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California Clapper Rail (*Rallus longirostris obsoletus*)
Population monitoring: 2005-2008

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Abstract

PRBO Conservation Science conducted call-count surveys for California Clapper Rail (*Rallus longirostrus obsoletus*) at 53 sites throughout the San Francisco Bay Estuary from 2005 through 2008. To maximize the spatial coverage of sites, surveys were coordinated with partners conducting call-count surveys (Avocet Research Associates, California Department of Fish and Game, California Coastal Conservancy's Invasive *Spartina* Project, and U.S. Fish and Wildlife Service) resulting in a total of 180 sites surveyed, covering all high-quality habitat and the majority of lower-quality habitat. We estimated annual site-specific density estimates using distance sampling and program DISTANCE and detected a negative short-term trend of -20.6% (±3.8%) from 2005 through 2008. There were no significant changes in densities from 2005 to 2006 or from 2006 to 2007. From 2007 to 2008, an Estuary-wide negative change was detected (-46.0%, ±6.75%) which was driven by a dramatic decrease in South San Francisco Bay (-57.4% ±5.0%).

We tested the power to detect a 10-year trend for five different monitoring scenarios and found that detecting an Estuary-wide negative trend of 13.9% or greater over a 10-year period with 80% power is possible under the current monitoring design (90 sites/year with effort allocated equally among sites). Power is improved when higher density sites are visited more often within a season and lower or zero density sites are visited less often. If effort is reduced to 45 sites/year, the minimum negative trend detectable is 19.9%, and for 30 sites/year (representing a bay region or group of restoration/treatment sites) the minimum negative trend detectable increases to 25.0% with 80% power. Detecting trends with 80% power at the "marsh complex" level (assumed to be a cluster of 6 marsh sites/year) is not be feasible over a 10-year period.

We also modeled Clapper Rail presence probability based on individual survey-point data. Models were driven primarily by salinity and proportion of wetlands within 1 km. The probability of Clapper Rail presence increased with wetland proportion up to 30% then decreased, while the effect of salinity on Clapper Rail presence was positive.

Ongoing monitoring in 2009 and 2010 will help determine if the drop in population from 2007 to 2008 is sustained. Analysis of the effects of invasive *Spartina* treatment and other potential environmental factors may help identify the causes of these population changes. Using data

from all sources (including East Bay Regional Park District and H.T. Harvey and Associates) we estimated a 2005-2008 minimum average population of 1425 ± 22 individuals.

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Introduction

From 2005 to 2008 PRBO Conservation Science (PRBO) and California Department of Fish and Game (CDFG) in collaboration with Avocet Research Associates (ARA), the California Coastal Conservancy's San Francisco Estuary Invasive Spartina Project (ISP), U.S. Fish and Wildlife Service (FWS), East Bay Regional Park District (EBRPD), and H.T. Harvey and Associates completed Estuary-wide call count surveys for the California Clapper Rail (*Rallus longirostris obsoletus*), hereafter Clapper Rail. The primary goal of these surveys was to assess the current population size and trends of the Clapper Rail. Interannual trends at multiple spatial scales will help identify factors associated with the Clapper Rail's continued survival.

Clapper Rails have been negatively impacted by a number of historic effects (e.g., loss and degradation of tidal marsh habitat and hunting) and ongoing effects such as pollutants, disturbance, and predation by non-native predators. Habitat alteration, such as the spread and subsequent control of non-native invasive cordgrass (*Spartina foliosa x alterniflora*), hereafter invasive *Spartina*, may also affect the rail's Estuary-wide population in a variety of ways. Sea level rise also has the potential to inundate Estuary marshes and drive the population down further. Numerous threats, combined with a small population size characterized by high annual variation, necessitate annual monitoring and critical assessment of threats in order to aid in the recovery of the species.

In this report, we provide an Estuary-wide population estimate, report on short-term trends (2005-2008) and interannual changes in abundance at different spatial scales, and analyze the power to detect population trends. We also provide an analysis of spatial patterns of Clapper Rail presence in relation to key landscape and habitat variables as well as recommendations for future monitoring and research.

Background

The California Clapper Rail is one of three subspecies of Clapper Rail recognized by the American Ornithologist's Union (AOU 1957) and is listed both state and federally as an endangered species. It occurs entirely within the San Francisco Bay Estuary and is dependent on tidal marsh habitat which has decreased over 80% from its historical extent (Goals Project 1999). Historically, the California Clapper Rail is thought to have been abundant in the Estuary, as "thousands" were reported to have been killed in a single day in

1859 for consumption in San Francisco and Sierra goldfields (Wilbur and Tomlinson 1976). Market hunting was arrested in 1913 (Wilbur and Tomlinson 1976) and California Clapper Rails began re-colonizing marshes in the first half of the 20th century (Grinnell and Miller 1944). The total California Clapper Rail population in the Estuary was first estimated in the 1970s at 4,200-6,000 birds (Gill 1979, Collins et al. 1994). Based on surveys from the mid-80s, the total population was placed at 1,200 to 1,500 individuals. In 1988 the population estimate dropped to 700 individuals and in 1990-91 the estimate dropped further to 300-500 (Albertson and Evens 2000). In the mid- to late-90s the population appeared to increase to an estimated 1,040 to 1,264 individuals (Albertson and Evens 2000). Predation by introduced red foxes (*Vulpes vulpes*) is blamed for the precipitous population decline in the late 1980s, and their ongoing control since then has been credited with the population's rebound (Harding et al. 2001).

Assessing the population status of Clapper Rails is made difficult by the Clapper Rail's secretive behavior and inconsistent and variable vocalizations. In addition, summarizing decades of surveys and assessing long-term trends is also difficult due to the spatial and temporal variation in survey effort and variation in methods used to collect and store data.

Methods

Field Surveys- Surveys by different partners were conducted for different reasons. Consequently, slightly different protocols were used (Appendix 1) but we believe these differences did not seriously affect our results. All of the surveys upon which this report is based were conducted between 19 December and 26 May from 2005 through 2008. All marshes ("sites") were surveyed 1 to 4 times per year (Table 1) by experienced, permitted biologists. Listening stations were primarily located at marsh edges, levees within and bordering marshes, boardwalks, boat-accessible channels within the marsh, and at 11 marshes in San Pablo Bay, within the marsh itself. Stations were placed 70 to 400 meters apart. Sites were located throughout San Pablo Bay (Pt. San Pedro and Pt. San Pablo east to Carquinez Bridge), South San Francisco Bay (San Francisco-Oakland Bay Bridge south), Central San Francisco Bay (Bay Bridge to Pt. San Pedro-Pt. San Pablo) and Suisun Bay (including Carquinez Straits) (Figure 1-3).

PRBO surveyed 53 sites using a call-count method (Type A-PRBO), with 10 minutes per listening station (Appendix 1). San Pablo Bay National Wildlife Refuge surveyed 5 sites using the same method. All Clapper Rails (as well as other rail species, including California Black Rail [*Laterallus jamaicencis coturniculus*], Virginia Rail [*Rallus limicola*], and Sora [*Porzana carolina*]) detected from a listening station were recorded along with the time, direction and distance from the listening station. The actual number of rails detected was recorded, or if the detection was not heard clearly because of confounding circumstances (e.g., distance from observer or environmental conditions) a range of number of rails (e.g., 1 to 2, 2 to 4) was recorded. If no Clapper Rails were detected within 200 meters of a listening station after 2 passive surveys, playback (up to 1 minute) of Clapper Rail vocalizations was used in an attempt to stimulate a response on a third survey. Playback surveys consisted of 5 minutes of passive listening (with no Clapper Rails detected), then 1 minute of playback followed by 4 minutes of passive listening. Clapper Rails detected during transit between listening stations as well as before or after the 10-minute listening period were also recorded, but not used in estimating densities based on distance sampling.

At a total of 99 sites, both ARA and ISP conducted Type A-ISP surveys, which differ from the Type A-PRBO surveys in that every detection of a single bird was recorded as a range of number of rails (e.g., a single "kek" was recorded as 1-2 Clapper Rails, assuming that the vocalizing bird may have a mate). Also, ARA utilized playback of rail vocalizations following the passive 10-minute period of the 3rd survey. At 7 sites, surveyors from ARA also employed a stationary method (Type B), remaining at a listening station for 30 to 120 minutes. ISP conducted presence-absence surveys (Type C) at 65 sites judged to have low potential for Clapper Rails (McBroom 2007). Playback of Clapper Rail vocalizations was performed during the first survey (and up to 2 subsequent surveys) if no Clapper Rail was detected passively in the first 5 minutes of the survey. Surveys were discontinued upon Clapper Rail detection. In Suisun Bay, DFG also performed Type C surveys, consisting of 10 minutes of passive listening at each station then up to 1 minute of playback of Clapper Rail calls followed by 1 minute of listening (Estrella 2007). Biologists at Don Edwards San Francisco Bay National Wildlife Refuge (DESFBNWR) used a similar method (Type D) at 11 narrow strip marshes with medium to high Clapper Rail densities, conducting 1 to 3 surveys with vocalization playbacks at each listening station. Sites were not resurveyed in the same season if a Clapper Rail was detected. FWS summarized the results of their surveys for use in this report. Surveys of Types A-D were conducted at a total of 178 sites, with more than one type of survey used at some sites in different years (Table 1 and Appendix 2).

H.T. Harvey and Associates provided Clapper Rail densities for six sites that they surveyed (Type H) without using a playback method (H.T. Harvey and Associates 2007). EBRPD also provided summarized data for 5 sites from 2005 that were surveyed using a combination of Type A and B methods (EBRPD unpubl. data).

Winter high tide surveys (Type E) were conducted by FWS and EBRPD at several South San Francisco Bay marshes; data from 2 of these marshes were included in this report (Table 1). During a very high tide, an airboat would traverse a marsh and refugia were examined for Clapper Rails, which were then counted. Airboat survey data were not used in the trend analysis.

Population Estimates- Our Estuary-wide population estimates are based only on sites surveyed during the 2005-08 period and represents 100% of high quality habitat and the majority of lower-quality habitat. Our estimate can be taken as a minimum. Estuary-wide Clapper Rail population estimates were developed in two different ways. In one method, the program DISTANCE (Buckland et al. 2001) was used to estimate Clapper Rail densities at all marshes with call count data (what we call "DISTANCE-derived"). Distance sampling helps to overcome the problem of a decline in detection probability of a bird with increasing distance from an observer (Thomas et al. 2002). Data from all visits to a listening station were used to create detection curves from which density for each site in each year was calculated. Only detections with a recorded distance or distance range were used. Detection distance ranges were averaged, and when detections were associated with a possible range of number of birds detected (e.g., 1 to 2 Clapper Rails), the lower estimate was used. Density estimates were not applied to sites where call count data were lacking or unavailable.

The other method of estimating population size (what we call "Observer-derived estimates") involved combining all unique detections recorded during a survey of a marsh, regardless of survey methodology and including birds detected outside the 10-minute survey periods at listening stations. This method does not account for the decline in detection probability of a bird with increasing distance from an observer. We used this method to incorporate data from a broader range of survey methods. This method may also be more suitable for comparing population estimates with historic surveys. If a range of individuals was recorded, the lower estimate was always used in order to be consistent with previous efforts to estimate population size and because methods varied for recording the upper range of individuals detected. At sites where marsh coverage at listening stations was greater than 75% (marsh coverage being the area within a 200-meter radius around each listening station), observers' survey results were used directly. At each site where coverage was less than 75%, detections within 200 meters of all listening stations for that site were used to calculate a density which was extrapolated over the entire site area. This method results in a likely slight underestimate of actual density. When multiple surveys of a site were conducted in one season, only the survey with the highest count of Clapper Rails for that site was used to calculate the population estimate.

To produce two complete and comparable population estimates (Observer-derived and DISTANCE-derived), winter high tide survey results and "summarized survey results" (count data summarized over the entire marsh site) were added to both estimates for remaining areas. Areas not covered by any surveys were not included in the total population estimate.

Trend Analysis- To analyze the between-year change in Clapper Rail density we used the DISTANCE-derived mean density estimates for each site in each year. We analyzed natural log-transformed mean density; a linear trend in log density implies a constant percent change in density over time (Nur et al. 1999). To account for differences in Clapper Rail density among sites, we controlled for the variation in density among sites as a "random effect." We then performed a mixed-effect linear regression using Stata 10.1 (StataCorp 2009) to fit a common slope for all sites (Estuary-wide trend) or for each region (San Pablo, Central and South San Francisco Bays). Suisun Bay was excluded because of the very low detection rate of California Clapper Rails in that region. The coefficients obtained were back-transformed into percent change per year. We calculated the standard errors of the back-transformed results as the geometric mean of two values: the estimate of the back-transformed "upper" S.E. (= $e^{(Y + 1\ s.e.)} - e^{Y}$) and the estimate of the back-transformed "lower" S.E. (= $e^{Y} - e^{(Y + 1\ s.e.)}$), where Y = the estimate from analysis on the log-transformed values. (Note that the back-transformed S.E.s are asymmetric). We used this approach for analyzing trend over the entire time period from 2005 to 2008, and for year-to-year changes.

