random direction) we collected information about vegetation and marsh features within a 5 m radius. This information included: the proportion of marsh vegetation, channels, ponds, bare ground and open water; the relative proportion of each plant species; at the nest and at 4 points 1 m from the nest: the number of times vegetation contacted a ¼" dowel at 10 cm height intervals from the ground (stem counts), and the maximum vegetation height. See Table 10 for a complete list of habitat and vegetation variables analyzed for nests. We characterize nest characteristics and surrounding microhabitat using information collected at each nest and compare microhabitat characteristics of nests with random points to determine possible microhabitat or vegetation preferences. Here we provide descriptive statistics only; sample size did not allow for carrying out statistical tests.

RESULTS

Population surveys

Of 34 sites surveyed, rails were detected at 22 (64.7%) sites and were absent at 12 (35.3%; Table 1). There were no detections at small marsh fragments in Marin County, Goodyear Slough managed marsh, Petaluma River Marsh and Greenpoint restoration sites, Richardson Bay, and Hoffman and Emeryville Crescent marshes in Northern Alameda County. Rails were heard spontaneously calling outside survey periods at Richardson Bay and Petaluma River Marsh. Tomales Bay was the only site where rails were not detected in 2000 and 2001, but were present in earlier surveys (Evens et al. 1991, Nur et al. 1997).

We heard the most rails in San Pablo Bay at Day Island, Black John Slough and nearby Greenpoint centennial marsh, Petaluma Marsh and Lower Tubbs Island muted marsh, and in Suisun Bay at Benicia State Park and Rush Ranch. We detected a moderate number of rails at China Camp, Corte Madera Ecological Marsh, Petaluma Rivermouth (outboard Sonoma Baylands), Pond 2A, Fagan Slough, Pt Pinole, San Pablo Creek marsh, and in Suisun Bay at Peyton Slough, Hill Slough and Grey Goose.

Abundance indices were lower than in earlier surveys at some sites and higher at others (Table 2). Of marshes with the highest densities in 1996 or earlier, abundance was lower in 2000 and 2001 at Day Island and Petaluma Marsh, but similar at Black John Slough. Abundance was also lower in 2001 than earlier surveys at Bolinas Lagoon and Mare Island. Abundance was higher at China Camp and at Lower Tubbs muted marsh. Overall, comparing 2000/01 surveys with 1986-1996 surveys, abundance indices were higher at four sites, lower at eight sites, with two sites showing no trend, and Hamilton Shore (McInnis marsh North) consistently showing no rails during the entire survey period (Table 2).

Of the thirty four sites surveyed, eighteen were sites where surveys have either not been previously conducted (n = 13) or no previous survey results have been reported (n = 5). At seven of the 18 sites, rails were detected, with two marshes demonstrating relatively high abundance (Greenpoint centennial and Tubbs Island muted marsh). Of the 13 new sites, five were small marsh fragments; no rails were detected at any of these sites.

Mean rail abundance index in San Pablo Bay was 0.757 birds detected/ha (95% CI = 0.516 – 0.998), compared to 0.708 rails detected/ha in Suisun (95% CI = 0.338 – 1.078); this difference is not significant (Table 3). In contrast, for the Outer Coast, mean abundance index was 0.13 birds detected per hectare, which lies outside the 95% CIs for San Pablo and for Suisun Bays.

Densities calculated using DISTANCE were markedly higher than abundance indices (Table 3); the average ratio of density to abundance index was about 4 to 1 (3.47:1 in San Pablo Bay and 4.86:1 in Suisun Bay). These results imply that only about 25% of Black Rails present in the surveyed area were actually detected ($p = 0.29$ and $p = 0.21$, respectively). Mean density in San Pablo Bay was estimated to be 2.63 birds/ha and in Suisun was 3.44 birds/ ha; the difference between these two densities was not significant (Table 3). There were insufficient sample points to analyze density in the outer coast separately. The overall mean abundance indices by region were lower than those calculated in 1996 by 39% to 50%, but this is due partly to the fact that more marshes were surveyed in 2000/01 and more of those marshes had no birds detected. Considering only marshes that were surveyed in both 1996 and 2000/01, the difference in abundance indices was only 28% to 38%, for Suisun and San Pablo Bays, respectively (Table 3).

We estimated that San Pablo Bay had 15,000 Black Rails, the highest Black Rail population in the Bay region in 2001 (range 11,000 – 19,000 birds, based on the 90% confidence interval of the adjusted abundance indices; Table 4). We estimated that there were 12,000 Black Rails in Suisun Bay region (range 6,700 to 17,200) and 280 Black Rails in the outer coast marshes (range 2 – 606 birds).

Habitat and Landscape Variables: Comparisons among Marshes

To examine the importance of local habitat and landscape variables we first analyzed factors determining presence or absence of rails, comparing among marshes. For these analyses we excluded Goodyear Slough, a marsh not subject to full or muted tidal action and Petaluma River Marsh, an early restoration site. We first examined local habitat (including vegetation) and landscape variables, analyzed one at a time, using logistic regression. The two most significant variables were area of marsh (positive; see Figure 2A; Likelihood Ratio Statistic [LRS] = 19.11, df = 1, $P < 0.0001$) and the amount of urban area within 500 m of the survey point (negative; see Figure 2B; LRS = 14.94, df = 1, $P = 0.0001$). The smallest marshes never contained rails and the largest marshes always had rails present. With regard to urbanization, no rails were detected at marshes that were highly urbanized, while marshes with no urban areas within 500 m of the survey point always had rails. Among landscape variables, also significant were amount of urban area within 250 m, within 1000 m, and within 2000 m of the survey point; amount of marsh area within 250 m, within 500 m, within 1000 m, and within 2000 m; and core area of the marsh. Among local habitat variables, only two were significant: vegetation structure (number of stems) above 30 cm height (LRS = 6.36, df = 1, $P = 0.012$) and height of Grindelia (LRS = 5.76, df = 1, $P = 0.016$). However, height of Grindelia was only determined as part of vegetation surveys conducted in 2001 (not in 2000) and was not defined for marshes without Grindelia. As a result data on this variable could only be analyzed at 15 marshes. Note that the percent cover of Grindelia was not significantly associated with Black Rail presence.

