Regional Trends in California Clapper Rail Abundance at Non-native *Spartina*-invaded Sites in the San Francisco Estuary from 2005 to 2007
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INTRODUCTION

In the last several decades, four non-native species of cordgrasses have been introduced to the San Francisco Estuary. One of the non-native cordgrass species, Atlantic smooth cordgrass (Spartina alterniflora) hybridized with native S. foliosa, producing an extremely robust and fertile “hybrid swarm” (Ayres 1999). The hybrid Spartina rapidly spread throughout the Estuary, modifying the ecological structure of both tidal marshes and mudflats. The Invasive Spartina Project (ISP) was created by the State Coastal Conservancy to arrest and reverse the spread of all four non-native cordgrass species in the Estuary. In addition to the coordinated effort to control invasive Spartina, ISP is tasked with annual monitoring of the California clapper rail at sites targeted for treatment.

The California clapper rail is an obligate tidal marsh bird with a geographic range currently limited to the San Francisco Estuary. It is classified an endangered species by both the federal and state governments. The spread of hybrid Spartina has had a large impact on clapper rail habitat, particularly in San Francisco Bay (south of the San Francisco-Oakland Bay Bridge) where the invasion began. To assess the effects of non-native Spartina and its removal, the ISP has been conducting breeding-season clapper rail surveys since 2005, before the first summer of bay-wide Spartina treatment. The data collected provide information on the distribution and abundance of rails at sites slated for Spartina control, guiding annual Spartina treatment strategies. Survey results are compared by year to detect any changes in clapper rail abundance before and after Spartina treatment.

This report presents the analysis of three years of clapper rail survey data at 60 sites, spanning six different regions in the San Francisco Bay (Figure 1). Data were collected by six organizations involved in California clapper rail recovery: Avocet Research Associates (ARA), East Bay Regional Park District (EBRPD), HT Harvey and Associates (HTH), Invasive Spartina Project, PRBO Conservation Science (PRBO), and U.S. Fish and Wildlife Service (USFWS). Abundances were estimated at each site and summed by region. The population trend was calculated for each region and for all sites combined (bay-wide). We found that in four of the six regions, clapper rail abundances appear to be stable or increasing. The two regions with the least impact from Spartina treatment seem to be stable or declining. The overall bay-wide trend in clapper rail abundances appears to be stable or increasing. Based the results of surveys conducted between 2005 and 2007, the impact of Spartina treatment on regional clapper rail populations seems to be negligible.

STUDY AREA

The scope of this study was limited to Spartina invaded marshes and mudflats in the Central and South San Francisco Bay spanning the counties of Marin, San Francisco, San Mateo, Santa Clara, Alameda, and Contra Costa. Sites were surveyed by several Bay Area organizations involved in California clapper rail recovery: ARA, EBRPD, HTH, ISP, PRBO, and USFWS. Site boundaries were defined prior to the start of this study by the ISP Control Program in order to identify regions of Spartina invasion to target for treatment.

This report includes data from 60 survey sites collected over a three-year period representing approximately 4,088 acres (1,654 hectares) of tidal marsh habitat. Only sites with three years of consecutive call count data were included in this analysis.

To analyze broader-scale trends in California clapper rail abundance, sites were grouped into larger regional boundaries, based on areas designated by USFWS (Figure 1). Each region is composed of a varying number of Spartina treatment sites and area of tidal marsh habitat (Appendix...
Of the ten defined regions, only six are presented in this report: San Leandro Bay; Hayward; East Bay; Don Edwards National Wildlife Refuge (D.E.N.W.R.); West Bay; and San Francisco Peninsula.

![Regional boundaries of the clapper rail survey areas.](image)
METHODS

Breeding season call count surveys for the California clapper rail were conducted for three consecutive years beginning in 2005. The data provided in this report are the combined effort of several regional organizations permitted to conduct clapper rail surveys (ARA, EBRPD, HTH, ISP, PRBO, and USFWS). All contributors met annually before the clapper rail survey season in order to maintain consistent methodology across all surveyors.

FIELD METHODS

California clapper rail breeding-season call-count surveys were conducted annually between January 15 and April 15 using standardized survey protocols approved by the U.S. Fish and Wildlife Service (Appendix 2). Surveys were conducted during a two hour window around sunrise or sunset. Except for sites which required high tides for boat access, no surveys were conducted when tides were above 4.5 feet. Because rails are more exposed to nocturnal and crepuscular predators during full moon periods, surveys were not scheduled during the full moon. Additionally, surveys were cancelled during rain or winds greater than ten miles per hour (10 mph).