Power Analysis- We performed a power analysis using the DISTANCE-derived density estimates and assessed the statistical power of various monitoring scenarios to detect trends over time. In general, as sample size increases, the ability or power to detect a population trend improves (i.e., a smaller trend can be detected). The analysis presented here seeks to evaluate the statistical power of the current study design and to provide guidance for future monitoring programs.

We estimated the magnitude of trend that could be detected by using the program MONITOR (Gibbs 1995). All trend values refer to annual trends, unless otherwise specified. MONITOR calculates the power associated with a trend by simulating a hypothetical dataset repeatedly (in this case, 1,000 iterations), based on a set of input values and allowing for stochastic variation in the data. For each iteration, the program calculates whether a statistically significant trend was detected given the simulated data. The proportion of trials resulting in a statistically significant result is the measure of statistical power (i.e., probability of detecting a significant trend, given such a trend exists in the data).

The program MONITOR calculates a trend for each sampling unit (using the mean and variability of the simulated data as described above) and then calculates an average trend across all sampling units. MONITOR allows for correlation of trends across units. We assumed that trends across listening stations displayed an intermediate degree of covariation; we reasoned that it is unrealistic to assume that trends for each station are identical across the study area. Thus, MONITOR picks a station-specific trend for each station with a specified mean value but with some variability around that trend specific to a station (i.e., some stations will demonstrate stronger trends than others, but the underlying mean trend is specified).

We investigated our ability to detect population trends under five monitoring scenarios over a projected period of 10 years (Table 2). We varied the level of “effort” (the number of sites surveyed or number of surveys per year at those sites), and we varied the distribution or allocation of those sites among 6 categories of Clapper Rail densities (zero to very low= 0 to 0.030 birds/ha, medium low= 0.031 to 0.128 birds/ha, medium= 0.129 to 0.225 birds/ha, medium high= 0.226 to 0.458 birds/ha, high= above 0.459 birds/ha. For the purposes of this analysis, each site contained the average number of listening stations (5.7). Scenario 1 represents our current effort and monitoring design (90 sites equally distributed among sites with a range of Clapper Rail densities and each surveyed three times per year). Scenario 2 represents a reallocation of our current effort. This scenario examines the improvement in the ability to monitor trends with more effort (more surveys) at high density marshes and less effort (30 very low density sites surveyed on a 3-year cycle of 10 sites per year) at low-density marshes. Scenario 3 represents a 50% reduction in effort (number of sites) but retains an equal distribution of sites varying in Clapper Rail density. Scenario 4 represents a 66% reduction in number of sites, to 30 sites, and also retains equal allocation of effort among sites in relation to rail density. This scenario examines the ability to detect trends in one bay region (e.g., South San Francisco Bay) or in one habitat (or treatment) type. Scenario 5 represents a 93% reduction in the number of sites to just 6 sites and examines the ability to detect trends at a complex level (e.g., within a National Wildlife Refuge or Ecological Reserve composed of multiple marshes).

Landscape Analysis- We used presence-only data from each listening station to develop a predictive model based on several environmental variables: point-level salinity and elevation; and the proportion of several land cover types (estuarine wetlands, all wetlands, high-intensity development, low-intensity development, and agriculture) within a 1-km radius area. Land cover data for 2001 were obtained from the NOAA Coastal Change Analysis Program (C-CAP; http://www.csc.noaa.gov/crs/lca/pacificcoast.html). Land cover grids (30 m) were used to develop continuous moving-window representations (proportion with a 1-km radius) of each land cover type of interest using ArcGIS Spatial Analyst. A 30-m summer salinity grid was generated by interpolating point data from three water quality monitoring data sources: the Integrated Regional Wetlands Monitoring Program (http://irwm.org/), the Department of Water Resources (http://www.iep.ca.gov/suisun/dataReports/index.html), and the San Francisco Estuary Institute (http://www.sfei.org/). We used a simple inverse distance-weighted algorithm (power = 2) within ArcGIS 9.2 to generate the interpolated salinity surfaces. For elevation we used the National Elevation Dataset from USGS (http://ned.usgs.gov/). We used a machine learning algorithm called Maxent (Phillips et al. 2006) to predict Clapper Rail distributions based on observed presence locations. Maxent is based on the principle of maximum entropy, and uses information about a known set of species occurrence points, compared with environmental background data, to develop parsimonious models of species occurrence. We allowed linear, quadratic, product, and hinge feature, and built the model on a random 75% of the presence data, reserving 25% for testing. We used an area-under-the-curve (AUC) statistic (Fielding and Bell 1997) to evaluate model predictive power.

Results

Population Estimate- We estimated the minimum total population size for the Estuary, based on a 2005 through 2008 average, to be 1,403 individuals using DISTANCE and 1,448 individuals using the observer estimate (Table 3). We estimated that about 57% of the total population exists in South San Francisco Bay, 33% in San Pablo Bay, 8% in Central San Francisco Bay and less than 1% in Suisun Bay and Carquinez Strait.

The largest population in Central San Francisco Bay is at Corte Madera Creek and the marshes immediately to the south (Corte Madera Ecological Reserve/Heerdt Marsh, Muzzi Marsh, and San Clemente Creek), with 96 (DISTANCE) to 102 (observer) California Clapper Rails (Appendix 2). Small populations (<10 individuals) exist in Bothin Marsh in Richardson Bay, Pickleweed Park in San Rafael, Emeryville Crescent, and Meeker Slough/Stege Marsh in Richmond.

Very small numbers (< 15 individuals) of Clapper Rails were detected in Suisun Bay and Carquinez Strait tidal marshes. Clapper Rails were detected at Benicia State Recreation Area, Point Edith marshes, Rush Ranch/First Mallard Slough, and along the strip marsh near the Reserve Fleet. A single individual was detected in 2008 in a managed marsh near Goodyear Slough. Clapper Rails were not detected at these sites every year.

The most populous site in San Pablo Bay was Gallinas Creek where we estimated an average of 244 (observer) to 251 (DISTANCE) Clapper Rails. Clapper Rails were detected at recently restored marshes on both the Petaluma River (Carl's Marsh and Sonoma Baylands restoration) and Napa River (Pond 2A). Clapper Rails have been documented breeding at Carl's Marsh (PRBO, unpubl. data). The Petaluma River from the Hwy. 37 bridge upstream to San Antonio Creek was estimated to support 52 (observer) to 70 (DISTANCE) Clapper Rails. A population of 37 (observer) to 52 (DISTANCE) Clapper Rails exists near the West Contra Costa County Sanitary Landfill, at the mouths of Wildcat Creek and San Pablo Creek.

In South San Francisco Bay, the Bair/Greco Island complex (including Bird Island and Belmont Slough) harbored an average of 197 (observer) to 216 (DISTANCE) Clapper Rails. San Leandro Bay had an average of 121 (DISTANCE) to 198 (observer) Clapper Rails with the majority at Arrowhead Marsh. Marshes in the Palo Alto area (Faber-Laumeister tracts, Palo Alto Baylands, and Palo Alto Harbor-Hooks Island) averaged 93 (DISTANCE and observer) Clapper Rails. Hayward Shoreline (Hwy. 92 north to the Tony Lema Golf Course in San Leandro) averaged 75 (DISTANCE) to 99 (observer) Clapper Rails. The estimated average population at Dumbarton Point was 36 (observer) to 71 (DISTANCE) Clapper Rails. The San Bruno-Colma Creek area averaged 18 (DISTANCE) to 69 (observer) Clapper Rails.

Trends- The Estuary-wide Clapper Rail population varied among years and showed an overall negative trend (-20.6%, P <0.0001) from 2005 to 2008 (Figure 4). The interannual changes in the Estuary-wide population were non-significant with the exception of an overall decrease (-46.0%, P <0.0001) from 2007 to 2008 (Table 4). From 2005 to 2008, the San Pablo Bay population decreased by 22.0% (P < 0.004; Figure 5 and Table 4) and South San Francisco Bay decreased by 22.2% (P <0.0001; Figure 6 and Table 4). Within each Bay region, the only significant interannual change occurred in South San Francisco Bay, where the population change from 2007 to 2008 was -57.4% (P <0.0001). Overall and interannual population changes in the Central Bay were either non-significant or could not be determined due to insufficient data (Figure 7 and Table 4).

We also found that Clapper Rail densities did not differ according to marsh area (P > 0.281); larger marshes and smaller marshes with at least two years of data and where California Clapper Rail were detected during at least one of the four surveyed years, had similar densities (Table 5).

Power Analysis- The ability to detect Estuary-wide trends in Clapper Rail density over a 10-year period varied among the five scenarios but was very good for Scenarios 1, 2 and 3, moderate for Scenario 4, and poor for Scenario 5. Given the current effort and site/visit allocation (Scenario 1), the minimum magnitude of a negative annual trend that could be detected with 80% power is 1.47% (13.8% for a cumulative 10-year trend; Table 6). The negative annual trend discernable with 80% power under Scenario 2 is 1.37% (12.9% cumulative) and represents a 5.4% absolute increase in power over Scenario 1 by re-allocating effort from lower-density sites towards higher-density sites. Reducing the field effort by half, Scenario 3, would allow a negative annual trend of at least 2.2% to be detected with 80% power (-19.9% cumulative). In Scenario 4, a ⅔ reduction in field effort (30 sites monitored per year), would only allow detection of a negative annual trend of at least 2.84% (25% cumulative). Scenario 5, representing the marsh complex-level (assumed to be a cluster of 6 sites surveyed per year), had very poor ability to detect trends with 80% power (10.0% annual and 170% cumulative). For each scenario, the power to detect negative trends is less than for positive trends of equal magnitude. This is because as the population decreases, an increasing number of stations will have zero detections, making further declines difficult to detect. This asymmetry is greatest in Scenario 5.

Landscape Analyses- Model predictive power for Clapper Rail presence was very good, with an area-under-the-curve (AUC) statistic (Fielding and Bell 1997) of 0.965 for the test dataset. The Maxent model predicted known rail locations with high accuracy (Figure 8). The model over-predicted in some areas that are unlikely to harbor Clapper Rails (e.g., Redwood Shores water pollution control plant, Charleston Slough flood control pond, industrialized San Francisco). The model successfully predicted high probabilities of Clapper Rail occurrence at known occupied sites that were not included in our model (e.g., LaRiviere Marsh, Ideal Marsh, Alameda Flood Control Channel, and Baumberg Tract). The presence of Clapper Rail was negatively associated with increasing proportions of both high-intensity (Figure 9a) and low-intensity development (Figure 9b) within a 1-km radius. Clapper Rail presence was positively associated with increasing salinity (Figure 9c). There was a negative association with surrounding agriculture proportion, although the variable did not contribute much to the model (Figure 9d). Clapper Rail responses to estuarine wetlands (Figure 9e) and all wetlands combined (estuarine + palustrine; Figure 9f were positive up to proportions of approximately 0.25, but exhibited negative responses at higher proportions of surrounding wetlands. Clapper Rail presence peaked at ~4 m above sea level, based on a coarse elevation dataset with low vertical accuracy (Figure 9g). Estuarine wetlands and salinity combined contributed over 88% of the model's predictive power.

Discussion

Population estimate- Collins et al. (1994) estimated 390-564 individuals (195-282 pairs) in San Pablo, Suisun, and west Central Bay from the 1992-93 surveys. In the same geographic area, we estimate 554 (observer) to 633 (DISTANCE) individual Clapper Rails for 2005-08. It would appear that the population over the last 15 years has remained stable or increasing. However, the way that the Collins et al. field data were collected and more importantly, how they were summarized, were different from methods in this report such that the two estimates may not be directly comparable. Our 2005-2008 Estuary-wide estimate of 1,403-1,448 individual Clapper Rails represents a minimum increase of 11% in the last decade from the next most recent Estuary-wide estimate from the mid- to late-90s of 1,040-1,264 individuals (Albertson and Evens 2000). Again, methods and sites surveyed were not identical.

Although Clapper Rail populations have certainly decreased from the tens of thousands of individuals that were estimated to inhabit the Estuary pre-1900s (USFWS 1984), estimates over the last 15 years suggest that Clapper Rails have probably not decreased and may have remained relatively stable or even increased through 2007.

Trends- The downward trend for 2005 to 2008 is very much driven by the negative change (-57%) from 2007 to 2008 in the South Bay, as 2005 to 2007 had little overall change Table 4). The population appeared relatively stable from 2005 to 2007. However, the decrease from 2007 to 2008 likely represents a true decrease in the Estuary-wide population and could be linked to a number of factors including extreme weather events, predation, heavy construction and pollutants (e.g., mercury contamination, the *Cosco Busan* oil spill, and raw sewage releases). Extreme weather events such as winter storms that coincide with extreme high tides can cause mortality due to exposure to the elements and exposure to predators (e.g., feral cats, foxes, raccoons, and raptors) as Clapper Rails are pushed to the marsh edge where little to no vegetative cover may occur (USFWS 1984). Anecdotal accounts from the White Slough marsh complex (Napa River) suggest that heavy construction in or adjacent to a marsh may account for changes in densities or occurrence there.