We then developed multi-variable models, to statistically account for Black Rail presence or absence, using stepwise logistic regression. The final model had two variables: marsh area and amount of urban area within 500 m of the survey point (Table 6). Each was significant while controlling for the effect of the other variable. After inclusion of these two variables, no other variables were significant, whether landscape or local habitat variables.

Habitat and Landscape Variables: Comparisons among Survey Stations

To complement analyses among marshes, in the next group of analyses we examined variation in presence or absence of rails among survey stations. Thus these analyses subsumed variation among marshes as well as within marshes, at a small geographic scale (stations were generally 200 m apart within a single marsh).

The following habitat variables were significant as predictors of Black Rail presence in single variable logistic regression models: percent cover of *Juncus, Lepidium latifolium,* *Salicornia, Scirpus maritimus* and *Typha*. A final model with multiple independent variables included the following : (+) number of stems under 10 cm, (-) maximum vegetation height; and the proportion of *Grindelia*, *Juncus, Lepidium, Salicornia, Scirpus maritimus* and *Typha* (Table 7). All these variables were still significant when controlling for differences between bays (using San Pablo and Suisun Bay data only).

Next we looked at landscape predictors of Black Rail presence evaluated on a point by point basis. The following variables were significant when examined individually: (-) distance to nearest 100 ha marsh; (-) proportion of urban habitat within both 250 and 500 m; (+) proportion of marsh within 250 and 500 m. The following variables were significant when all six variables were included in a multi-variable model: (-) distance to water, (-) distance to nearest 100 ha marsh, (-) marsh size; (+) core area, (+) shape index and (+) proportion of marsh within 250 m (Table 7). Note that in the multivariable model there is a positive relationship to core area (which is correlated with total marsh area), but that once one controls for core area, the effect of total area is negative. In other words, black rails are more likely to be present where core area is large relative to total area and, conversely where total area is small relative to core area.

We then developed a statistical model predicting Black Rail presence with combined landscape and local habitat variables. However, the best predictive "combined" model turned out to be the same as the local habitat model (Table 7). That is, no landscape variables significantly improved the statistical model when local habitat (i.e., vegetation) variables were included in the model.

We then looked at factors predicting Black Rail presence *within* a marsh, by statistically controlling for differences in these factors among marshes. For San Pablo Bay marshes, rail presence was strongly associated with proximity (measured in km) to water edge (β = - 7.53, S.E. = 2.19, P = 0.001; model statistics: Pseudo R^2 = 0.2278, P = 0.0004). No other landscape or local variables were significant. In Suisun Bay marshes, the significant variable was a different one: Black Rail presence was associated with the amount of marsh habitat (ha) within a 250 m radius of the survey points (β = 0.433, S.E. = 0.172, P = 0.012; model statistics: Pseudo R^2 = 0.2621, P = 0.011).

Nest monitoring

More than 26 Black Rail nests were found by chance during the search for nests of other species, and in several instances, by searching vegetation in areas of high Black Rail vocal activity. Twenty-three nests were found while active, and the outcomes of 20 were relatively certain (Table 8). At least 6 the nests were presumed successful, but up to 6 more could have also been successful. The corresponding success rate was 23 - 46 %. Some nests were abandoned, and in San Pablo Bay this may have been due to tidal flooding because the eggs were covered with fine silt. Tidal flooding is also responsible for approximately 10% of Samuel's Song Sparrow nest failures at our San Pablo Bay study sites (Chan et al. 2001).

The earliest Black Rail nest seen with eggs was on March 20, 2001 at China Camp. Recent fledglings were seen on April 20, 2001, at Petaluma Rivermouth, which corresponds to a clutch completion date of no later than March 31. The latest active nests were observed in mid-July in 1999 and 2001 at Black John Slough. Most nests were found the first 2 weeks of April, often around April 10. This is probably the start of the nesting season for most pairs. In 1999, 2 rail nests were discovered sequentially 5 m apart, which we assumed were 2 attempts by the same pair. It is unknown whether Black Rails commonly have multiple nesting attempts per year.

Complete vegetation measures were collected from only one Black Rail nest from Suisun Bay, so our observations are applicable primarily to nests in San Pablo Bay. Nests were found in a variety of plant substrates (Figure 3). Most nests found were in pickleweed, or a combination of pickleweed and alkali bulrush or salt grass.

The average nest height was 12.35 cm (Table 9). Nests were often placed very close to the ground, especially when built in pickleweed. Nests in pickleweed were generally covered completely by vegetation from all but one direction, which was probably the entrance. However, some nests built in stands of vertical alkali bulrush were very similar to those of other open-cup nesting birds (e.g. Common Yellowthroat, Song Sparrow), with a more central placement in a vegetation clump. Nests were built of rough pickleweed stems or alkali bulrush leaves without a fine lining and usually of the same material as the nest substrate. The walls on one nest built in alkali bulrush and saltgrass were interwoven with the surrounding vegetation so that the grass formed walls and a roof.

Habitat characteristics and vegetation composition in the area surrounding the nest differed from that in random non-use sites, but sample sizes were too small to test these differences statistically (Table 10). Rails appeared to be selecting for areas with denser and/or taller vegetation for their nest sites, as indicated by the larger number of stem hits (an index of vegetation height and density) above 10 cm at the nest itself and above 40 cm at the sample points in the surrounding 5 m the nest than in non-use sites. Vegetation height at the nest also appeared to be higher than at the non-use sites. Where alkali bulrush was present, it appeared that nests were more likely to be found there than in lower vegetation, including pickleweed. However, in areas without alkali bulrush, Black Rails seemed to select areas with higher pickleweed cover for nesting. Common marsh plants found in lower proportions at nest sites than in non-nest sites included saltgrasss, *Jaumea carnosa*, peppergrass and California cordgrass (*Spartina foliosa)*. The latter is an indicator of low marsh elevation, assumed to be a counter-indicator of Black Rail presence (Nur et al. 1997), but not found to be significant in our analyses of Black Rail survey data.