Typically, survey stations were placed at 200-meter (m) intervals on peripheral paths around the site. In large marsh parcels, PRBO surveyors placed stations at 400 m intervals, as recommended by Conway in Standardized North American Marsh Bird Monitoring Protocols (2005). The number of survey stations established at each site varied due to site size, configuration, and accessibility. The locations of the survey stations were entered into a GIS and navigated to in the field using a GPS unit. For consistency and repeatability, all efforts were made to use the same survey station locations that were established during the previous survey seasons.

Sites were surveyed three times during each breeding season, except when weather and time did not permit for the completion of three rounds (Table 1, Appendix 1). Effort was made to maintain at least one week between replicate surveys to disperse the counts throughout the breeding season.

Each survey station was visited by a trained observer once per round for 10 minutes. All rails detected either visually or aurally were recorded. For each bird or pair of birds that were detected, the observer recorded: (1) the number of birds, (2) the call type, and (3) the time detected. Additionally, most surveyors recorded the approximate locations of each rail/pair on a field map of the site (except EBRPD).

Because of the secretive nature of marsh birds, rails may not be detected during passive listening surveys. The use of broadcast calls to elicit vocalizations significantly increases the detection probability of most rails (Gibbs and Melvin 1993). In our study, broadcast calls were typically used only during the final round of surveys if no clapper rails had been previously detected within 200 meters of the survey station. However, at sites with no previous documentation of clapper rails and with marginal rail habitat associations, ARA and ISP conducted active surveys, using broadcast calls during each round (Appendix 3-5). Clapper rail calls were broadcast after five minutes of passive listening at the station. The pre-recorded vocalizations were provided by U.S. Fish and Wildlife Service (Joy Albertson) and were played for one minute from a compact disc player with portable speakers. If a clapper rail responded during the broadcast call, the speakers and player were immediately turned off.
DATA COLLECTION AND MANAGEMENT

Field data were typically entered manually on preprinted data forms. However, some surveyors preferred to record all data on a field map. Original datasheets were photocopied and duplicates were housed in separate locations.

Data were entered into an electronic spreadsheet as soon after collection as possible. Each of the contributing organizations maintained their own dataset. ISP and PRBO Conservation Science entered data into an Access database, originally developed by PRBO. ARA and USFWS both entered and stored data in excel spreadsheets. Data for Arrowhead Marsh were provided by EBRPD and entered by ISP into the Access database for analysis. Data were proofed against original datasheets for accuracy.

Additionally, ISP and USFWS plotted estimates of clapper rail locations into a GIS. At higher density sites, locations were triangulated from multiple survey stations improving the estimate of numbers detected during each round. ISP linked the spatial data contained in a GIS to the data stored in tabular format in Access to create a personal geodatabase (a collection of geographic datasets contained in an Access database).

Clapper rail distribution data were annually submitted to the California Natural Diversity Database, as required by state permits. Additionally, all data were shared with PRBO Conservation Science for future analysis of bay-wide California clapper rail populations.

DATA INTERPRETATION AND ANALYSIS

The number of unique detections (no repeat detections) was tallied for each site every round. Each type of detection (clatter, duet, kek, visual, etc.) represented a standardized range of individual clapper rails. For instance, a clatter, which may represent a single unmated bird or a pair, was counted as 1.5 birds. Birds that were detected from more than one station or by more than one observer during a single round were counted only once toward the final tally. These ranges were summed and averaged for each site every round to estimate the mean number of rails detected by site for each year.

Because not all sites were surveyed from the same survey stations each year, an index of abundance was calculated to compare sites across years. First, survey area was estimated in a GIS by calculating a 200 meter buffer around each survey station clipped at the marsh perimeter. A 200 m buffer was chosen because error in observer detection increases at distances beyond 200 m. Next, the mean number of rails detected was divided by the survey area to estimate the number of clapper rails per unit area. This was our index of abundance, or estimated density. The estimate of site abundance (clapper rails per site) was calculated from the product of the density by site area.

We used a linear regression to analyze the clapper rail abundance estimates at each site by year, using year as the independent variable to produce a slope for each site across the three years of the study. We then averaged the regression slope for all sites across each region to assess the regional trend in clapper rail abundance.
RESULTS

Data used in this analysis represents the results of 439 breeding-season call-count surveys conducted between 2005 and 2007 at 60 sites in the San Francisco Bay.