The most immediate factor that may have caused the observed decline in the Clapper Rail population is the ongoing control and removal (through chemical and mechanical means) of invasive hybrid *Spartina* (cordgrass). In high densities, invasive *Spartina* can alter the topography and hydrology of an entire marsh, clogging the channels that are important to Clapper Rails for foraging and nesting (Zaremba and McGowan 2004). However, non-native cordgrass can also be used by Clapper Rails for breeding and refugia from high waters and predators (Grijalva and Kerr 2006), as well as foraging habitat. Removal of invasive, non-native *Spartina* was predicted to reduce available habitat at some sites until re-vegetation by native marsh species occurred (Grijalva and Albertson 2005). From 2007 to 2008, the only significant change in Clapper Rail densities (-57%) occurred in the same region (South San Francisco Bay) as the majority of invasive *Spartina* control efforts. In San Pablo Bay where invasive *Spartina* control was minimal, the change in density from 2007 to 2008 was not significant ($P>0.3$). However, both regions suffered similar overall declines despite the unequal level of invasive *Spartina* control between the two regions. Both San Pablo Bay and San Francisco Bay declined by 22% ($P<0.004$ and $P<0.0001$, respectively) from 2005 to 2008. Annual site-specific data on the extent and efficacy of invasive *Spartina* control from 2005-2008 are necessary to draw meaningful conclusions about the impacts of invasive *Spartina* control on the Clapper Rail population. It is possible that a larger Clapper Rail population was sustained by large amounts of non-native cordgrass, and cumulative effects from several years of invasive *Spartina* control may be a contributing factor to the 2007 to 2008 decline, It is also possible that non-native cordgrass attracts dispersing Clapper Rails, and that the birds have lower breeding success in invasive Spartina (Evens et al. *In press*).

Cumulative effects from other factors in prior years may also play a role in the decline of Clapper Rail populations. Without comprehensive studies on all aspects of the population dynamics of Clapper Rails in all marshes, including both uninvaded marshes and non-native *Spartina* invaded ones in both San Pablo Bay and San Francisco Bay, there will remain a large degree of speculation as to the causes of any population fluctuations (USFWS 1984, Evens et al. *In press*). Poor nest success over a number of years could lead to a sudden population decline. Research from the 1990s implicated predation and environmental contamination as major causes of Clapper Rail nest failure (Schwarzbach 2006). Also, reproductive success may be reduced in invaded marshes as they often lack the diversity of age structure and channelization typical of long-occupied marsh habitats (Evens et al. *In press*). Additional research into the breeding ecology, together with population monitoring and radio telemetry studies which examine immigration and emigration rates, will be needed to establish root causes of population decline and inform the recovery of California Clapper Rails.

Monitoring Strategies- Scenario 1 provides adequate estimation of Clapper Rail population trends at the Estuary level and gives equal allocation to sites with zero to low-density, allowing potential colonization of unoccupied sites by Clapper Rails to be detected. Scenario 2 provides the best ability to detect trends and interannual changes in population at the Estuary level. However, fewer surveys at sites with zero to low density lead to a decreased ability to detect colonization or extirpation at those sites. Small, low-density sites contribute less to an Estuary population estimate than higher density sites, and are more likely to be extirpated (Begon et al. 1990, USFWS 1984). Scenario 3 suggests that a reduction in effort to 45 sites annually will be adequate to monitor Estuary-wide trends. Scenario 4 suggests that it will be possible to monitor trends in different regions (e.g., San Pablo Bay), habitats, or treatments (e.g., *Spartina* control sites) that include at least 30 sites. Scenario 5 suggests that it will not be feasible to monitor trends at groupings of 6 sites (or less)—equivalent to a marsh complex such as Tolay Creek (5 sites) or Palo Alto (7 sites)—using call-count methodology.

Landscape analyses- Model results are consistent with what is known about Clapper Rail habitat associations, although potential correlation among variables limits the interpretation of these results. The negative association with landscape-level urbanization in our models has been demonstrated by others (Foin et al. 1997). Clapper Rails are heavily impacted by predators associated with human development, including rats, foxes, raccoons and feral cats (Albertson 1995, Collins et al. 1994, USGS unpubl. data.). The positive influence of estuarine wetlands up to 30% cover within 1 km is also consistent with this observation, as are numerous habitat fragmentation studies (e.g., Soulé et al. 1987). The rail's negative association with landscape-level wetland cover above 30% was likely due to the relatively low number of presence locations in the diked and managed wetlands of Suisun Bay, which were not differentiated from tidal wetlands in the land cover layer used for this analysis. The relationship with salinity was primarily positive, reflecting the observed restriction of this species to salt marshes, although the response curve was not monotonic, possibly a result of the coarseness of the salinity estimates, as well as the influence of other variables not captured by the spatial data layers used. For example, the area from the Carquinez Straits west to Sonoma Creek (Mare Island marshes, Boxer Marsh, and Sonoma Creek mouth east) is identified as a having a probability of occurrence 0.21 to 0.80. These bayfront strip marshes have low channelization and Clapper Rails are unlikely to be present in substantial densities (Collins et al. 1994). Also, the east side of Sonoma Creek mouth is heavily impacted by recreational fishing and denuded of suitable vegetation cover along Sonoma Creek.

Recommendations

Based on our results, we provide the following recommendations for Clapper Rail monitoring and research. Specific monitoring recommendations will depend in part on objectives (e.g., assessing rail response to management at an individual marsh will require a different method than if the objective is to detect a regional trend). The power analyses in this report were aimed at describing our ability to detect regional and Estuary-wide trends over a 10-year period under varying levels of effort, spatial extent and design. Other objectives such as determining year-to-year trends at smaller spatial scales or assessing the impact of restoration or other site-specific actions will require more intensive methods.

Population Monitoring

- Develop a funding strategy for a coordinated Estuary-wide monitoring program for Clapper Rails designed to meet the main objectives stated in the Recovery Plan

(USFWS 1984).

- Annual monitoring at the current level should continue in order to capture the full range of “normal” population fluctuations.
- At a minimum, continue Bay-wide annual monitoring (≥45 sites Estuary-wide) such that Clapper Rail response to *Spartina* control can be adequately assessed.
- Increase effort (visits) at high density sites and reduce effort at low density sites to more effectively detect trends over 10 years.
- Use territory mapping or stationary counts if population estimates or trends are needed for individual sites or marsh complexes (≤6 sites).
- Survey previously un-surveyed marshes that are predicted in Maxent to have a moderate to high probability of occurrence (e.g., Petaluma Marsh, Boxer Marsh, American Canyon wetlands, and Mare Island marshes).
- Survey Arrowhead Marsh (a high-density site) using standardized call-count methods (3 visits during January-March).
- Survey Suisun Bay marshes using standardized call-count methods (repeat visits to sites in consecutive years even after detections; use of permanent listening stations).
- Survey Coon Island, Gallinas Creek and other regional centers of high Clapper Rail abundance annually.
- Survey Wildcat Marsh, San Pablo Creek, and other isolated sites with low protection.

Research and Data Management

- Assess the effects of invasive S*partina* treatment on Clapper Rail populations by analyzing the relationship between annual site-specific changes in rail numbers and annual, spatially explicit changes in invasive *Spartina* abundance and density.
- Assess the importance of vegetation, channels, wetland type, and elevation using improved GIS layers to be developed by various agencies including USGS, San Francisco Estuary Institute, PRBO, and UC Berkeley, in 2009-10.
- Conduct further studies on the breeding ecology of Clapper Rail, especially reproductive success and habitat requirements for nesting success.
- Assess the ability of passive call counts (A and B: transect and stationary) to detect rails by coordinating surveys with telemetry studies and analyzing the detection rates of marked individuals.
- Assess potential effects of the *Cosco Busan* oil spill on Clapper Rails by analyzing

differences in population trends among marshes with varying degrees of impact from the spill.

- Assess effects of heavy construction on Clapper Rail densities and detectability, noted by Clapper Rail researchers anecdotally.
- Determine long-term Clapper Rail population trends (1970s to present).
    - Integrate current and historic survey data from various survey types (e.g., high tide airboat, stationary, playback, and passive surveys).
    - Develop statistically adjusted density estimates based on survey method.
- Use the California Avian Data Center to manage Clapper Rail data from multiple partners, allow partners to determine levels of data sharing, and to facilitate analyses using diverse databases.

Tables

Table 1. Sites surveyed from 2005 to 2008 by Bay with map identification number (for Figure 1), PRBO site code, site area in hectares, and survey type (Appendix 1).

Site Name	Map #	Site Code	Site Area (ha)	Survey Type
Central San Francisco Bay				
Lower Corte Madera Creek	21	CMCL	10.1	A, C
Corte Madera Creek Mouth	20	CMCM	2.7	A
Upper Corte Madera Creek	19	CMCU	5.3	A
Creekside Park	17	CRPA	7.8	A
Greenbrae Boardwalk	16	GBBW	4.2	A
Heerdt Marsh	15	HEER	31.5	A
Larkspur Ferry Cove	14	LARK	0.7	C
Muzzi/Marta's Marsh	12	MUZZ	58.0	A
Boardwalk Number 1	11	PIPE	14.4	A
Emeryville Crescent - west	27	EC	34.1	A, C
Blackie's Pasture	8	BLPA	5.9	A, C
Greenwood Beach Rd/Richardson Bay	7	GRBE	3.7	A
Harbor Cove Fragment	6	HCF	1.0	A
Strawberry Point	2	STRA	10.3	A, C
Strawberry Cove	3	STRC	4.3	C
Bothin Marsh/Tam High Fragment	4	THF	42.2	A
Hoffman Marsh	30	HOM	14.1	A
Meeker Slough	31	MEEK	9.3	A, B
Pickleweed Park	24	PIPK	5.5	A
San Pablo Bay				
China Camp	119	CCM	98.6	A
Gallinas Creek- upper reach	116	GACRN	8.2	A
Gallinas Creek south	114	GACRS	9.7	A
Hamilton North	111	HAAF	21.2	A
Mitchell Fragment	117	MIF	11.1	A
McInnis Marsh	113	MIM	135.9	A
Hamilton South	112	MIN	93.7	A
Santa Venetia	118	STVE	9.2	A
Dutchman Slough/Cullinan Ranch	45	CURA	664.5	A
Dutchman Slough Mouth	44	DUTC	11.7	A
Napa Centennial Marsh	47	NACM	84.9	A, C
Napa Plant Site Restoration	48	NAPL	109.3	C
Pond 2A Restoration	49	PTAR	210.9	A
White Slough Marsh	43	WSM	203.7	A
Bull Island	56	BUIS	43.8	A
Coon Island	55	COIS	162.4	A
Fagan Slough	57	FAGA	217.8	A
Bahia Channel	86	BACH	14.4	A, B
Bahia Restoration Marsh	88	BARM	144.2	A
Black John Slough A	89	BJA	31.4	A
Black John Slough B	90	BJB	43.5	A
Black John Slough north	91	BJSN	137.3	A
Petaluma River-west side	85	GRCM	31.0	A
Green Point Marsh	84	GRPT	30.6	A
Green Point Restoration Marsh	83	GRRM	25.9	A
Carl's Marsh	81	PRM	22.1	A
Day Island Wildlife Area	106	BPF	42.9	A, B
Gambinini Marsh	99	GAMA	32.4	A
Petaluma R.-Tule Sl./Lakeville Marina	93	PERI	908.9	A, C

Site Name	Map #	Site Code	Site Area (ha)	Survey Type
San Pablo Bay				
Novato Creek Upper Reach	109	BMAK	55.0	A
Novato Creek Mouth N&S	110	NCRM	102.6	A
Pinole Creek mouth	39	PICR	5.3	A
Pt. Pinole south-Giant Marsh	37	PPF	11.2	A
Pt. Pinole north-Whittel Marsh	38	PTPN	23.5	A
Pt Pinole south pocket marshes	36	RCRA	10.0	A
San Pablo Creek	35	RIF	52.3	A
Wildcat Marsh S/Castro Creek	33	WICA	17.3	A, B
Wildcat Marsh N/Castro Creek	34	WIMA	119.6	A
Petaluma River Mouth	78	RMA	73.1	A
Sonoma Marina	80	SOMA	26.0	A, B
Skaggs Island Bridge / Napa Street	66	SKIS	232.7	A
Sonoma Creek Mouth	68	SOCR	70.4	A
Sonoma Baylands east	77	SOBE	57.0	A
Tolay Creek	75	TCM	113.8	A
Lower Tubbs Island (muted marsh)	74	TMM	100.4	A
South San Francisco Bay				
Coast Guard Island	123	CGIS	1.3	C
Airport Channel	125	AICH	4.9	A, C
Alameda Island East	126	ALAM	1.6	A, C
Arrowhead Marsh	127	ARHE	16.9	A, B, E
Bay Farm Island	128	BFIS	3.0	A, C
Coliseum Channels	129	COCH	6.8	A, C
Doolittle Pond	131	DOPO	1.2	A, C
Elsie Roemer	132	ELRO	6.9	A
Fan Marsh	133	FANM	8.7	A
MLK Regional Shoreline	134	MLKS	18.5	A
MLK Restoration Marsh	135	NEMA	14.0	A
San Leandro Creek	136	SLEA	4.0	A, C
Bockmann Channel	145	BOCH	1.0	A, C
Bunker Marsh	143	BUNK	13.4	A
Citation Marsh	142	CITA	44.5	A
Cogswell Marsh, A	146	COGS	76.6	A, C
Dogbone Marsh	141	DOGB	2.8	A, C
East Marsh	140	EAST	14.8	A
Hayward Landing	147	HALA	4.7	A, C
H.A.R.D. Marsh	148	HARD	26.4	A
Johnson's Landing	149	JOLA	5.0	A, C
North Marsh	139	NORT	35.7	A
Oro Loma East	150	ORLE	79.7	A
Oro Loma West	151	ORLW	52.9	A
San Lorenzo Creek & Mouth	152	SLRZ	12.7	A
Sulphur Creek	154	SULF	3.3	A, C
Triangle Marsh	155	TRMA	5.0	A
N Whales Tail	156	WTM	66.2	A, D
Upstream of 20 Tides	158	ALCK	66.3	D
S Whales Tail	160	WTS	59.1	D
Cargill Mitigation Marsh	159	CAMM	18.6	D
Mt. Eden Creek	157	EDEN	19.0	D

Table 1 continued.