DISCUSSION

Comparison of Black Rail detections in 2000/01 with earlier surveys by Evens and colleagues (Evens et al. 1991, Nur et al. 1997, and Evens & Nur in press), indicated no marked trends comparing the 1980's, 1996, and 2000/01. At some marshes detections increased, at some they decreased. Marshes with rails detected in the 1980's or 1996 still had rails detected in 2000/01, with a single exception: Tomales Bay. Similarly, marshes without rails in earlier surveys still had no rails. There is thus no evidence for local extirpation of Black Rails, nor any evidence that Black Rails colonize vacant marshes. However, this study is the first to report results of Black Rail surveys at eighteen sites, seven of which had rails. Thus, it is not known whether the seven marshes with detections in 2000/01 had rails in the 1980's or 1990's.

The overall density estimate obtained by Nur et al. (1997), derived from 1996 surveys and using the program DISTANCE, was 3.10 birds/ha, which is very similar to the density estimates obtained here (2.63 birds/ha in San Pablo and 3.43 birds/ha in Suisun, yielding an unweighted mean of 3.03 birds/ha). This provides further indication of no net population change from 1996 to 2000/01.

Evens and Nur (in press) derived population estimates for each region: 289 rails in the Outer Coast marshes, 7,100 in San Pablo Bay and 7,200 in Suisun Bay. These estimates were based on 1) density estimates obtained by DISTANCE (see above), 2) abundance indices (described in Nur et al. 1997), 3) an estimate of tidal marsh habitat acreage, and 4) an estimate of the proportion of suitable habitat. Estimates presented here utilized components 1), 2), and 3). If one were to take into account component 4), then the two population estimates are similar. We have not tried to estimate the proportion of suitable habitat at this time, but the results presented here (for landscape and local habitat factors influencing Black Rail presence) can help refine the definition of "suitable habitat", for use in subsequent GIS-based population estimation.

Use of distance-sampling (e.g., program DISTANCE) to estimate density, and ultimately population size, is preferable to relying solely on the number of birds detected during surveys (e.g., Evens et al. 1991). But results presented here and in Nur et al. (1997) demonstrate that only 1/3 to 1/4 of Black Rails are detected during surveys. Nevertheless, there are several pitfalls to accurate estimation of density, due to inherent variability in Black Rail survey data. Firstly, the rate of Black Rail vocalizations has been shown to depend on where in the breeding cycle the pair is, tide, weather and moon phase (Spear et al. 1999). In addition, it is difficult to estimate distance from observer to calling bird accurately both because the bird is rarely seen and because their calls are often muffled or seem to emanate from multiple locations, as though the bird is a ventriloquist. Another factor is observer ability in detecting calls and estimating distance.

We used DISTANCE-sampling to estimate detectability and density, but results can be biased if distances are poorly estimated, or if there is significant movement away from or towards the observer. Evens et al. (1991) and Legare et al. (1999) have shown that Black Rails tend to move toward the observer before responding to tape-recorded calls, on average of 6-8 m. We plan to model the effects of movement towards observers and determine the impacts on density estimates.

Analyses presented here, with regard to factors influencing Black Rail presence/absence focused on two geographic scales: variation among marshes, and variation among individual survey stations, both within and across marshes. With regard to variation among marshes, two landscape variables were especially good predictors: marsh size and percent urbanization. This information can be very useful to managers and agencies in identifying priority sites to protect for, or survey for, Black Rails. This information can also help inform the design of restoration projects by identifying sites that will likely have Black Rails once restoration is complete, or at least underway. Finally, such information will help us better estimate total population size, by identifying marshes, throughout San Pablo and Suisun Bays that are suitable for Black Rails.

At the finer scale, this study demonstrated several factors that are responsible for variation in Black Rail presence among survey stations. These factors include specific vegetation types, vegetation density and height, amount of marsh in the surrounding 250 ha, and distance from water (bay or river). Our experience in the field, finding Black Rail nests and hearing vocalizations in consistent areas throughout the breeding season, leads us to believe that their territories are often small (certainly less than 100 m in diameter). Analyses we have conducted with other tidal marsh species (Alameda, Suisun and San Pablo Song Sparrow, Salt Marsh Yellowthroat and Marsh Wren; Nur et al. 2001; Stralberg et al. 2001) indicate that both local habitat (vegetation type and structure) and landscape factors (surrounding land use from 250 on up to 2000 m areas, size and shape of marsh, etc.) can be important, depending on the species. The Black Rail in particular seems to respond to vegetation type and structure (the proportion of various plant species and vegetation density below 10 cm). Once local habitat variables were considered, landscape factors did not contribute significantly to explaining variation among survey stations. Thus, at the smallest scale, roughly that of the home range of a Black Rail, vegetation characteristics predominate in explaining the presence or absence of rails. Nevertheless, the landscape statistical model presented (Table 7B) can still be useful for situations in which detailed vegetation information is not available.

We found more Black Rail nests than previously reported by San Francisco Bay researchers, and this data may contribute to knowledge of the timing of breeding and nest site selection. Although our sample sizes are small, we are beginning to gain an understanding of the types of vegetation in which nests are most likely to be built, although the data may be biased because we may be finding the most poorly concealed nests. We have found nests in pickleweed, and combinations of pickleweed and other vegetation, including alkali bulrush, or alkali bulrush alone. Our preliminary examination of vegetation characteristics around nests indicates that rails are selecting for their nest sites areas with denser and/or taller vegetation. We plan to examine these relationships statistically when we have a larger sample size.