In 2005, we conducted 136 rounds of surveys and detected a mean of 434 clapper rails. The mean bay-wide density in 2005 was 0.233 rails per acre (0.576 rails/ha), or about 548 rails at all sites combined. In 2006, we conducted 144 rounds of surveys and detected n = 563 clapper rails. The average density was 0.274 rails per acre (0.677 rails/HA), or about 757 rails in the entire study area. In 2007, we conducted 159 rounds of surveys and detected 575 clapper rails. The bay-wide average density was 0.282 rails per acre (0.696 rails/HA) in 2007, or about 709 rails bay-wide. The mean trend in bay-wide abundance was +1.34% annually, calculated from the mean slope of site regression lines. The slopes ranged from -8.4 at Outer Bair (ISP Sub-site 02c, or “02c”) to +23.62 at Arrowhead Marsh (17c) (Table 2, Appendix 1).

Table 1. Summary of clapper rail abundance estimates and trends in the San Francisco Bay

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Sites</th>
<th>Area (acres)</th>
<th>Regional Abundance</th>
<th>Regional Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>San Leandro Bay</td>
<td>10</td>
<td>198</td>
<td>142</td>
<td>218</td>
</tr>
<tr>
<td>Hayward Region</td>
<td>14</td>
<td>848</td>
<td>67</td>
<td>104</td>
</tr>
<tr>
<td>East Bay Region</td>
<td>14</td>
<td>1082</td>
<td>108</td>
<td>155</td>
</tr>
<tr>
<td>D.E.N.W.R.</td>
<td>3</td>
<td>826</td>
<td>63</td>
<td>117</td>
</tr>
<tr>
<td>West Bay Region</td>
<td>2</td>
<td>949</td>
<td>87</td>
<td>103</td>
</tr>
<tr>
<td>San Francisco Peninsula</td>
<td>17</td>
<td>185</td>
<td>80</td>
<td>62</td>
</tr>
<tr>
<td>All Regions</td>
<td>60</td>
<td>4088</td>
<td>548</td>
<td>757</td>
</tr>
</tbody>
</table>

Figure 2. San Francisco Bay clapper rail abundance estimate trends by survey regions

SAN LEANDRO BAY REGION

San Leandro Bay is an urbanized region that has been heavily invaded by hybrid *Spartina*. Recent treatment of the cordgrass by the ISP Control Program has been very effective. The region contains 14 sites, encompassing 198 acres (80 hectares) of marsh habitat (*Appendix 1*). In 2005, 22 rounds of surveys were conducted and about 135 clapper rails were detected. The average regional density was 0.608 rails/acre (1.507 rails/HA). The estimated regional abundance for 2005 was 135 rails per region. In 2006, 201 clapper rails were detected during 30 rounds of surveys in the San Leandro Bay region. The regional density estimate in 2006 was 0.718 rails/acre (1.774 rails/HA) and the regional abundance estimate for was 201 rails/region. In 2007, another 30 rounds of surveys were conducted and about 225 clapper rails were detected in the Hayward and San Leandro region. The mean density in 2007 was 0.865 rails/acre (2.136 rails/HA) and the annual abundance estimate was 225 rails/region. The mean trend in regional abundance was +4.71% annually, ranging from -1.44 at Elsie Roemer (17a) to +23.62 at Arrowhead Marsh (17c) (*Table 2, Appendix 1*). Because data from Arrowhead Marsh were calculated using a unique data interpretation protocol and because Arrowhead Marsh supports more than half of the clapper rail abundance in the region, this site likely drives the observed trend.

To assess the larger-scale trend of the region, data from San Leandro Bay were recalculated excluding Arrowhead Marsh (17c). Excluding Arrowhead, the mean density for the San Leandro Bay region in 2005 was 0.422 rails/acre (1.043 rails/HA); in 2006, it was 0.441 rails/acre (1.089 rails/HA); and in 2007, it was 0.582 rails/acre (1.437 rails/HA). The estimated annual abundance for the region was 47 rails in 2005, 84 rails in 2006, and 94 rails in 2007. The mean trend in regional abundance became +2.613% annually, ranging from -1.44 at Elsie Roemer (17a) to +12.50 at MLK Restoration Marsh (17h).
Figure 4. San Leandro Bay Region clapper rail abundance estimate trends by site area
HAYWARD REGION

The Hayward and San Leandro region contains 14 sites, encompassing 848 acres (343 hectares) of marsh habitat (Appendix 1). This area historically has had a relatively heavy Spartina infestation; however, effective treatment in 2006 and 2007 has reduced Spartina acreage in the region. In 2005, 37 rounds of surveys were conducted and about 67 clapper rails were detected. The average regional density was 0.074 rails/acre (0.184 rails/HA). The estimated regional abundance for 2005 was 67 rails per region. In 2006, 102 clapper rails were detected during 42 rounds of surveys in the Hayward and San Leandro region. The regional density estimate in 2006 was 0.136 rails/acre (0.336 rails/HA) and the regional abundance estimate for was 102 rails/region. In 2007, 43 rounds of surveys were conducted and about 110 clapper rails were detected in the Hayward and San Leandro region. The mean density in 2007 was 0.139 rails/acre (0.345 rails/HA) and the annual abundance estimate was 110 rails/region. The mean trend in regional abundance was +1.56% annually, ranging from -1.50 at Oro Loma West (07b) to +5.66 at North Marsh (20f) (Table 2, Appendix 1).