Site Name	Map #	Site Code	Site Area (ha)	
South San Francisco Bay				
AFCC - Pond 3	165	PND3	52.1	D
AFCC - Channel Mouth	161	AFCC	109.0	D
Ideal Marsh North	163	IDEN	15.3	D
Ideal Marsh South	164	IDES	51.4	D
Dumbarton West- Boardwalk west	174	DUMW	194.1	A
Calaveras Point	182	CAPT	180.2	A
Mowry Slough South	178	MOSL	45.9	A
Mowry Marsh North	179	MOWN	167.5	E
Newark Slough	168	NEW	75.0	A
La Riviere Marsh	166	LARI	44.0	D
Coyote Creek North Bank	190	COYN	41.6	H
Coyote Creek South East	188	COYSE	90.5	H
Mud Slough_Coyote Creek	185	MUDC	66.0	H
Coyote Creek South Tributary Marsh	189	COYS	48.4	H
Alviso Slough	196	ALSL	105.3	A
Charleston Slough	200	CHSL	16.9	A
Guadalupe Slough	195	GUSL	89.8	A
Lock A2W	197	LONG	7.5	A
Alviso Slough mouth	192	MAL	7.8	A
Mountain View Slough	198	MVSL	27.5	A
Cooley Landing restoration	206	COLA	70.3	A
Faber Marsh	204	FABE	41.8	A
Laumeister Marsh	205	LAUM	36.6	A
Palo Alto Baylands	202	PAB	45.8	A
Palo Alto Harbor-Hook Island	201	PAHA	41.3	A
Ravenswood Slough	207	RAV	48.2	A
Ravenswood Open Space	208	RAVO	14.4	A
Belmont Sl.	226	BELM	55.5	A
Corkscrew Sl.	221	CORK	80.4	A
Foster City	228	FOST	3.7	C
Greco Island North	212	GRIN	202.6	A
Greco Island South	211	GRIS	94.4	E
Middle Bair East	218	MBE	82.5	A
Middle Bair SE	217	MBSE	78.9	A
Bair Island	219	OBE	228.9	A
Redwood Shores	223	RESH	70.6	A
West Point Slough NW	210	WPSN	2.4	A
West Point Slough SW/SE	209	WPSS	16.5	A, C
Lew Galbraith Golf Course	137	MEGO	0.8	C
Oyster Bay Regn'l Shoreline	138	OYBA	7.3	A, C
San Mateo Creek	229	SACR	1.1	C
Seal Slough	227	SEAL	23.5	A
Coyote Point Marina	230	COPT	5.0	A, C
Easton Creek Mouth	233	EACR	2.2	C
Fisherman's Park	231	FMPK	0.6	C
Mills Creek Mouth	235	MICR	1.7	A, C
Sanchez Marsh/Park Plaza Fragment	234	PAF	5.8	A, C
South San Francisco Bay				
SFO	236	SFO	38.0	A, C
Colma Creek	245	COCR	5.8	A, C
Navigable Channel	242	NACH	1.8	A, C
"Old Marina"	241	OLDM	2.1	A, C
San Bruno Creek	240	SABR	2.3	A, C
San Bruno Point	239	SBPT	0.6	A, C
San Bruno Marsh	238	SBRN	14.3	A
Sam Trans Peninsula	237	SBRS	5.7	A, B
Brisbane Lagoon	250	BRLA	7.3	A, C
South Candlestick Cove	252	CAND	0.8	C
Oyster Cove	246	OYPC	1.3	A, C
Oyster Point Marina	247	OYPM	1.2	C
Oyster Point Park	248	OYPP	0.9	C
Sierra Point	251	SIPT	1.1	A
Suisun Bay & Carquinez Strait				
Martinez Shoreline	259	MZF	43.8	A
Benicia SRA	258	SBM	72.2	C
Rush Ranch - First Mallard	277	FMSL	169.8	C
Goat Island	278	GIF	6.3	C
Grizzly Island North Shore	271	GRIZ	37.0	C
Hill Slough East	282	HEF	23.8	C
Hill Slough - North East	281	HINE	124.1	C
Hill Slough - South East	280	HISE	125.2	C
Hill Slough West	283	HWF	12.7	C
Montezuma-Grizzly	274	MNTZ	553.4	C
Blacklock Restoration	288	BLAR	27.3	C
Peytonia Slough	284	PEYA	179.5	C
Rush Ranch A	276	RRA	37.8	C
Rush Ranch - Second Mallard Slough	275	SMSL	313.4	C
Bullhead Marsh	295	BHM	171.4	C
Pacheco Creek Marsh	296	PEM	419.8	C
Roe Island	294	ROEIS	91.2	C
Goodyear Slough (Bahia)	265	GSB	78.5	C
Lower Joice Island	270	JOIC	111.5	C
Suisun Mouth South Marsh - Morrow Island	266	MORR	48.0	C
Navy Point	260	NAVY	1.6	C
Reserve Fleet south	261	RVFT	93.8	C
Delta				
Brown's Island	301	BRIS	276.4	A, C
Sherman Island	302	SHIS	393.2	A, C

Table 2. Five monitoring scenarios used in the power analysis. Sites contain an average of 5.7 listening stations. Scenarios 1, 2, and 3 represent Estuary-wide monitoring scenarios. Scenarios 4 and 5 represent reduced survey efforts.

Scenario 1- current effort and design (90 sites)		
Density	**Sites**	**Surveys/yr**
Zero to very low	30	3
Med-low	15	3
Medium	15	3
Med-high	15	3
High	15	3
Scenario 2- current effort, re-allocated (90 sites)		
Density	**Sites**	**Surveys/yr**
Zero- very low	10/yr Rotated	2
Med-low and medium	30	3
Med-high and high	30	5
Scenario 3- effort reduced to 50% of current design (45 sites)		
Density	**Sites**	**Surveys/yr**
Zero to very low	15	3
Med-low	6	3
Medium	7	3
Med-high	6	3
High	7	3
Scenario 4- effort reduced by 66% (30 sites)		
Density	**Sites**	**Surveys/yr**
Zero to very low	10	3
Med-low	5	3
Medium	5	3
Med-high	5	3
High	5	3
Scenario 5- effort reduced by 93% (6 sites)		
Density	**Sites**	**Surveys/yr**
Zero to very low	2	3
Med-low	1	3
Medium	1	3
Med-high	1	3
High	1	3

Table 3. DISTANCE vs. Observer-derived estimates of total number of California Clapper Rails, average 2005-08.

Bay	Number of Individuals (DISTANCE)	Number of Individuals (Observer)
Central San Francisco Bay	121	108
San Pablo Bay	442	521
South San Francisco Bay	878	761
Suisun Bay	7	13
Total	**1,448**	**1,403**

Table 4. Analysis of interannual change and trends in Clapper Rail abundance for San Pablo, South San Francisco, and Central San Francisco Bays, combined and separate.

Region	Time period	% change	SE	P value	Regression coefficient	SE reg. coeff.
All	2005-08	-20.6%	3.8%	<0.0001	-0.231	0.048
All	2005-06	19.3%	17.7%	0.23	0.177	0.148
All	2006-07	-14.6%	11.3%	0.23	-0.157	0.132
All	2007-08	-46.0%	6.8%	<0.0001	-0.616	0.125
San Pablo Bay	2005-08	-22.2%	6.7%	0.004	-0.252	0.087
San Pablo Bay	2005-06	13.0%	19.7%	>0.4	0.122	0.174
San Pablo Bay	2006-07	-25.3%	23.1%	>0.3	-0.291	0.308
San Pablo Bay	2007-08	-23.6%	23.2%	>0.3	-0.270	0.302
South SF Bay	2005-08	-22.0%	4.7%	<0.0001	-0.249	0.060
South SF Bay	2005-06	22.2%	27.2%	>0.3	0.200	0.222
South SF Bay	2006-07	-3.5%	13.1%	>0.7	-0.035	0.135
South SF Bay	2007-08	-57.4%	5.0%	<0.0001	-0.853	0.117
Central SF Bay	2005-08	-5.0%	19.2%	>0.8	-0.051	0.202
Central SF Bay	2005-06	Insufficient data				
Central SF Bay	2006-07	Insufficient data				
Central SF Bay	2007-08	-25.4%	33.5%	>0.5	-0.293	0.446

Table 5. Effect of marsh area (natural log-transformed) on Clapper Rail density (natural log-transformed), controlling for annual trend and for Bay Region (San Pablo Bay vs. South San Francisco Bay) including marshes surveyed in 2 or more years where density >0 in 1 or more years, 2005 to 2008.

Density (ln)	Coefficient	SE	P value	95% CI Low	95% CI High
Annual trend	-0.227	0.052	< 0.001	-0.329	-0.124
Marsh area (ln)	0.106	0.098	> 0.281	-0.087	0.299
Bay region	-0.090	0.316	> 0.776	-0.710	0.529

Table 6. Power analysis results from program MONITOR. Power level represents percent chance to detect the stated positive or negative annual and cumulative change. Refer to methods for scenario design details.

Scenario	**Power Level**	**Minimum Positive Annual Change**	**10-year Positive Change**	**Minimum Negative Annual Change**	**10-year Negative Change**
1- current effort and design (90 sites)	80%	1.4%	14.9%	-1.5%	-13.8%
	90%	1.6%	17.2%	-1.7%	-16.1%
2- current effort, re-allocated (90 sites)	80%	1.3%	13.5%	-1.4%	-12.9%
	90%	1.5%	16.1%	-1.6%	-14.9%
3- effort reduced 50% (45 sites)	80%	2.0%	21.9%	-2.2%	-19.9%
	90%	2.3%	26.0%	-2.6%	-23.0%
4- effort reduced 66% (30 sites)	80%	2.5%	28.4%	-2.8%	-25.0%
	90%	3.0%	33.9%	-3.4%	-29.2%
5- effort reduced 93% (6 sites)	80%	10.0%	170%	N/A	N/A
	90%	N/A	N/A	N/A	N/A
	40%	N/A	N/A	-10.6%	-67.4%
	50%	N/A	N/A	-15.0%	-80.3%

Figures

Figure 1. Map of sites surveyed in San Pablo and Central San Francisco Bays between 2005 and 2008 by PRBO and partners. Sites color-coded by observer-derived density estimate averaged over 2005 to 2008. Site numbers correspond to sites in Table 1 and Appendix 2.

