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MARSH STUDIES IN
SOUTH SAN FRANCISCO BAY:
2005 – 2008

CALIFORNIA CLAPPER RAIL AND
SALT MARSH HARVEST MOUSE
SURVEY REPORT, 2006

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1.0 EXECUTIVE SUMMARY

1.1. CALIFORNIA CLAPPER RAIL

Eight transects along marshes in the South San Francisco Bay that had been previously surveyed for the federally endangered California Clapper Rail (CCR) during the 1989 and 1990 breeding seasons were surveyed during the 2006 breeding season. Survey methods in 2006 differed from those used in 1989 and 1990, due to the requirement to follow the U.S. Fish and Wildlife Service's survey protocol in 2006, yet survey timing in 2006 differed from the protocol due to the inability to access levees during March and much of April as a result of rain. Nevertheless, data from these surveys provide an accurate assessment of the relative distribution of CCR in the marshes surveyed during the 2006 breeding season, and allow the relative abundance of CCR on a given transect to be compared between 1989, 1990, and 2006.

Marshes that were expected to have low to medium CCR densities ("low-density marshes" along Transects 4-8) were surveyed along transects partitioned with listening stations at 200-meter intervals; each station was surveyed with 10-minute passive listening sessions on four separate days. Marshes expected to have high CCR densities ("high-density marshes" along Transects 1-3) were surveyed from stationary listening positions at 200-meter intervals; each station was surveyed with 90-minute passive listening sessions on three separate days. Surveys were conducted between 9 February and 9 May 2006. CCR detections were mapped based on survey results, and duplicate detections were omitted from the dataset before distance sampling was used to estimate CCR densities for each transect.

Large numbers of CCR were detected on Transects 1, 2, 3, and 5, but relatively few CCR were detected on Transect 4, and none were detected on Transects 6, 7, or 8. Two additional 90-minute surveys at single stations on Transects 6 and 7, and three additional 90-minute surveys at stations on Transect 8, also failed to detect any CCR. To compensate for differences in survey effort between high-density and low-density transects, data from the first 10 minutes of each survey along the high-density transects were used for comparison with data from the low-density transects, allowing a rough comparison of abundance among transects. The proportion of CCR detected on a given transect was highest on Transect 5 (Goose Point Marsh). The most notable differences in relative CCR abundance among years were that CCR were detected on Transects 7 (Warm Springs Marsh) and 8 (South Coyote Slough Marsh) in 1990, but not in 1989 or 2006, and that CCR were not detected in 2006 on Transect 6 (Triangle Marsh), where they were detected in fairly high numbers in 1989 and 1990. The relatively high number of CCR detected on Transect 5 in 2006, compared to 1989 and 1990, is also notable.

Changes in habitat suitability, changes in predator abundance and distribution, and changes in distribution as a result of variability in overall CCR populations in the South Bay were considered as potential reasons for the differences in relative distribution of CCR among the three years considered. The increase in CCR abundance at Transect 5 (Goose Point Marsh) between 1989/1990 and 2006 cannot be clearly linked to the increase in alkali bulrush at this location, as the brackish marshes dominated by alkali bulrush lacked CCR altogether in 2006. However, the decrease in CCR abundance at Transect 6 (Triangle Marsh), where peppergrass increased at the expense of pickleweed between 1989 and 2006, and the increase in CCR abundance at Transect 2 (Calaveras Point), where cordgrass and alkali bulrush cover increased as did overall acreage of tidal marsh, are likely reflections of changes in CCR habitat quality and extent. However, the extent to which vegetation changes have affected the distribution and abundance of CCR in the study area is unclear. The most obvious evidence suggesting that factors other than vegetation changes are responsible for a substantial portion of interannual variability in CCR numbers is the dramatic change in CCR abundance in brackish marshes between 1989 and 1990, despite fairly consistent vegetation conditions in those marshes during the two years.

Although mammalian predator abundance has likely decreased in these South Bay marshes since 1990 due to a control program on Refuge lands, avian predators, especially California Gulls and Common Ravens, have increased considerably. If 2006 CCR numbers in the South Bay were low in response to one or more factors unrelated to habitat (*e.g.*, predation, low food supplies, or poor productivity in previous years), it is also possible that CCR distributed themselves according to habitat preference, so that preferred salt marsh and transitional habitats were occupied first, and no "excess" of CCR was present to occupy brackish marshes.