Figure 5. Hayward Region site and regional boundaries
Figure 6. Hayward Region clapper rail abundance estimate trends by site area
EAST BAY REGION

The region of East Bay between Highway 92 and 84 (East Bay) contains 14 sites, encompassing 1082 acres (438 hectares) of tidal marsh habitat (Appendix 1). This area has a moderate level of Spartina invasion. In 2005, USFWS conducted a total of 32 rounds of surveys and detected about 93 clapper rails. The average regional density was 0.123 rails/acre (0.305 rails/HA). Extrapolated to the entire area, the estimated regional abundance for 2005 was 108 rails/region. In 2006, USFWS detected 127 clapper rails during 25 rounds of surveys in the East Bay region. The regional density estimate in 2006 was 0.168 rails/acre (0.416 rails/HA). The regional abundance estimate for the year was 155 rails per region. In 2007, USFWS conducted 28 rounds of surveys and detected about 106 clapper rails in the East Bay region. The mean density in 2007 was 0.125 rails/acre (0.308 rails/HA) and the annual abundance estimate was 137 rails/region. The mean trend in regional abundance was +1.03% annually, ranging from -7.00 at AFCC Lower Channel (01b) to +9.14 at South Whale’s Tail (13e) (Table 2, Appendix 1).

Figure 7. East Bay Region site and regional boundaries
Figure 8. East Bay Region clapper rail abundance estimate trends by site area

\[ R^2 = 0.3767 \]
The Don Edwards National Wildlife Refuge (D.E.N.W.R.) region consists of three large sites with a relatively small level of *Spartina* invasion. The region encompasses about 826 acres (334 hectares) of tidal marsh habitat (*Appendix 1*). In 2005, eight rounds of surveys were conducted in the region and about 32 clapper rails were detected. The average regional density was 0.079 rails/acre (0.195 rails/HA). Extrapolated to the entire regional area, the estimated regional abundance in 2005 was 63 rails per region. In 2006, about 53.8 clapper rails were detected during another eight rounds of surveys in the D.E.N.W.R. region. The regional density estimate increased in 2006 to 0.142 rails/acre (0.351 rails/HA). The regional abundance estimate for the year was 117 rails per region. In 2007, eight rounds of surveys were conducted and 48 clapper rails were detected in D.E.N.W.R. region. The mean density in 2007 was 0.126 rails/acre (0.311 rails/HA) and the annual abundance estimate was 93 rails/region. The mean trend in regional abundance was +5.11% annually, ranging from +3.0 at LaRiviere (05d) to +6.4 at Newark Slough (05e) (*Table 2, Appendix 1*).
Figure 10. Don Edwards National Wildlife Refuge clapper rail abundance estimate trends by site area
WEST BAY REGION

The region of West Bay between Highway 92 and 84 (West Bay) includes only two large sites with three consecutive years of data. Because of the small number of sites included in the analysis, the regional estimates lack accuracy. The two sites within this region are Outer Bair (02c) and Greco Island North (02f) and total to about 949 acres (384 hectares) of tidal marsh habitat (Appendix 1). In 2005, six rounds of surveys were conducted in the West Bay region and about 28 clapper rails were detected. The average regional density was 0.092 rails/acre (0.228 rails/HA). Extrapolated to the entire regional area, the estimated regional abundance in 2005 was 87 rails per region. In 2006, about 16 clapper rails were detected during another six rounds of surveys in the West Bay region. The regional density estimate in 2006 was 0.112 rails/acre (0.276 rails/HA). The regional abundance estimate for the year was 103 rails per region. In 2007, five rounds of surveys were conducted and 23 clapper rails were detected in the West Bay region. The mean density in 2007 was 0.074 rails/acre (0.177 rails/HA) and the annual abundance estimate was 68 rails/region. The mean trend in regional abundance was -4.76% annually, ([-1.10] at Greco Island North and [-8.41] at Outer Bair) (Table 2, Appendix 1).
Figure 12. West Bay Region clapper rail abundance estimate trends by site area clapper rail abundance estimate trends by site area
The San Francisco Peninsula region spans San Francisco and San Mateo counties and includes 17 fairly small sites (mean site area = 10.9 acres). The sum of site areas for this region tallies to 185 acres (75 hectares) of fragmented marsh habitat (Appendix 1). In 2005, 31 rounds of surveys were conducted and about 80 clapper rails were detected. Because site area and survey area were identical, the regional abundance estimate was 80 rails/region. The average regional density in 2005 was 0.277 rails/acre (0.685 rails/HA). In 2006, about 62 clapper rails were detected during 33 rounds of surveys in the San Francisco Peninsula region. The regional density estimate in 2006 was 0.255 rails/acre (0.631 rails/HA) and the regional abundance estimate was 62 rails/region. In 2007, 45 rounds of surveys were conducted and 63 clapper rails were detected in this region. The mean density in 2007 was 0.238 rails/acre (0.587 rails/HA) and the annual abundance estimate was 63 rails/region. The mean trend in regional abundance was -0.50% annual change, ranging from -7.25 at Inner Harbor (18d) to +4.8 at Seal Slough (19p) (Table 2, Appendix 1).
Figure 14. San Francisco Peninsula Region clapper rail abundance estimate trends by site area
DISCUSSION