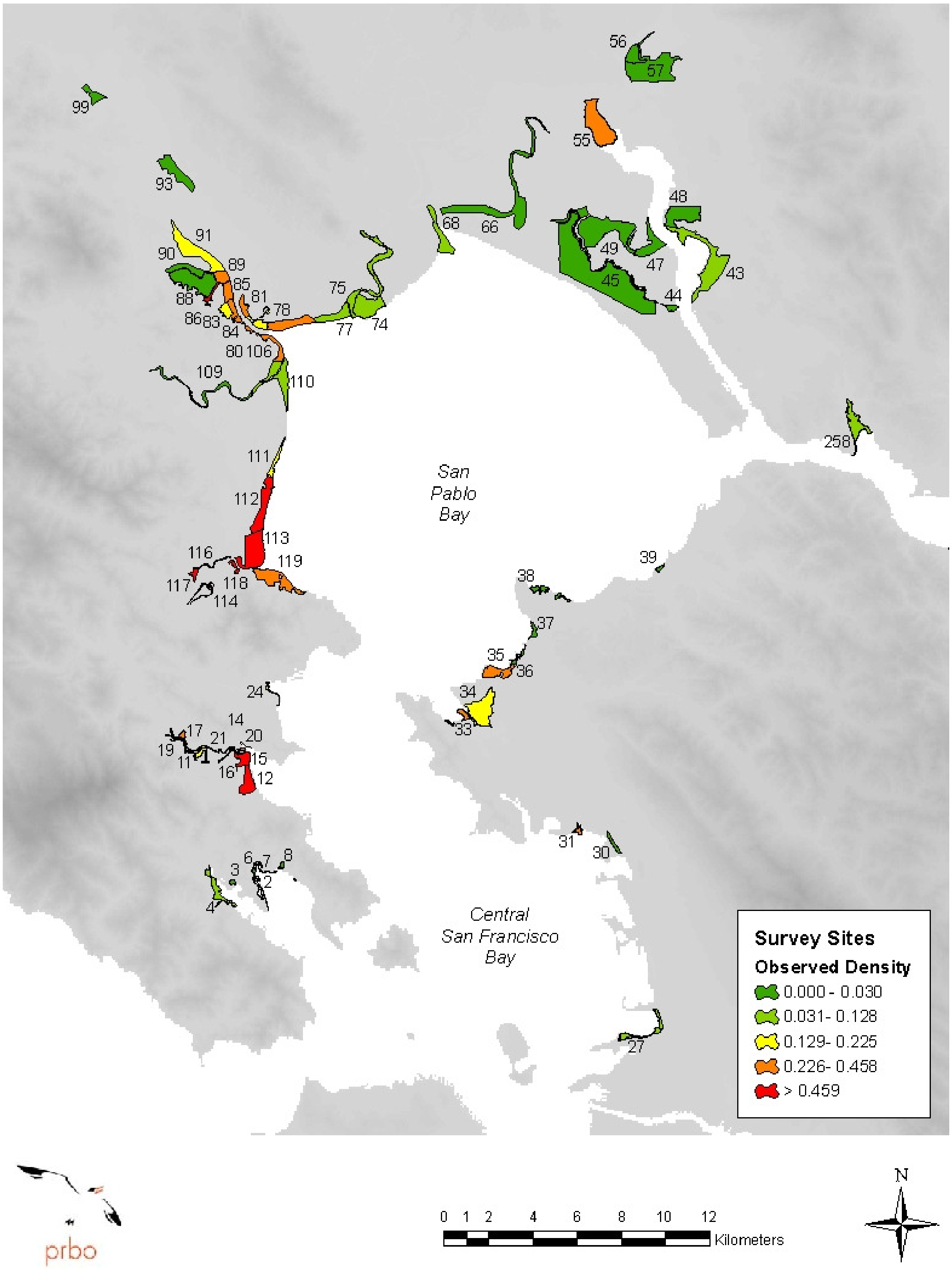
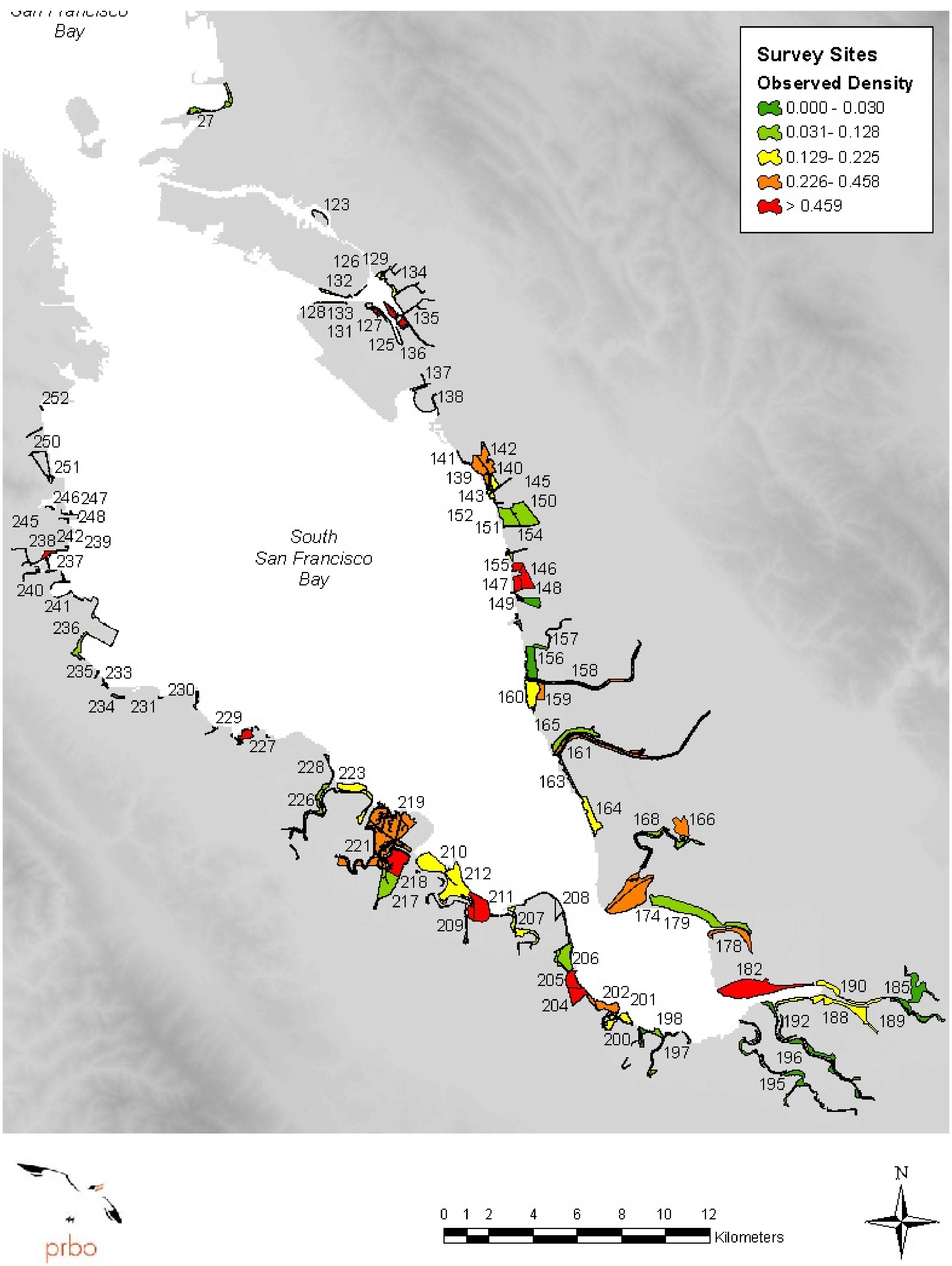


Figure 2. Map of sites surveyed in South San Francisco Bay between 2005 and 2008 by PRBO and partners. Sites color-coded by observer-derived density estimate averaged over 2005 to 2008. Site numbers correspond to sites in Table 1 and Appendix 2.



prbo

Figure 3. Map of sites surveyed in Suisun Bay between 2005 and 2008 by PRBO and partners. Sites color-coded by observer-derived density estimate averaged over 2005 to 2008. Site numbers correspond to sites in Table 1 and Appendix 2.

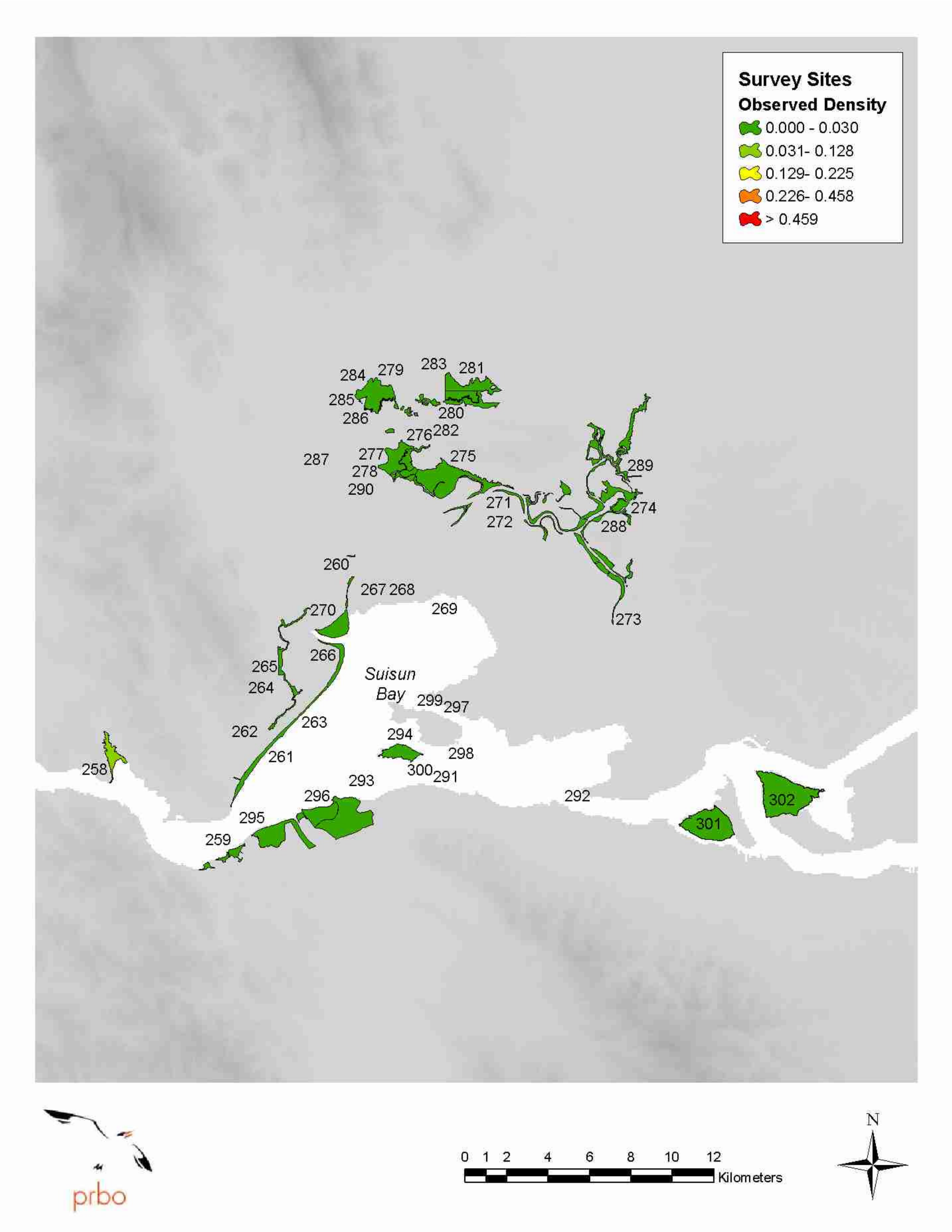


Figure 4. Change in Estuary-wide Clapper Rail density (all sites in San Pablo, Central and South San Francisco Bays), 2005-08. The plotted values are shown for illustration only and represent raw unadjusted mean densities for all sites surveyed in that year. The fitted line is derived from the site by site analysis and assumes a constant percent change per year. Error bars represent 1 Standard Error.

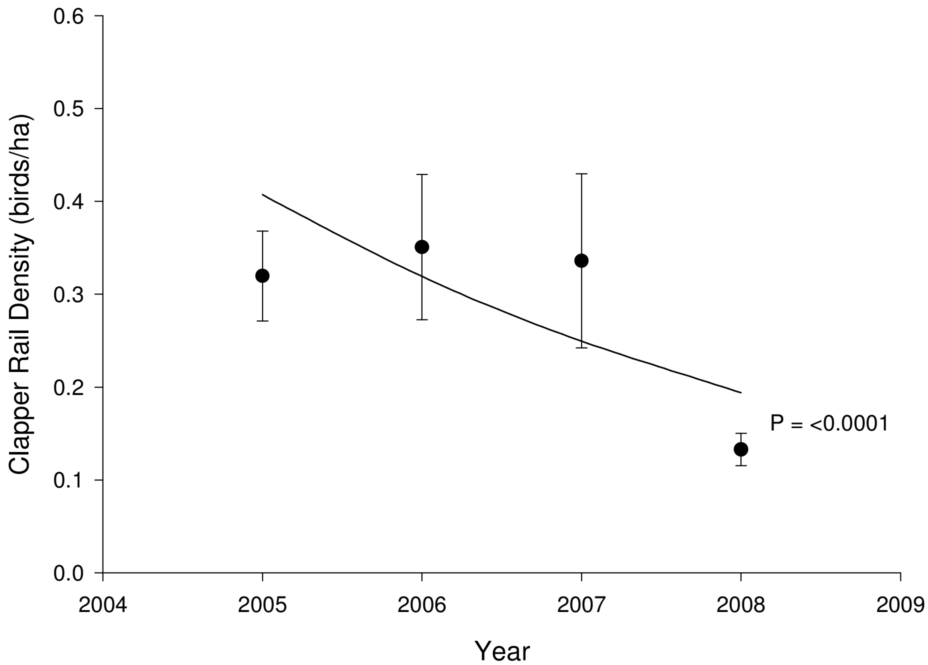


Figure 5. Change in San Pablo Bay Region Clapper Rail density, 2005-08. The plotted values are shown for illustration only and represent raw unadjusted mean densities for all sites surveyed in that year. The fitted line is derived from the site by site analysis and assumes a constant percent change per year. Error bars represent 1 Standard Error.