We assume that all rails detected during the breeding season surveys attempt to breed within the vicinity of the station at which we detect them, but we don't know if they are able to breed successfully there. A sample size of at least 20 active nests per marsh is recommended to determine the rate of nesting success at that site (Nur et al. 1999), and our sample size is well under 20 per marsh. Without these data we cannot say if a particular marsh is good Black Rail breeding habitat; a marsh with high rail abundance could very well be a population sink (Pulliam 1988). In addition, a sample size of at least 20 nest and 20 non-nest sites is recommended to statistically model habitat selection, or determine relationships between habitat parameters and nest success (Nur et al. 1999). We routinely collect GPS coordinates at nest sites, and we plan to use this information in the future, when sample sizes are higher, to examine the relationship between nest success and nest placement at the landscape scale (e.g. distance to upland edge).

Conclusions

Our preliminary conclusions are that Black Rails are sensitive to marsh size and appear to be absent from small fragments. There is a strong disassociation with urbanization, but the mechanisms that are responsible for this pattern are not yet identified. We conclude that Black Rails prefer marshes that are saline to brackish and have high cover of *Salicornia, Scirpus maritimus, Typha, Lepidium latifolium* and/or *Juncus* (all but the first are found in more brackish conditions; *Lepidium*, an invasive non-native plant, is found predominantly in higher elevation marsh areas with lower rates of tidal inundation); have a high density of plant stems or leaves within 10 cm of the ground (such as *Salicornia* or a mixture of *Salicornia* and *Scirpus*); are near water (a bay or river); are large and far from urbanization; and are close to other large marshes.

While there is evidence that Black Rail presence is associated with the above habitat characteristics and landscape features, the ecological significance of this association is unknown. For example, we do not know if survival and productivity are enhanced in marshes that share these characteristics, compared to other marshes. Nest-monitoring of Black Rails is a means to obtain such information, but, as noted above, larger sample sizes will be needed in order to identify factors that promote Black Rail reproductive success.

We have several recommendations for further study. Firstly, we recommend increased effort towards studies of Black Rail nesting success and nest site characteristics, to determine factors that promote reproductive success and hence, population stability. We also recommend that surveys for Black Rails be conducted at a wide range of marsh types in the San Francisco Bay including muted, managed and restoration sites so that factors associated with Black Rail presence in those areas can be better studied. Our sample size of these marsh types was small, although larger than in most other regional studies. There are additional factors we did not study, but merit attention, which may influence the distribution and abundance of Black Rails: marsh elevation, food availability, predator abundance and the levels of environmental contaminants. Although we found a positive relationship between rails and non-native *Lepidium latifolium*, we did not find nests in this plant species; the effects of the spread of *Lepidium* on Black Rails and other marsh birds should be studied, because as it spreads other vegetation beneficial to wildlife is crowded out. Likewise, the effects of invasive *Spartina* species, in particular *S. alterniflora*, should be investigated, although at this time there is limited invasion by the latter species in prime Black Rail habitat in the north bay.

We have several preliminary recommendations for land managers seeking to acquire existing tidal marsh habitat, or to improve and restore other bayland habitats for Black Rails:

1. Large marshes in areas with less urban development are more likely to benefit Black Rail populations than smaller marsh fragments in urban areas.
2. The best marsh configuration would maximize the amount of marsh in the surrounding area as well as maximizing core marsh area, i.e. marsh edge should be minimized. All else being equal, marshes should have a circular or square shape rather than a long narrow shape. Other landscape-level factors to consider are distance to water (shorter the better) and proximity to other large marshes (the closer the better).

Restoration schemes, or tidal management practices promoting dense vegetation, including *Salicornia* and *Scirpus maritimus*, or in more brackish areas, *Juncus* and *Typha*, should be encouraged. The diked or managed salt marshes we are familiar with do not have the necessary vegetation density.

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FIGURE 1. Sites surveyed for California Black Rails, 2000-2001. Nest plots are indicated with arrows. CC = China Camp, RM = Petaluma Rivermouth, BJ = Black John Slough, SB = Benicia State Park, RR = Rush Ranch. Abundance index categories shown are for surveys in 2001, or 2000 if survey was conducted that year only. See Table 1 for names of survey sites indicated by numeric labels.