1.2. SALT MARSH HARVEST MOUSE

Three marshes in the South San Francisco Bay previously surveyed for the federally endangered salt marsh harvest mouse (SMHM) in late summer 1990 (Calaveras Point, Triangle, and Warm Springs marshes) were surveyed again in late August and September of 2006. These marshes were surveyed for a total of 2,000 trap nights in a two-phase study of the abundance and habitat use of the SMHM. The purpose of the first phase of this present study was to determine whether the densities of SMHM in the South Bay have changed over the last 16 years along with the observed changes in marsh vegetation and structure that have occurred during that time period.

The number of SMHM trapped in this phase of the 2006 study was not significantly different from the number trapped in these marshes in 1990 (H. T. Harvey & Associates 1990a, 1990b). The number of SMHM captured did not significantly change in spite of the fact that the vegetation in the marshes had changed substantially in the intervening 16 years. These vegetation changes included Calaveras Point Marsh more than doubling in depth and developing a more complex vegetation mosaic, Triangle Marsh becoming more dominated by brackish alkali bulrush, and Warm Spring Marsh having a greater percent cover of invasive peppergrass. These results suggest that the marshes have approximately the same density of harvest mice that they did in 1990, even though there have been considerable changes in vegetative cover.

During the second phase of the 2006 study, surveys were performed in mid-September during high tides that inundated the marsh plain. The purpose of this second phase was to determine whether SMHM preferentially utilize the higher portions of brackish alkali bulrush habitat during high tide events. For this phase, traps were placed approximately 1 meter above the marsh plain in the thick thatch of the alkali bulrush. This differs from the more typical SMHM trapping method of placing the traps directly on the substrate of the marsh plain during an especially low tidal cycle, which was the technique used in Phase One and in the 1990 study. This second trapping was performed only in the brackish Warm Springs Marsh and the transitional Triangle Marsh, both of which are dominated by alkali bulrush. This was the first time this method of trapping has been employed in the southern San Francisco Bay.

The number of SMHM captured at Triangle Marsh were not significantly different between the first and second phases, but the number captured in the second phase at Warm Springs Marsh was marginally significantly greater (p=0.056) than the number captured in Phase One. These data indicate that SMHM utilize brackish alkali bulrush habitat to a greater extent that previously thought, and in particular appear to preferentially utilize such habitat above the thatch layer during high tides. It is noted that the 8 individuals captured in Phase Two is approximately half of the density of SMHM captured at saline Calaveras Marsh or transitional Triangle Marsh. This reveals a previously unknown aspect of SMHM habitat use in the southern San Francisco Bay.

The degree to which SMHM in general use stands of alkali bulrush, however, cannot be determined by our results. Further study will be needed to ascertain whether alkali bulrush is a typical part of the habitat of the SMHM in the more brackish marshes of southern San Francisco Bay, and what its relative habitat value is to the endangered SMHM. Additionally, vegetation correlation analyses indicate that SMHM are significantly negatively correlated with peppergrass, and their competitors are significantly positively correlated, suggesting that the spread of invasive peppergrass may reduce the quality of brackish marsh habitat for the SMHM.