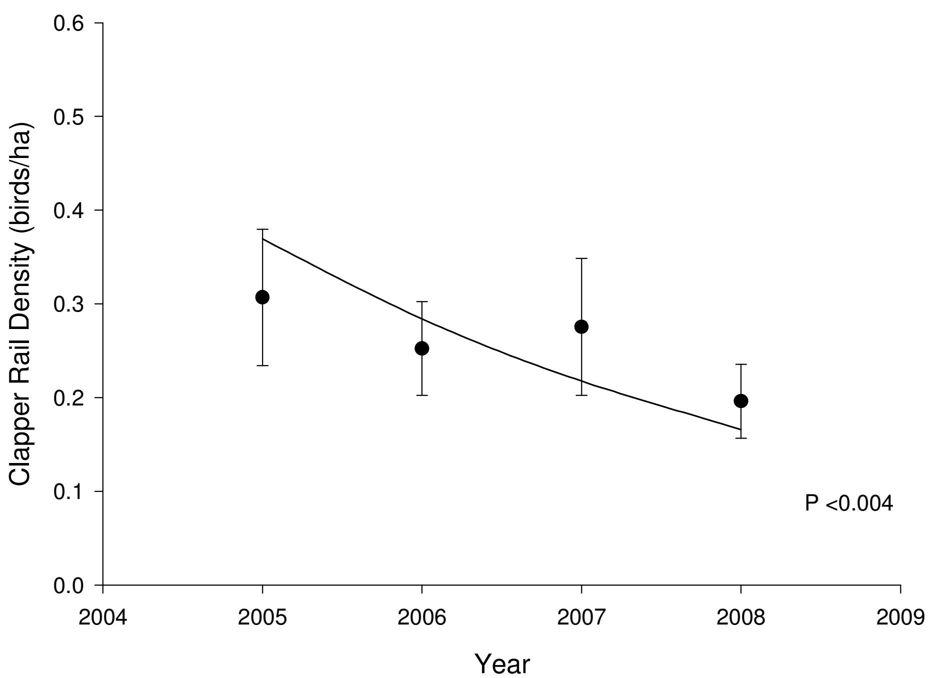


Figure 6. Change in South San Francisco Bay Region Clapper Rail density, 2005-08. The plotted values are shown for illustration only and represent raw unadjusted mean densities for all sites surveyed in that year. The fitted line is derived from the site by site analysis and assumes a constant percent change per year. Error bars represent 1 Standard Error.

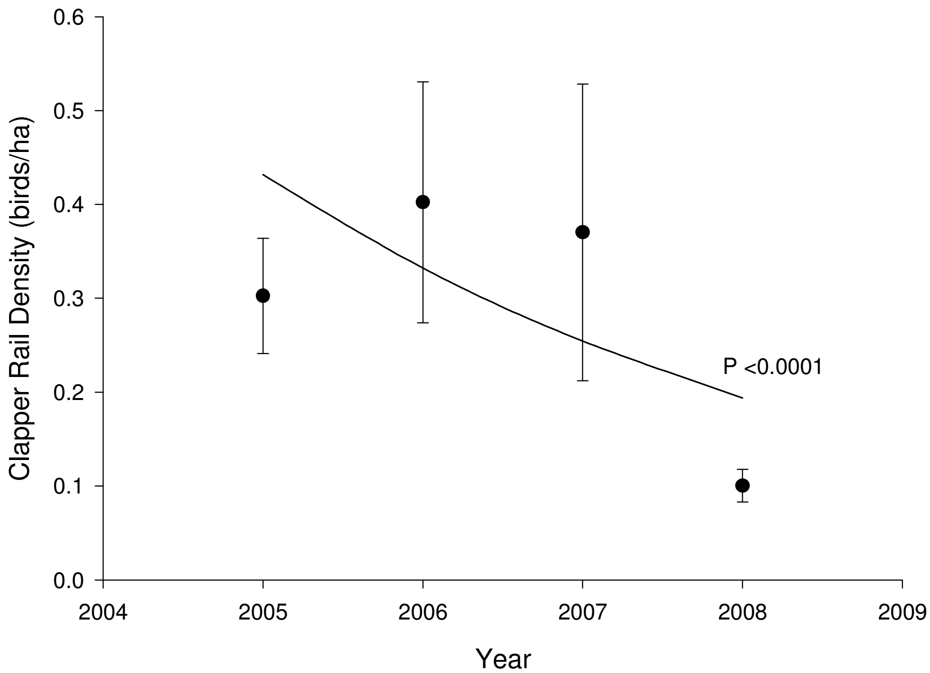


Figure 7. Change in Central San Francisco Bay Region Clapper Rail density, 2005-08. The plotted values are shown for illustration only and represent raw unadjusted mean densities for all sites surveyed in that year. The fitted line is derived from the site by site analysis and assumes a constant percent change per year. Error bars represent 1 Standard Error.

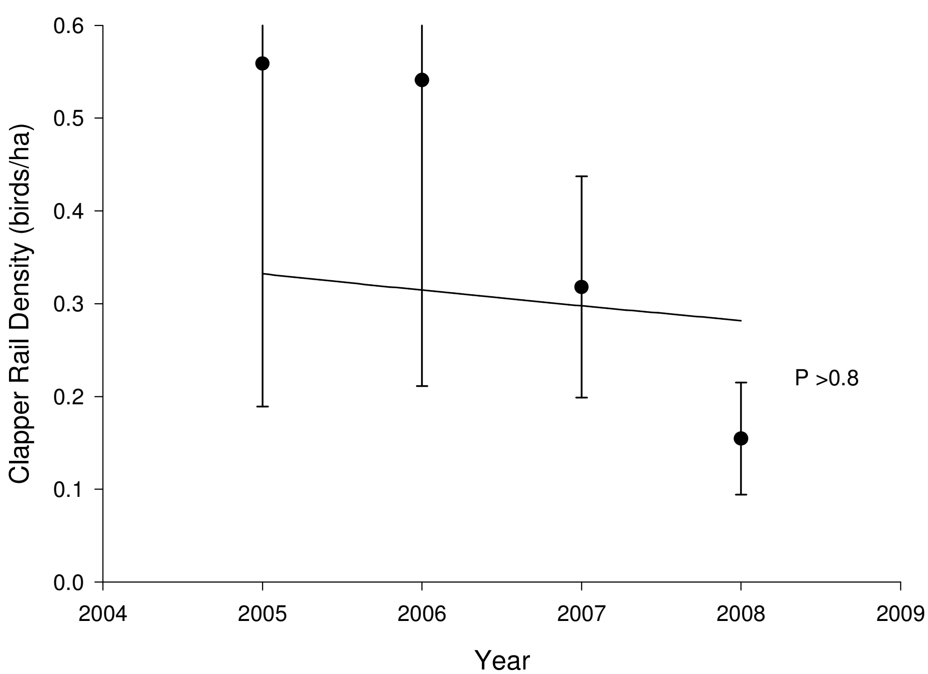
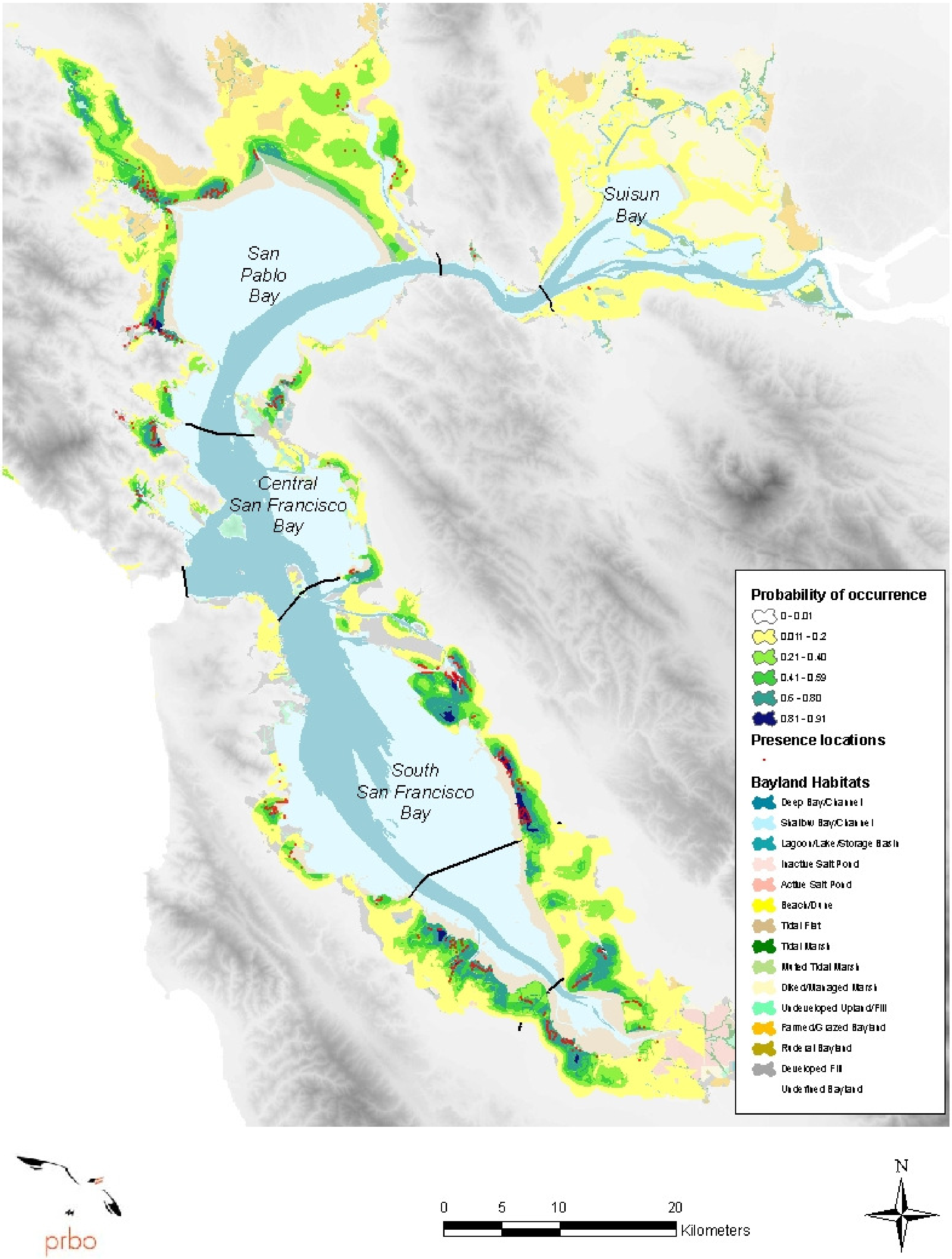


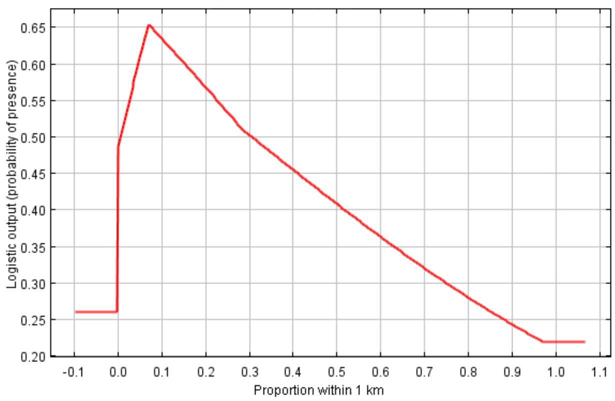
Figure 8. Predicted California Clapper Rail probability of occurrence based on Maxent model.



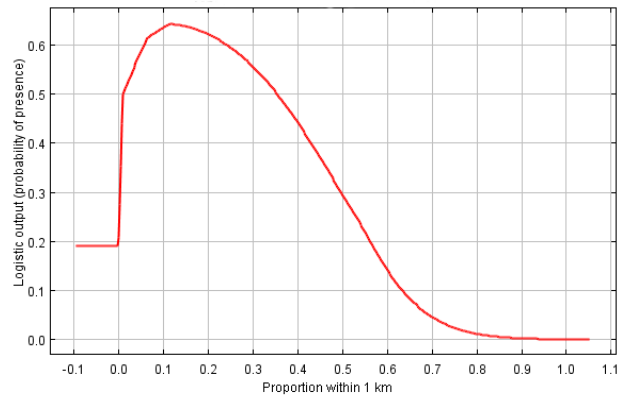
prbo

Figure 9. Maxent-modeled relationship between California Clapper Rail presence and landscape variables (proportion within 1-km radius, except salinity): (a) high-intensity development; (b) low-intensity development proportion; (c) salinity; (d) agriculture; (e) estuarine wetlands; (f) palustrine and estuarine wetlands combined; and (g) elevation.

a



b



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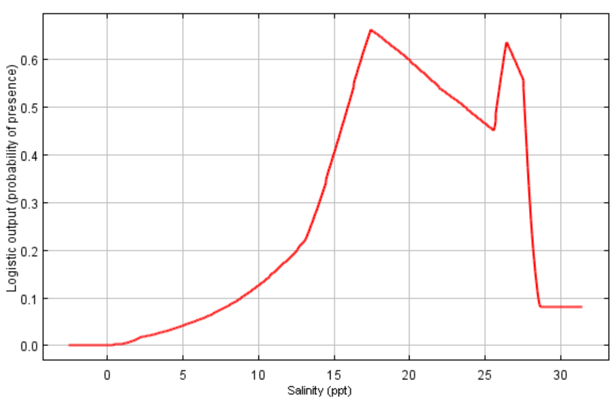