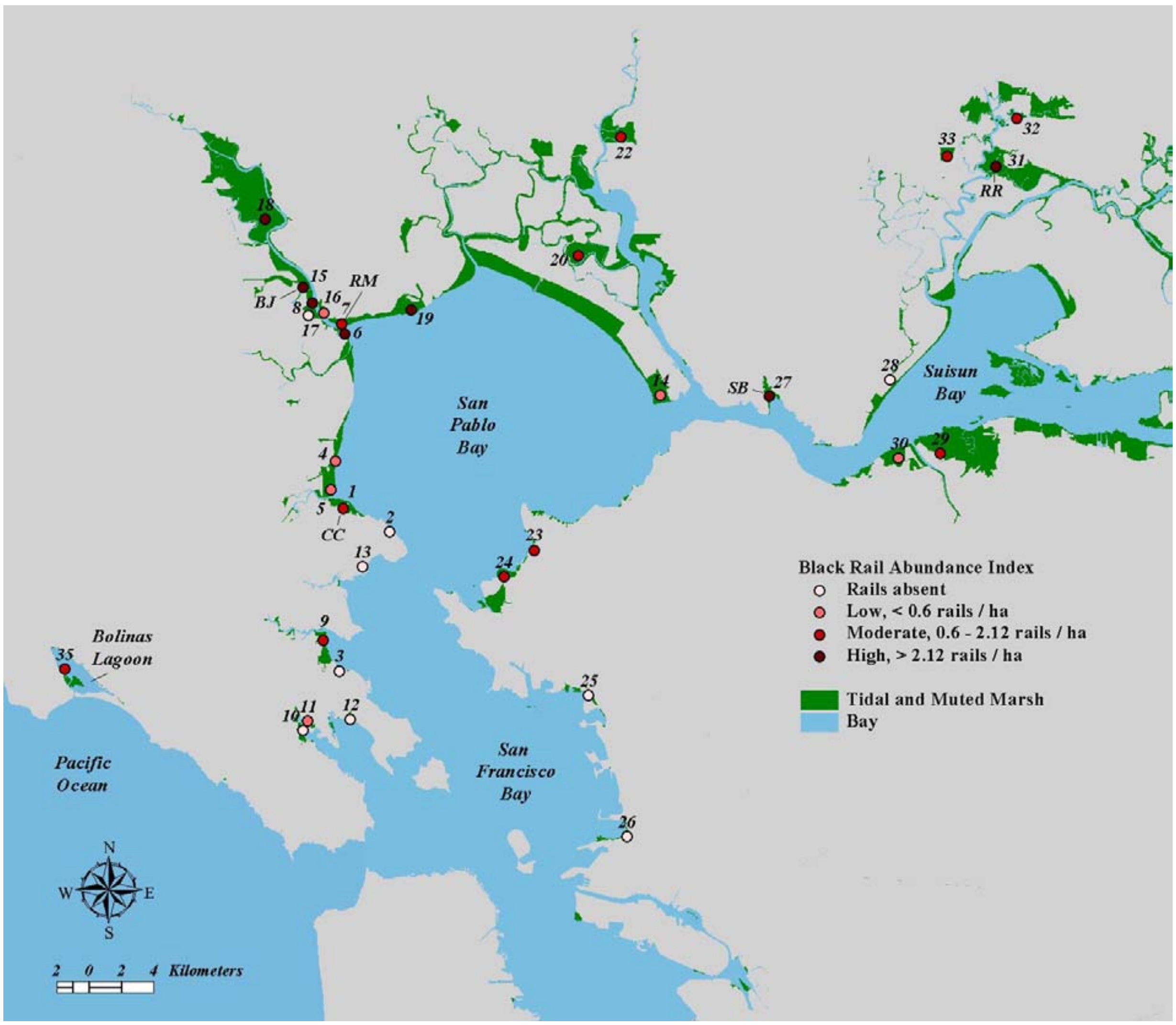
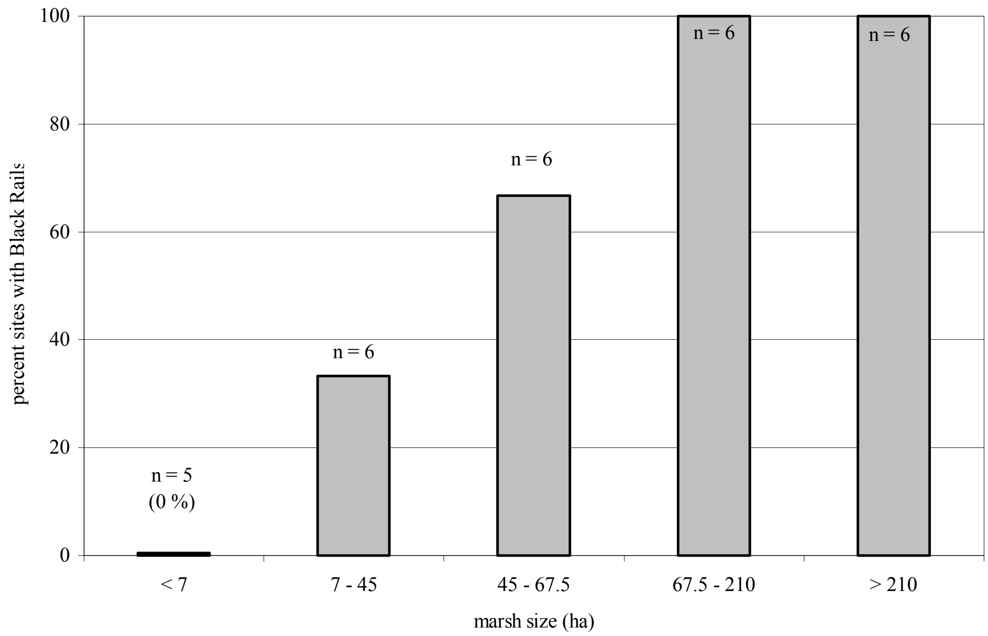


FIGURE 2. Relationship between Black Rail presence at a marsh and significant marsh attributes determined by logistic regression. The percent of sites with Black Rails within each size category is indicated, where n = the number of marshes in that category.