Our analysis for the period 2005-2007 indicate that clapper rail populations in the San Francisco Bay may be in an upward trajectory, as indicated by the mean slope +1.34% annual change in abundance. Of the six regions analyzed for this study, the four regions on the eastern side of the bay (San Leandro Bay, Hayward, East Bay, and D.E.N.W.R.) also show an increasing trend in abundance. The two regions on the western side of the bay (Peninsula and West Bay), on the other hand, have negative trends and may indicate a decline in the trajectories of these regional abundances. However, Conway (2005) warns that reliable estimates of population trends require at least five years of survey data. Bias can result if the first or last year of the study period represents outlier data. For instance, a smaller survey effort may have suppressed clapper rail estimates during the first year of the study, biasing the overall trend in a positive direction.

We indirectly assessed the impacts of *Spartina* treatment on clapper rail populations in the San Francisco Bay by estimating bay-wide rail abundances across the three years of *Spartina* treatment (2005-2007). Because we did not quantify *Spartina* abundance, we cannot correlate any effects of the ISP Control Program with changes in clapper rail abundance and distribution. However, six of the sites in the San Francisco Peninsula region (the entire Colma Creek complex) showed declining trend lines although no *Spartina* control took place at those sites until after the period of this study. Additionally, the site with the largest negative trend in clapper rail populations, Outer Bair North, has only a moderate hybrid invasion and minimal impacts from *Spartina* control (aerially treated once per year). Bay-wide and at other regions with larger impacts from *Spartina* control, clapper rail populations appear to be increasing. These observations seem to indicate that there is little to no relationship between the treatment of invasive *Spartina* and regional clapper rail populations.

There are many factors which may be influencing changes in clapper rail populations in the San Francisco Estuary. Foin et al. identified habitat quality as one of the contributing factors influencing clapper rail distribution and abundance (1997). California clapper rails are restricted to tidal marshes and prefer both low marsh habitat, with direct tidal circulation and emergent vegetation for cover while foraging; and high marsh habitat, with networks of tidal channels and nesting substrates above mean high water (Albertson 2000). Other factors that may contribute to clapper rail population fluctuations include: weather and flooding events (Schwarzbach 2006); contaminants, particularly mercury and barium (Schwarzbach 2001 & 2006); and fluctuations in predator populations, including predators of adult rails, such as the red fox (Harding 2001) and Northern Harriers (Foin 1997) and predators of rail nests, such as the Norway rat (Schwarzbach 2006). Because this study presents the summary of findings from multiple observers from several organizations, the data are noisy. Sources of variation other than changes in the clapper rail population sizes may be attributed to many factors. Unfortunately, we did not calculate an estimate of the detection probability to control for some of these variables, a shortcoming of this study. For our call-count surveys, the detection probability is defined by the product of the probability that a clapper rail will vocalize and the probability that the observer will detect the vocalization (Conway 2004). Factors influencing the probability of vocalization included: differences in time of survey (sunrise vs. sunset), differences in protocols (active vs. passive survey), and differences in season (early breeding season vs. late breeding season). Factors influencing the probability of observer detection included: differences in survey effort (e.g. number of rounds completed), any variation in survey area (e.g. number and placement of stations per site), and observer bias (e.g. errors in distance estimates). Our criteria for weather, tide phase, and moon phase were restricted by the
standard survey protocols; thus, some measure of control was gained over these three variables in our study. Future studies by PRBO Conservation Science plan to use this dataset summarize using more sophisticated statistical tools to estimate population trends while controlling for detection probability.

REFERENCES