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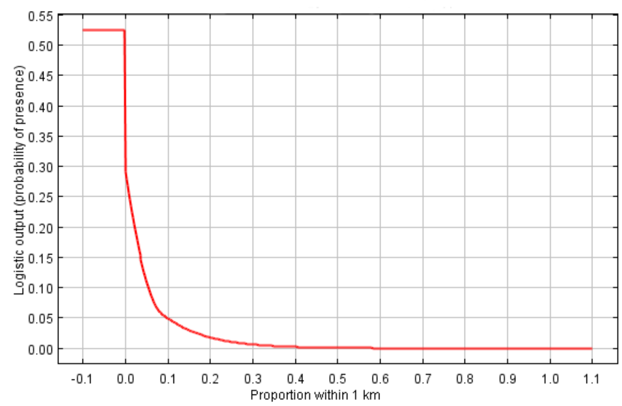
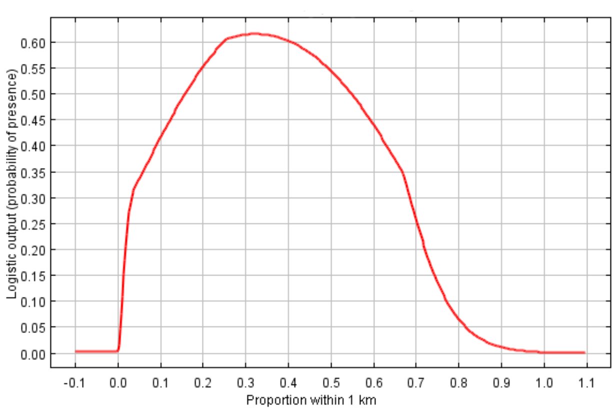


e



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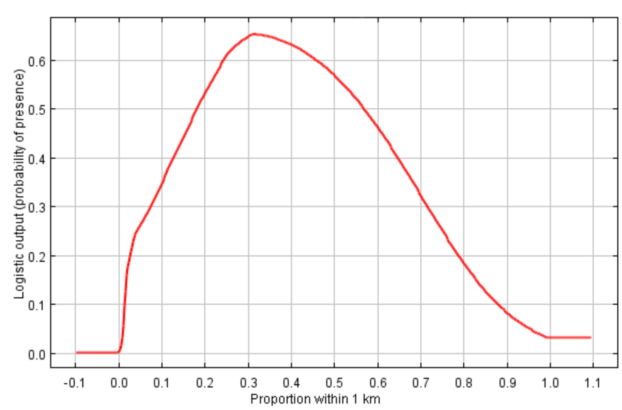
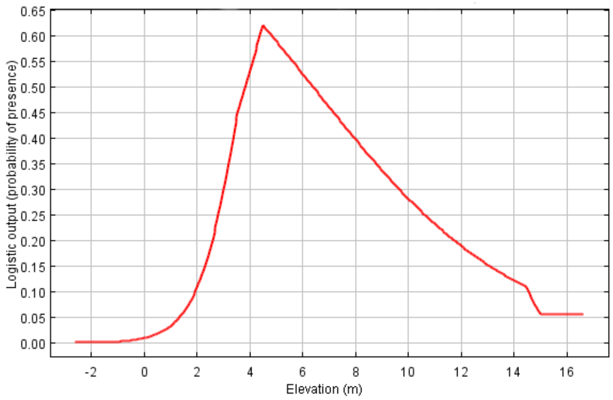


Figure 9 continued
g



Literature Cited

Albertson, J.D. 1995. Ecology of the California clapper rail in South San Francisco Bay. M.S. Thesis, San Francisco State Univ. 200pp.

Albertson, J.D., and J.G. Evens. 2000. California Clapper Rail. Pages 332-341 in Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. P.R. Olofson, editor. San Francisco Bay Regional Water Quality Control Board, Oakland, California.

American Ornithologists' Union (AOU). 1957. Checklist of North American Birds, fifth ed. American Ornithologists' Union.

Begon, M., J. Harper, and C. Townsend. 1990. Ecology: individuals, populations, and communities. Blackwell Scientific Publications, Cambridge, Massachusetts.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling. Oxford University Press, Oxford.

Collins, J.N., J.G. Evens, and B.J. Grewell. 1994. A synoptic survey of the distribution and abundance of the California Clapper Rail (*Rallus longirostris obsoletus*) in the northern reaches of the San Francisco Estuary during the 1992 and 1993 breeding seasons. Technical Report to California Department of Fish and Game, Yountville.

Estrella, S. 2007. California Clapper Rail California Black Rail Suisun Marsh Survey 2007. Report to California Department of Water Resources.

Evens, J., K. Zaremba, and J. Albertson. In press. Non-Native Cordgrass and the California Clapper Rail: Biogeographical overlap between an Invasive plant and an endangered bird. In Ayres, DR, DW Kerr, SD Ericson and PR Olofson, Eds. 200X. Proceedings of the Third International Conference on Invasive Spartina (San Francisco, CA), San Francisco Estuary Invasive Spartina Project of the State Coastal Conservancy (California), Cambridge Publications Limited, Cambridge, UK.

Fielding, A.H., J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ. Conserv. 24:38-49.

Foin, T.C., E.J. Garcia, R.E. Gill, S.D. Culberson, J.N. Collins. 1997. Recovery strategies for the California clapper rail (*Rallus longirostris obsoletus*) in the heavily-urbanized San Francisco estuarine ecosystem. Landscape and Urban Planning 38: 229-243.

Gibbs, J.P. 1995. Program Monitor: Estimating the statistical power of ecological monitoring programs. Version 6.3. URL:www.esf.edu/efb/gibbs/monitor/monitor.htm

Gill Jr., R. 1979. Status and distribution of the Californai Clapper Rail (*Rallus longirostris obsoletus*), Calif. Fish and Game 65(1): 36-49.

Goals Project. 1999. Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco, Calif./S.F. Bay Regional Water Quality Control Board, Oakland, Calif.

Grijalva, E. and J. Albertson. 2005. Non-Native Spartina Control Impact Evaluation Matrix (SCIE-M) Estimating the impact of *Spartina* control on the California clapper rail carrying capacity of San Francisco Bay tidal marshes.

Grijalva, E. and D. Kerr. 2006. San Francisco Estuary Invasive *Spartina* Project 2005 Field Operations Report. Prepared for the California Coastal Conservancy.

Grinnell, J. and A.H. Miller. 1944. The distribution of the birds of California. Pacific Coast Avifauna 27.

H.T. Harvey and Associates. 2007. Marsh studies in South San Francisco Bay: 2005-2006 California Clapper Rail and Salt Marsh Harvest Mouse. Prepared for City of San Jose Environmental Services Department.

Harding, E.K., D. Doak, and J.D. Albertson. 2001. Evaluating the effectiveness of predator control: the non-native red fox as a case study. Conservation Biology 15: 1114–1122.

McBroom, J. 2007. Report of California Clapper Rail Surveys Conducted at Thirty-five San Francisco Estuary Invasive Spartina Control Sites in 2007. Prepared for the California Coastal Conservancy.

Nur, N., S.L. Jones, and G.R. Geupel. 1999. A statistical guide to data analysis of avian monitoring programs. U.S. Fish and Wildlife Service, BTP-R6001-1999, Washington DC.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Applications 190:231-259.

Schwarzbach, S.E., J.D. Albertson, and C.M. Thomas. 2006. Effects of predation, flooding, and contamination on reproductive success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk 123(1):45-60.

Soulé, M.E., D.T. Bolger, A.C. Alberts, J. Wright, M. Sorice, and S. Hill. 1988. Reconstructed dynamics of rapid extinctions of chaparral requiring birds in urban habitat islands. Conserv Biol 2:75-92.

StataCorp. 2005. Stata statistical software: release 9.0. College Station, Texas: Stata Corporation.

Thomas, L., S. Buckland, K. Burnham, D. Anderson, J. Laake, D. Borchers, and S. Strindberg. 2002. Distance Sampling. Encyclopedia of Environmetrics 1:544-552.

USFWS. 1984. The Salt Marsh harvest Mouse and California Clapper Rail Recovery Plan. Nov. 16, 1984. Prepared by the U.S. Fish and Wildlife Service in cooperation with Dr. Howard S. Shellhammer, San Jose State University, Thomas E. Harvey, San Francisco Bay National Wildlife Refuge, Monty D. Knudsen and Peter Sorensen, U.S. Fish and Wildlife Service, Sacramento Endangered Species Office.

Wilbur, S., and R. Tomlinson. 1976. The literature of western clapper rails, Special scientific report-Wildlife # 194, U.S. Fish and Wildlife Service.

Zaremba, K. and M. McGowan. 2004. San Francisco Estuary Invasive Spartina Project Monitoring Report for 2003. Prepared for the California Coastal Conservancy.

Appendices

Appendix 1. Summary of California Clapper Rail survey methods (McBroom 2007).

Method	Protocol Name	Protocol Description
A-PRBO	Walking Transect Survey	One or more observers move from station to station for 10-minute periods. Three survey rounds, with recording of Clapper Rail vocalizations played on 3rd round if no prior detections. Rail detections recorded as detected in field, with uncertainty expressed as a range of number of birds (e.g., a poorly heard "clatter" that may have been 1 or 2 birds vocalizing is recorded as 1-2 Clapper Rails)
A-ISP	Walking Transect Survey	One or more observers move from station to station for 10-minute periods. Three survey rounds, with recording of Clapper Rail vocalizations played on 3rd round if no prior detections. Rail detections assigned categorically to a detection type and range of number of birds (e.g., a "kek" detected in field is recorded as 1-2 Clapper Rails).
B	Stationary Survey	Requires one person at each station for 1½ hour. Typically 3 survey rounds, with recording played at end of 3rd round if no prior detections.
C	ISP Presence/Absence Survey	Used to determine presence or absence of CLRA at sites slated for *Spartina* control. Same as Type A, except recording can be played from first survey round, and surveys can be discontinued upon detection.
D	DESFBNWR Modified Transect Survey	Used by DESFBNWR biologist in narrow strip marshes with medium to high rail density - Similar to Type C, except densities are extrapolated by Refuge biologist.
E	Winter High Tide Survey	CLRA are flushed out of marsh habitat by airboat and counted during winter high tide.
H	HT Harvey Surveys	10-90 minute surveys at stations 200 meters apart. Three to four survey rounds. No playback of Clapper Rail vocalizations.

Appendix 2. Sites surveyed 2005 to 2008 with calculated densities and map number. Refer to Table 1 for full site names.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
Central San Francisco Bay																
	Corte Madera															
		CMCL	21	10.1							3	0	0	3	0.037	0.198
		CMCM	20	2.7							3	0.477	1.106	3	0.086	0.369
		CMCU	19	5.3							2	0.028	0.188	3	0.029	0.376
		CRPA	17	7.8				3	0.338	1.148	3	0.636	1.531	3	0.294	1.021
		GBBW	16	4.2							1	1.761	0.000			
		HEER	15	31.5	3	1.559	1.141				3	0.936	0.698	3	0.844	0.539
		LARK	14	0.7										2	0.110	1.338
		MUZZ	12	58.0	3	0.676	0.626	3	1.186	1.035	3	0.374	0.325	3	0.452	0.449
		PIPE	11	14.4							3	0.176	0.277			
	Emeryville															
		EC	27	34.1	4		0.059**	3	0.099	0.176	3	0.115	0.147	3	0.070	0.117
	Richardson Bay															
		BLPA	8	5.9	1	0	0				3	0	0	3	0	0
		GRBE	7	3.7							4	0	0			
		HCF	6	1.0							3	0	0			
		STRA	2	10.3							4	0	0	3	0	0
		STRC	3	4.3										3	0	0
		THF	4	42.2	1	0	0				5	0.020	0.047	3	0.105	0.189
	Richmond Harbor															
		HOM	30	14.1										3	0	0
		MEEK	31	9.3							4	0.477	0.536	3	0	0
	San Rafael															
		PIPK	24	5.5							3	0.088	0.362	3	0.294	1.447

Appendix 2 continued.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
San Pablo Bay																
	Gallinas Creek															
		CCM	119	98.6	3	0.275	0.227	4	0.463	0.337	3	0.616	0.240	3	0.404	0.220
		GACRN	116	8.2	3	0.506	0.245	3	0.110	0.123	3	0.205	0.736	3	0.059	0.368
		GACRS	114	9.7	3	0.342	0.620	3	0.743	1.344	3	0.480	0.827	3	0.147	0.207
		HAAF	111	21.2	3	0.151	0.330	1	0.220	0.189						
		MIF	117	11.1	3	0.294	0.811	3	0.587	0.541	3	2.055	0.721	3	0.367	0.541
		MIM	113	135.9	3	1.451	1.236	3	0.991	0.927	3	0.264	0.326	3	0.541	0.468
		MIN	112	93.7	3	0.708	0.519	3	0.640	0.465	1	0.660	0.598	3	0.587	0.961
		STVE	118	9.2	3	0.778	2.185	3	0.646	2.404	3	0.528	1.967	3	0.367	0.874
	lower Napa River															
		CURA	45	664.5				3	0	0	2	0	0			
		DUTC	44	11.7	3	0	0	3	0	0						
		NACM	47	84.9				3	0	0	1	0	0			
		NAPL	48	109.3							1	0	0			
		PTAR	49	210.9	3	0.012	0.009				3	0	0			
		WSM	43	203.7	3	0.235	0.174	3	0.096	0.053	3	0.147	0.177	3	0.006	0.011
	upper Napa River															
		BUIS	56	43.8	2	0	0									
		COIS	55	162.4	2	0.325	0.265							3	0.128	0.137
		FAGA	57	217.8							2	0.044	0.011	3	0	0
	lower Petaluma River															
		BACH	86	14.4	7	0.991	1.532				4	0.180	0.557	3	0.238	0.905
		BARM	88	144.2							3	0	0			
		BJA	89	31.4							4	0.340	0.088			
		BJB	90	43.5							2	0	0			
		BJSN	91	137.3				3	0.168	0.161						
		GRCM	85	31.0	4	0.204	0.214	1	0.660	0.016	2	0	0	3	0.220	0.017
		GRPT	84	30.6				3	0.509	0.114	3	0.404	0.287	3	0.430	0.330
		GRRM	83	25.9	5	0.248	0.128	1	0.330	0.016	2	0	0			
		PRM	81	22.1	5	0.176	0.317	3	0.162	0.227	3	0.542	0.499	3	0.037	0.091
	Petaluma River Mouth															
		BPF	106	42.9				4	0.563	0.233	3	0.312	0.257	3	0.073	0.047
	Petaluma Marsh															
		GAMA	99	32.4										3	0	0
		PERI	93	908.9	1	0	0	1	0.040	0.002						