A. Marsh size



B. Mean area of urban land use within 500 m of survey points.

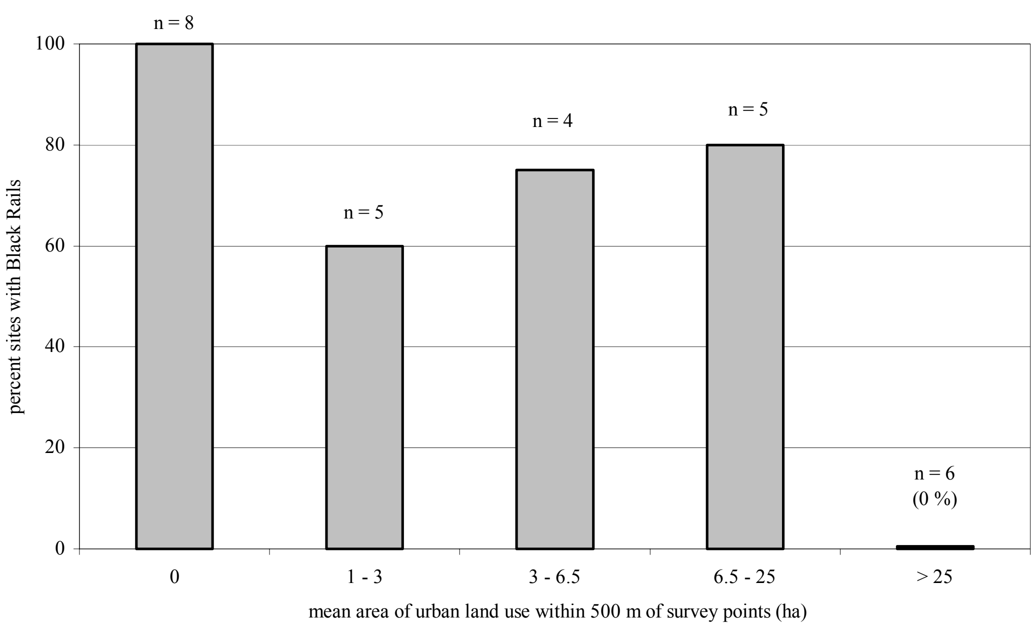


FIGURE 3. Plant substrate for Black Rail Nests found in1996-2001, San Francisco Bay region. CC = China Camp, RM = Petaluma Rivermouth, BJ = Black John Slough, SB = Benicia State Park, RR = Rush Ranch

TABLE 1. California Black rail abundance indices (1986-2001 surveys), abundance rank and estimated absolute density (2001 surveys only). Density was calculated using DISTANCE software (see text). Abundance ranking for 2001 surveys, and 2000 if 2001 not conducted: low <0.25, mod = 0.25-0.9, high >0.9 birds detected/ha. - = no data. * = rails not detected during survey but detected at another time during the breeding season (site ranked as "low").

Site	Map Ref	Marsh area (ha)	Abund 1986 [1]	Abund 1988 [2]	Abund 1996 [2]	Abund 2000	Abund 2001	N 2001	S.E. 2001	Abund Rank	Density ± S.E.2001
SAN PABLO BAY											
China Camp	1	94.3	0.35	0.12	0.10	0.37	0.58	29	0.23	Mod	2.41 ± 1.06
China Camp fragments	2	0.84	-	-	-	-	0	2	0	Absent	0
Triangle marsh	3	5.02	-	-	-	-	0	1	0	Absent	0
Gallinas Creek (McInnis)	4	271.38	0.12	0.07	0.88	1.28	0.24	10	0.24	Low	1.00 ± 1.02
Hamilton Shore (McInnis N)*	5	271.38	-	0.00	0.00	0	-	-	-	Low	-
Day Island	6	67.59	4.95	-	-	2.22	0.91	8	0.44	High	3.74 ± 1.98
Sonoma Baylands (Petaluma R. Mouth)	7	114.65	-	1.22	2.89	0.81	-	-	-	Mod	-
Petaluma R. marsh (Carl's Marsh)*	8	19.83	-	-	-	-	0	7	0	Low	0
Corte Madera/Muzzi	9	104.65	0	-	-	-	0.29	10	0.29	Mod	1.03 + 1.13
Richardson Bay*	10	41.95	0	-	-	0	0	6	0	Low	0

Site	Map Ref	Marsh area (ha)	Abund 1986 1	Abund 1988 2	Abund 1996 2	Abund 2000	Abund 2001	N 2001	S.E. 2001	Abund Rank	Density + S.E.2001
Travelodge fragment	11	2.37	-	-	-	-	0	1	0	Absent	0
Harbor Cove fragment (Tiburon)	12	4.13	-	-	-	-	0	1	0	Absent	0
Beach fragment (Marin)	13	1.32	-	-	-	-	0	1	0	Absent	0
Mare Island Pt. (E)	14	186.51	-	0.90	0.85	0.20	0.24	20	0.17	Low	1.00 + 1.02
Black John Slough	15	27.85	4.25	1.53	2.89	2.01	2.82	6	1.16	High	11.65 + 5.31
Greenpoint Centennial	16	29.79	-	-	-	-	2.42	6	0.88	High	11.98 + 4.44
Greenpoint restoration (Toy)	17	23.28	-	-	-	-	0	4	0	Absent	0
Petaluma Marsh	18	1108.11	5.66	2.04	-	-	1.27	19	0.50	High	5.25 + 2.32
Lower Tubbs muted marsh	19	100.26	-	-	-	0.49	1.61	6	1.98	High	6.66 + 3.59
Pond 2A	20	210.91	-	-	-	-	0.81	9	0.40	Mod	3.33 + 1.79
Fagan Slough*	22	177.46	-	2.06	3.84	0.97	-	-	-	Mod	-
Point Pinole S	23	9.28	-	-	-	-	0.69	7	0.45	Mod	0.25 + 0.52
San Pablo Creek (Richmond)	24	60.69	-	-	-	-	0	8	0	Mod	0
Hoffman Marsh	25	13.62	-	-	-	-	0	3	0	Absent	0

Site	Map Ref	Marsh area (ha)	Abund 1986 [1]	Abund 1988 [2]	Abund 1996 [2]	Abund 2000	Abund 2001	N 2001	S.E. 2001	Abund Rank	Density ± S.E.2001
Emeryville Crescent	26	33.73	-	-	-	-	0	4	0	Absent	0
SUISUN BAY											
Southampton/Benicia State Park	27	65.98	-	0.58	1.65	0.20	1.28	17	0.47	High	11.87 ± 7.00
Goodyear Slough	28	33.76	-	-	-	-	0	10	0	Absent	0
Point Edith	29	414.59	-	-	-	0	0.80	6	0.81	Mod	8.33 ± 9.17
Bullhead Marsh (Peyton slough)	30	205.70	-	-	-	-	0.24	10	0.24	Low	2.74 ± 2.90
Cutoff Slough (N)Rush Ranch	31	478.97	-	0.65	0.85	-	0.97	10	0.54	High	10.11 ± 7.24
Hill Slough	32	20.20	-	-	1.31	-	0.40	6	0.40	Mod	4.73 ± 7.89
Grey Goose Fragment	33	61.43	-	-	-	-	0.81	6	0.81	Mod	8.33 ± 9.17
OUTER COAST											
Tomales Bay (S)*	34	61.85	1.06	1.38	0.95	0	0	19	0	Low	*
Bolinas Lagoon	35	65.92	0.20	1.10	0.75	0.57	0.27	18	0.18	Low	*

1 Evens et al. 1986; 2 Nur et al. 1997.

TABLE 2. Comparison of 1986/1996 surveys and 2000/01 surveys.