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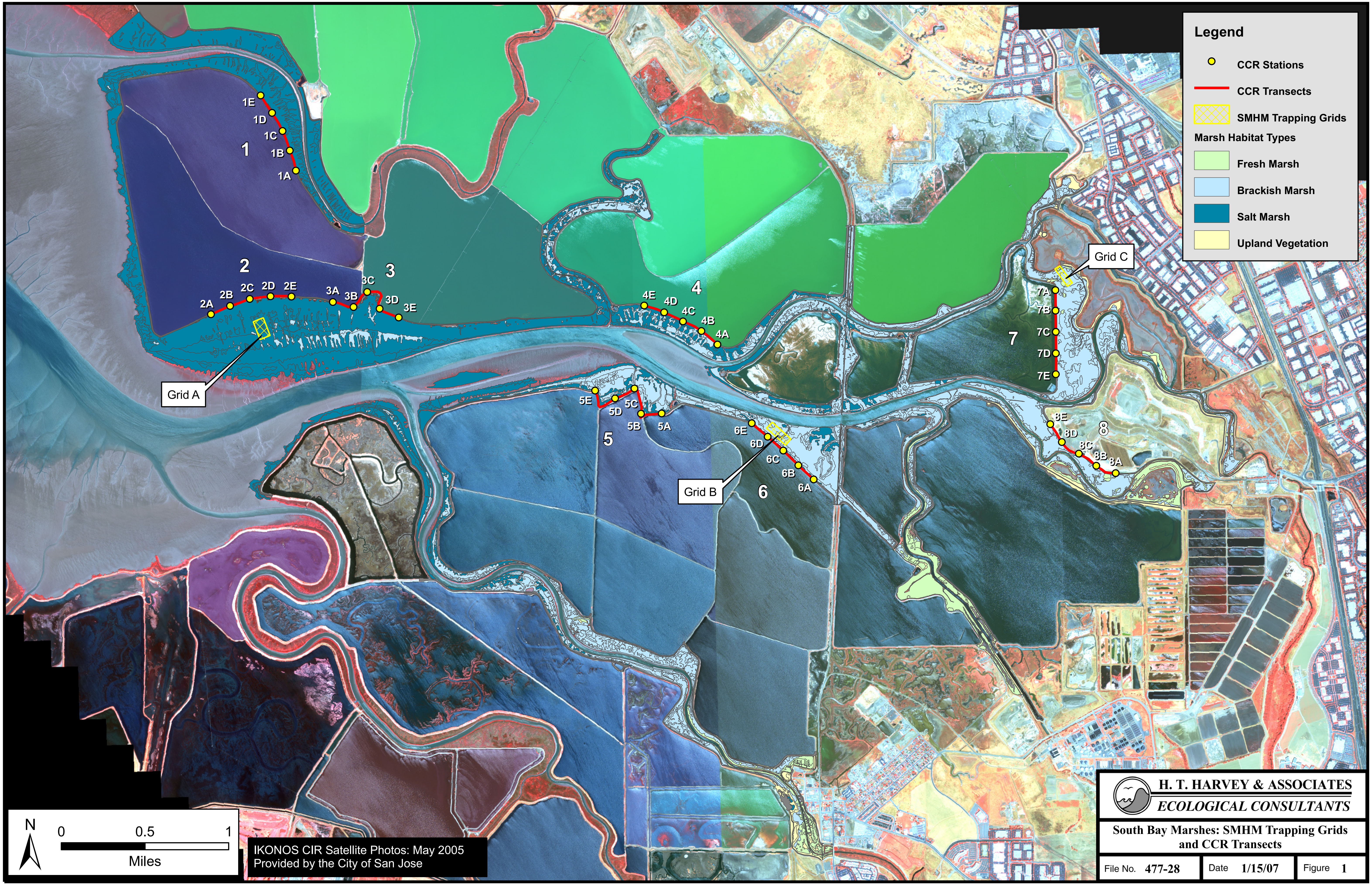
3.0 INTRODUCTION

Large-scale plant community changes in the marshes of South San Francisco Bay were first observed in the 1970s. Early studies conducted for the South Bay Dischargers Authority in 1984 confirmed those habitat changes. One of the contributing factors to decreased salinity in the South Bay is the freshwater effluent from the San Jose/Santa Clara Waste Water Treatment Plant. Both the Regional Water Quality Control Board and the State Water Resources Control Board recognized the effluent coming from the Plant as a potential contributor to Bay freshening and were concerned that this was leading to the conversion of South Bay salt marshes to brackish marshes. In 1989, as part of a monitoring program required by the San Francisco Bay Regional Water Quality Control Board, the City of San Jose commissioned a more detailed study of the marshes potentially affected by the freshwater discharge from the Water Pollution Control Plant (WPCP). Subsequent mapping studies were conducted in 1991, 1994, and annually thereafter. These studies documented changes in the distribution and aerial extent of salt, brackish and freshwater marsh.