Appendix 2 continued.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
San Pablo Bay																
	Novato Creek															
		BMAK	109	55.0				3	0	0						
		NCRM	110	102.6				3	0.086	0.049				3	0.000	0.058
	Richmond / Pinole															
		PICR	39	5.3							3	0	0			
		PPF	37	11.2				3	0	0						
		PTPN	38	23.5	3	0	0	3	0	0						
		RCRA	36	10.0										3	0.016	0.100
		RIF	35	52.3							3	0.238	0.172	3	0.569	0.363
		WICA	33	17.3	4	0.139	0.149				4	0.594	0.164			
		WIMA	34	119.6	3	0.191	0.056	4	0.161	0.107	3	0.157	0.104	3	0.330	0.371
	Sonoma Baylands															
		RMA	78	73.1				1	0.220	0.135	3	0.279	0.199	3	0.205	0.166
		SOMA	80	26.0	3	0.264	0.154	3	0.176	0.077						
	Sonoma Creek															
		SKIS	66	232.7				3	0	0						
		SOCR	68	70.4				3	0.065	0.043	3	0.103	0.071	3	0.069	0.028
	Tolay Creek															
		SOBE	77	57.0				3	0.052	0.035				3	0.037	0.035
		TCM	75	113.8	3	0.024	0.018	3	0.061	0.035	3	0.024	0.009	3	0.012	0.009
		TMM	74	100.4	3	0.050	0.030	3	0.071	0.050	3	0.087	0.100	3	0.064	0.050
South San Francisco Bay																
	Alameda															
		CGIS	123	1.3				1		0	3	0	0			
	San Leandro Bay															
		AICH	125	4.9	3	0.324	0.813	3	0.075	1.219	3	0.241	2.032	3	0.047	1.219
		ALAM	126	1.6	1	0.073	0.608	3	0.029	1.217	3	0.059	1.217	3	0	0
		ARHE	127	16.9	3	1.699	5.155	3	6.066	8.177	2	9.576	8.296	1		6.637**
		BFIS	128	3.0	1	0.147	1.317	3	0.115	1.647	3	0.157	2.305	3	0.010	0.329
		COCH	129	6.8	1	0	0	3	0	0	3	0.073	0.147	3	0.049	0.294
		DOPO	131	1.2	1	0.110	1.645	3	0.183	0.823	3	0.257	3.290	3	0.257	5.758
		ELRO	132	6.9	4		1.746**	3	0.314	1.600	4	0.134	0.727	3	0.052	0.582
		FANM	133	8.7	1	0.881	0.461	3	0.697	0.692	3	1.258	1.846	3	0.514	1.153
		MLKS	134	18.5	3		0.216**	3	0.302	0.971	4	0.167	0.917	3	0.096	0.378
		NEMA	135	14.0	2		0.428**	3	0.608	1.641	3	1.145	2.926	3	0.346	1.073
		SLEA	136	4.0	3	0.055	0.249	3	0.060	0.998	3	0.110	1.746	3	0.063	0.998

Appendix 2 continued.

Bay	Complex	Site	Map ID	Site Area (ha)	2005 # visits	2005 Density (DISTANCE)	2005 Density (Observed)	2006 # visits	2006 Density (DISTANCE)	2006 Density (Observed)	2007 # visits	2007 Density (DISTANCE)	2007 Density (Observed)	2008 # visits	2008 Density (DISTANCE)	2008 Density (Observed)
South San Francisco Bay																
	Hayward Shoreline															
		BOCH	145	1.0	2	0	0	3	0	0	3	0	0	3	0	0
		BUNK	143	13.4	3	0.299	0.373	3	0.367	0.522	3	0.165	0.224	3	0.073	0.149
		CITA	142	44.5	3	0.140	0.112	3	0.231	0.090	3	0.461	0.202	3	0.241	0.225
		COGS	146	76.6	3		0.496**	4	0.592	0.836	3	0.538	0.875	3	0.256	0.359
		DOGB	141	2.8	2	0	0	3	0.024	0.351	3	0.049	0.702	3	0	0
		EAST	140	14.8	3	0.147	0.000									
		HALA	147	4.7	2	0	0	3	0.061	0.213	3	0	0	3	0	0
		HARD	148	26.4										3	0	0
		JOLA	149	5.0	1	0	0	3	0.157	0.000	3	0.049	0.200	3	0.083	0.601
		NORT	139	35.7	3	0.257	0.196	3	0.273	0.252	3	0.262	0.224	3	0.165	0.196
		ORLE	150	79.7							4	0.110	0.000	3	0.021	0.000
		ORLW	151	52.9	4		0.113**	3	0.108	0.246	4	0.091	0.246	3	0.016	0.094
		SLRZ	152	12.7	3	0.220	0.394	3	0.220	0.551	3	0.248	0.788	3	0.037	0.315
		SULF	154	3.3	1	0.257	0.299				4	0.202	0.000	3	0.024	0.299
		TRMA	155	5.0				2	0.110	0.200						
	Baumberg															
		WTM	156	66.2	1	0.028	0.038***	1		0.060**	2		0.098**	2		0.045**
		ALCK	158	66.3	2		0.332**									
		WTS	160	59.1	2		0.144**	1		0.186**						
		CAMM	159	18.6	2		0.215**	1		0.483**	2		0.322**	2		0**
		EDEN	157	19.0										1		0**
	AFCC / Ideal															
		PND3	165	52.1	3		0.096**	2		.0115**	2		0.211**	3		0.134**
		AFCC	161	109.0	3		0.367**	2		0.395**	2		0.170**	2		0.206**
		IDEN	163	15.3	2		0.359**	3		0.490**	2		0.196**	1		0.131**
		IDES	164	51.4	3		0.078**	1		0.272**	2		0.224**	2		0.156**
	Dumbarton Pt.															
		DUMW	174	194.1	3	0.258	0.132	3	0.576	0.372	3	0.503	0.153	3	0.135	0.089
	Mowry / Calaveras															
		CAPT	182	180.2				3	1.02*		3	0.135	0.061			
		MOSL	178	45.9	3	0.134	0.184	3	0.78*					3	0.073	0.072
		MOWN	179	167.5										1		0.096**

Appendix 2 continued.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
South San Francisco Bay																
	Newark Slough															
		NEW	168	75.0	3	0.029	0.089	3	0.092	0.224	3	0.115	0.222	3	0.031	0.104
		LARI	166	44.0	2		0.364**	2		0.478**	2		0.500**	2		0.432**
	Coyote Creek															
		COYN	190	41.6				4	0.13*							
		COYSE	188	90.5				4	0.16*							
		MUDC	185	66.0				4	0*							
		COYS	189	48.4				4	0*							
	Alviso															
		ALSL	196	105.3							3	0	0			
		CHSL	200	16.9										3	0.024	0.059
		GUSL	195	89.8							3	0.009	0.011			
		LONG	197	7.5										3	0	0
		MAL	192	7.8							3	0.037	0.129			
		MVSL	198	27.5										3	0.037	0.036
	Palo Alto															
		COLA	206	70.3							3	0.028	0.028	3	0.037	0.043
		FABE	204	41.8	3	0.744	0.455	3	1.111	1.341	3	0.860	1.150	3	0.602	0.383
		LAUM	205	36.6	3	0.881	0.737	3	1.235	1.381	3	0.929	1.024	3	0.367	0.490
		PAB	202	45.8	3	0.231	0.240	3	0.597	0.502	3	0.608	0.524	3	0.168	0.153
		PAHA	201	41.3										3	0.159	0.145
	Ravenswood															
		RAV	207	48.2				3	0.321	0.270	3	0.210	0.249	3	0.063	0.083
		RAVO	208	14.4										3	0	0
	Bair / Greco															
		BELM	226	55.5										3	0.055	0.054
		CORK	221	80.4				3	0.294	0.162				1		0.50**
		FOST	228	3.7				1		0	3	0	0			
		GRIN	212	202.6	3	0.272	0.231	3	0.147	0.202	3	0.238	0.215	3	0.202	0.161
		GRIS	211	94.4				1		0.583**				1		0.424**
		MBE	218	82.5	3	0.660	0.529	3	1.101	0.691	3	0.836	0.556	3	0.367	0.278
		MBSE	217	78.9				3	0.061	0.125				3	0.183	0.255
		OBE	219	228.9	3	0.172	0.084	3	0.380	0.377	3	0.335	0.184	3	0.102	0.095
		RESH	223	70.6				3	0.206	0.479						

Appendix 2 continued.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
South San Francisco Bay																
	Bair / Greco															
		WPSN	210	2.4				3	0	0						
		WPSS	209	16.5				3	0	0	3	0	0	3	0	0
	Oyster Bay															
		MEGO	137	0.8	1	0	0									
		OYBA	138	7.3	3	0	0				3	0.037	0.412	3	0	0
	San Mateo															
		SACR	229	1.1				1	0	0	3	0	0			
		SEAL	227	23.5	2	0.587	0.213	3	0.489	0.810	3	0.734	1.705	3	0.073	0.256
	Burlingame															
		COPT	230	5.0	2	0	0				3	0	0			
		EACR	233	2.2				1	0	0	3	0	0			
		FMPK	231	0.6				1		0	3	0	0			
		MICR	235	1.7							3	0.044	0.582	3	0	0
		PAF	234	5.8	2	0	0	3	0	0	3	0	0	3	0	0
	SFO															
		SFO	236	38.0							3	0.091	0.131	3	0.035	0.053
	San Bruno_Colma															
		COCR	245	5.8				1	0.352	2.579	2	0.110	0.688	3	0.049	0.516
		NACH	242	1.8				1	0.550	2.807	1	0.220	1.123	3	0.257	0.157
		OLDM	241	2.1	1	0.440	0.955	2	0.000	0.477	3	0.073	0.000	3	0	0
		SABR	240	2.3	1	0.440	0.886				3	0.000	0.443	3	0	0
		SBPT	239	0.6							3	0.037	1.622	3	0.055	1.622
		SBRN	238	14.3	1	0.807	1.680	3	0.294	0.560	3	0.491	1.050	3	0.294	1.050
		SBRS	237	5.7	3	1.125	5.416	3	0.697	5.591	3	0.416	3.319	3	0.135	0.131
	South San Francisco															
		BRLA	250	7.3				1		0				3	0	0
		CAND	252	0.8							3	0	0			
		OYPC	246	1.3				1	0.220	0.786	3	0.037	0.786	3	0	0
		OYPM	247	1.2				1	0	0	3	0	0	3	0	0
		OYPP	248	0.9				1	0	0	3	0	0	3	0	0
		SIPT	251	1.1							3	0.110	2.851	3	0.073	1.901

Appendix 2 continued.

					2005			2006			2007			2008		
Bay	Complex	Site	Map ID	Site Area (ha)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)	# visits	Density (DISTANCE)	Density (Observed)
Suisun Bay & Carquinez Strait																
	Carquinez Strait															
		MZF	259	43.8				3	0	0						
		SBM	258	72.2				1	0.073	0.028						
	North Suisun															
		FMSL	277	169.8	1	0	0	1	0.010	0.006	1	0	0	1		0
		GIF	278	6.3				1	0	0						
		GRIZ	271	37.0				1	0	0						
		HEF	282	23.8	1	0	0	1	0	0				1		0
		HINE	281	124.1				1	0	0	1	0	0	1		0
		HISE	280	125.2	1	0	0	1	0	0	1	0	0	1		0
		HWF	283	12.7				1	0	0						
		MNTZ	274	553.4							1	0	0			
		PEYA	284	179.5				1	0	0	2	0	0			
		RRA	276	37.8	1	0	0	1	0.016	0	1	0	0	1		0
		SMSL	275	313.4	1	0	0	1	0	0	2	0	0	1		0
		BLAR	288	27.3										1		0
	South Suisun															
		BHM	295	171.4	1	0	0									
		PEM	296	419.8	1	0	0	1	0.037	0.005	1	0	0			
		ROEIS	294	91.2				1	0	0	1	0	0			
	West Suisun															
		GSB	265	78.5				1	0	0				1	N/A	0.020
		JOIC	270	111.5	1	0	0	1	0	0	2	0	0	1		0
		MORR	266	48.0	1	0	0									
		NAVY	260	1.6	2	0	0									
		RVFT	261	93.8	1	0	0	1	0	0	2	0	0	1		0
Delta																
	West Delta															
		BRIS	301	276.4	2	0	0				1	0	0			
		SHIS	302	393.2	2	0	0									

*=HT Harvey methods

**=Summary data

***=Summary data, 2 rounds