A) Sites surveyed in 1986/96 and in 2000/01.

Total number of sites	**Number of sites showing increase from 1986/96 to 2000/01**	**Number of sites showing decrease from 1986/96 to 2000/01**	**Number of sites showing no overall change from 1986/96 to 2000/01**
14	4 (29%)	8 (57%)	2 (14%)

B) Sites surveyed in 2000/01 with no previously reported surveys.

Total number of sites	**Sites at which rails detected**	**Sites at which no rails detected**
18	7 (39%)	11 (61%)

TABLE 3. Regional Black Rail abundance and density estimates for Bay regions, 1996 and 2001[1]. The weighted mean abundance index was calculated by averaging individual point station abundances. Estimated absolute density was calculated with program DISTANCE, by averaging site-level densities weighted by number of points per site.

Bay	Mean Abundance Index ± S.E. 1996	Weighted Mean abundance index ± S.E. 2001 for sites surveyed in 1996 and 2001	Weighted Mean abundance index ± S.E. 2001	Estimated Absolute Density ± S.E. 2001	Number of sites surveyed 2001
San Pablo Bay	1.25 ± 0.345	0.769 ± 0.178	0.757 ± 0.123	2.63 ± 1.05	21
Suisun Bay	1.43 ± 0.320	1.027 ± 0.299	0.708 ± 0.189	3.44 ± 0.73	6
Outer Coast	0.46 ± 0.196	0.131 ± 0.091	0.131 ± 0.091	-	2

1 Averages do not include surveys conducted in 2000, Petaluma River Marsh restoration site or two central San Francisco Bay sites surveyed in 2001. For sites surveyed in 1996 and 2001, see Table 1.

TABLE 4. Northern San Francisco Estuary regional Black Rail population estimates, based on 2001 survey data. Population size calculated as density estimates (from DISTANCE program) multiplied by the total area of tidal marsh (Marshall and Dedrick 1994). Population size range based on 90% confidence intervals (see text).

Bay	Area of Tidal marsh, ha (Marshall & Dedrick 1994)	Weighted Mean abundance index ± S.E. 2001	Density Estimate	Point estimate Black Rail population size (Area x Density)	Range Black Rail Population Size 2001
San Pablo Bay	5695	0.757 ± 0.123	2.62	14,960	10,960 – 18,960
Suisun Bay	3477	0.708 ± 0.189	3.44	11,960	6,710 – 17,220
Outer Coast	543	0.130 ± 0.091	0.52	282	2 – 606

TABLE 5. List of the independent variables explored for relationship to Black Rail presence using logistic regression. The point scale data were collected in the field. Landscape metrics were generated using ArcView 3.12 (see methods).

POINT SCALE VARIABLES	
Distance to closest channel	Percent cover common plant species:
Width closest channel	*Baccharis pilularis*, coyote brush
Percent vegetation cover within 50 m	*Distichlis spicata*, salt grass
Percent channel cover within 50 m	*Frankenia salina*
Percent pond cover within 50 m	*Grindelia stricta*, gumplant
Number of stems below 10 cm	*Juncus* spp, rush
Number of stems 10-20 cm	*Lepidium latifolium*, peppergrass
Number of stems 20-30 cm…..etc	*Salicornia virginica*, pickleweed
Number of stems 60-100 cm	*Scirpus maritimus*, alkali bulrush
Number of stems >100 cm	*Scirpus acutus*, tule
Height of highest stem	*Spartina foliosa*, cordgrass
LANDSCAPE SCALE VARIABLES	
Distance to upland edge	Surrounding land use:
Distance to water edge	Proportion of marsh area within a radius of: 250 m, 500 m, 1000 m, 2000 m
Distance to nearest urban area	Proportion of urban area within a radius of: 250 m, 500 m, 1000 m, 2000 m
Distance to nearest 25 ha marsh	Marsh configuration:
Distance to nearest 50 ha marsh	• Perimeter/area ratio
Distance to nearest 100 ha marsh	• Shape index
Marsh size	• Fractal dimension
Core area (area >50 m from marsh edge)	

TABLE 6. Presence of Black Rails in relation to local habitat and landscape variables: analysis of marsh to marsh variation using logistic regression.

Dependent variable for all: presence or absence of Black Rails at each marsh, based on detections within 50 m of survey stations. All P values refer to Likelihood Ratio Tests.

Model statistics: Pseudo $R^2 = 0.591$, Log-likelihood = -7.471
LRS = 21.56, d.f. = 2, $P < 0.0001$

Independent variables (both considered simultaneously):

Area of Marsh (ha)	$\beta = 0.0341 \pm 0.0222$	$P = 0.017$
Urban area within 500 m (ha)	$\beta = -0.101 \pm 0.061$	$P = 0.040$

TABLE 7. Presence of Black Rails in relation to local habitat and landscape variables: analysis of survey point to survey point variation using logistic regression.

Dependent variable for all: presence or absence of Black Rails within 50 m of survey point. P value for individual variables is for Wald's Z.

A) Local Habitat Model.
Model statistics: Pseudo $R^2 = 0.1646$. Log-likelihood = -92.429
LRS = 36.43, d.f. = 8, $P < 0.0001$

Grindelia	$\beta = 8.19 \pm 3.43$	$P = 0.017$
Juncus	$\beta = 12.35 \pm 4.17$	$P = 0.003$
Lepidium	$\beta = 8.38 \pm 2.78$	$P = 0.003$
Salicornia	$\beta = 3.98 \pm 1.13$	$P = 0.000$
Scirpus maritimus	$\beta = 7.59 \pm 1.64$	$P = 0.000$
Typha	$\beta = 8.27 \pm 2.25$	$P = 0.000$
Stems under 10 cm	$\beta = 0.31 \pm 0.12$	$P = 0.012$
Maximum height, veg.	$\beta = -0.033 \pm 0.014$	$P = 0.018$

B) Landscape Scale Model
Model statistics: Pseudo $R^2 = 0.1019$. Log-likelihood = -114.016
LRS = 25.89, d.f. = 6, $P = 0.0002$

Independent variables (all considered simultaneously):

Distance to water	$\beta = -0.002 \pm 0.0009$	$P = 0.026$
Dist. to nearest 100 ha marsh (m)	$\beta = -0.0001 \pm 0.00004$	$P = 0.003$
Marsh size	$\beta = -0.030 \pm 0.010$	$P = 0.004$
Core area	$\beta = 0.033 \pm 0.012$	$P = 0.005$
Shape index	$\beta = 1.088 \pm 0.401$	$P = 0.003$
Area of marsh within 250 m (ha)	$\beta = 0.096 \pm 0.038$	$P = 0.011$

C) Combined Landscape and Local Habitat Model.

Identical to Local Habitat Scale model, above.

TABLE 8. Outcomes of California Black Rail nests, San Pablo and Suisun Bay, California, 1998 to 2001.

SITE	N	fledged	depredated	abandoned	unknown
1998					
Rush Ranch (RR)	1	0	0	0	1
1999					
China Camp (CC)	1	0	1	0	0
Petaluma R mouth (RM)	9	2	2	3	2
Black John Slough (BJ)	1	0	0	1	0
Benicia (SB)	1	0	0	1	0
2000					
China Camp (CC)	5	1	2	1	1
Petaluma R.mouth (RM)	3	2	1	0	0
Black John Slough (BJ)	3	1	0	1	1
2001					
China Camp (CC)	1	0	0	0	1
Black John Slough (BJ)	1	0	0	1	0
Total, All Years:	26	6	6	8	6

TABLE 9. Mean California Black Rail nest and nest substrate measurements.

Variable	Mean	S. D.	N
outside diameter (mm)	117.4	14.16	17
inside diameter (mm)	68.85	13.3	13
outside depth (mm)	67.13	22.21	15
inside depth (mm)	23.20	9.378	10
nest height (cm), ground to nest bottom	12.35	7.288	17
number of support branches	29.0	22.5	18
diameter of support branches (mm)	2.14	1.80	18
nest substrate height (cm)	68.94	29.47	18
nest clump height (m)	0.830	0.349	15
nest concealment (mean of visual estimates above nest and from 4 directions)	79.22	8.238	17

TABLE 10. Summary of vegetation measures collected within 5 m of Black Rail nest sites and randomly chosen points.

Variable	Black Rail nest sites			Random non-nest sites **		
	Mean	S.E.	N	Mean	S.E.	N
Distance to water	15.40	3.326	17	16.69	1.850	140
Width closest channel	1.85	0.569	17	2.40	0.272	136
Percent shrub cover	4.03	2.259	17	2.62	0.662	145
Percent vegetation cover	93.81	1.634	17	92.46	0.935	143
Percent open ground	3.26	0.861	17	2.43	0.240	143
Percent channel cover	2.65	1.446	17	4.42	0.810	143
Percent drift/debris	0.28	0.279	17	0.66	0.322	143
Percent open water	0.00	0.000	17	0.03	0.035	143
Average stem density <10 cm	3.40	0.323	17	3.29	0.176	145
Average stem density 10-20 cm	3.27	0.206	17	2.91	0.170	145
Average stem density 20-30 cm	1.81	0.215	17	1.98	0.160	145
*Average stem density 30-40 cm	0.91	0.231	9	0.63	0.216	7
*Average stem density 40-50 cm	0.53	0.208	9	0.11	0.059	7
*Average stem density 50-60 cm	0.38	0.184	9	0.00	0.000	7
*Average stem density 60-100 cm	0.51	0.315	9	0.00	0.000	7
*Average stem density >100 cm	0.11	0.089	9	0.00	0.000	7
Average stem density >30 cm	1.84	0.474	17	1.87	0.250	144
Average maximum vegetation height	39.83	6.102	13	39.92	2.339	145
Stem density <10 cm at nest	2.71	0.506	17	3.36	0.179	145
Stem density 10-20 cm at nest	3.88	0.624	17	2.80	0.169	145
Stem density 20-30 cm at nest	2.41	0.536	17	1.92	0.143	145
Stem density >30 cm at nest	2.47	0.814	17	1.70	0.511	144
Maximum vegetation height at nest	44.67	7.668	12	35.33	1.776	144
Average percent cover:						
Distichlis spicata	6.99	3.946	17	12.81	1.796	143
Frankenia salina	0.44	0.321	17	0.25	0.097	143
Jaumea carnosa	0.35	0.284	17	1.94	0.500	143
Juncus spp	0.31	0.309	17	0.63	0.518	143
Lepidium latifolium	0.01	0.015	17	2.51	1.065	143
Salicornia virginica	81.76	6.448	17	69.40	2.859	141
Scirpus maritimus	9.91	4.401	17	6.06	1.396	143
Spartina foliosa	0.09	0.074	17	1.43	0.516	143

* variables collected only in 2000 and 2001; non-use values for these variables were taken at point 30 m from a Black Rail nest

** data collected in 1999 at points randomly placed and clustered around point count survey points (see text).