Changes in marsh composition could potentially affect two wildlife species listed as Endangered or Threatened under the Federal Endangered Species Act, the California Clapper Rail (*Rallus longirostris obsoletus*; CCR) and the salt marsh harvest mouse (*Reithrodontomys raviventris*; SMHM). A breeding-season survey for the CCR was conducted in marshes of the South Bay in 1989 (H. T. Harvey & Associates 1989), and surveys for both of these species were conducted in 1990 (H. T. Harvey & Associates 1990a, 1990b, 1990e). This report represents a continuation of the WPCP monitoring program to remain in compliance with the City's Regional Water Quality Control Board discharge permit, which states: *In order to provide information on the presence or absence of California clapper rail and salt marsh harvest mouse, the Discharger will conduct a synoptic survey for these species in the year 2006. The Discharger shall submit to the Board, the CDFG, and the USFWS, Sacramento Office, its proposed survey work plan 6 months prior to beginning the survey. The final report shall be included with the annual South Bay Action Plan to be submitted by February 28th, 2007.*

Surveys conducted in 2006 comprised a level of effort similar to CCR and SMHM surveys conducted in 1990, and were performed in near-identical locations (Figure 1). The fundamental objectives of these surveys is to provide information on the presence or absence of these species in the main study area, to ascertain how the populations of these species may have changed since 1990, and to re-establish a baseline for further monitoring efforts. These surveys may also suggest whether the changes in salt marsh vegetation that have occurred since 1990 in South San Francisco Bay marshes has influenced longer-term population trends for these two wildlife species. Finally, these surveys further address the question of whether and to what degree brackish, or partially brackish, marshes can provide suitable habitat for the CCR and SMHM.



IKONOS CIR Satellite Photos: May 2005
Provided by the City of San Jose

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South Bay Marshes: SMHM Trapping Grids
and CCR Transects

File No. 477-28 | Date 1/15/07 | Figure 1

4.0 CLAPPER RAIL SURVEYS

4.1. BACKGROUND

Optimal habitat for the CCR consists of tidal salt marsh in San Francisco Bay with direct tidal circulation, an intricate network of tidal sloughs, pickleweed (*Salicornia virginica*) with cordgrass (*Spartina* spp.), gumplant (*Grindelia* spp.), and other high-marsh plants, and abundant and dense high-marsh vegetation for cover during high tides (Albertson and Evans 2000). Brackish marshes are also used as nesting habitat to some extent by CCR (Gill 1979, Albertson and Evens 2000), although the use of brackish marshes by CCR has reportedly varied among studies, and occasionally, among years (H. T. Harvey & Associates 1989, 1990e). Breeding-season surveys conducted by H. T. Harvey & Associates (1989) in the South Bay in 1989 detected no CCR in three brackish marshes but found the species along all transects in transitional and salt marshes. However, surveys conducted by the same observers in the same location the following year found CCR along all transects (H. T. Harvey & Associates 1990). Nevertheless, CCR densities in 1990 were highest on average in transitional and salt marshes, while densities were lowest in marshes categorized as brackish (H. T. Harvey & Associates 1990e).

A number of changes in the South Bay, with respect to CCR, have occurred since 1989 and 1990. The vegetation in a number of the transitional marshes of South San Francisco Bay has shifted toward greater predominance of species associated with brackish marsh conditions between 1989 and 2005 (H. T. Harvey & Associates 2005). If a decline in CCR densities in these marshes were observed in the 2006 surveys as compared to 1989 and 1990, this might suggest that the increasingly brackish nature of these marshes has adversely affected the CCR. Alternatively, no significant change in CCR densities in the transitional marshes between 1989/1990 and 2006 would imply that the changes in vegetation have not negatively impacted CCR populations, or that any negative influence of the vegetation change was not detectable in light of the other factors influencing the marshes since 1990. Beginning in 1991, intensive predator-control efforts have been enacted on Don Edwards San Francisco Bay National Wildlife Refuge (Refuge) lands in the South San Francisco Bay, which had a documented benefit to CCR populations (Harding et al. 1998). An increase in CCR densities between 1990 and 2006 could also be attributable to predator control. The salt marshes of Calaveras Point have significantly increased in total area and plant species diversity since 1989/1990 (H. T. Harvey & Associates 2004), potentially increasing the extent and improving the quality of habitat for the CCR.

It was also hoped that the 2006 survey would give further insight into whether brackish habitat dominated by alkali bulrush (*Scirpus robustus*) constitutes suitable habitat for CCR. While CCR have been observed in this habitat, they were recorded here in 1990 but not in 1989, and presence alone does not necessarily indicate that such habitat can truly support a CCR population (H. T. Harvey & Associates 1990e). It is possible that bulrush stands constitute low-quality "sink" habitat that is only occupied by those CCR that cannot obtain a territory in the higher quality "source" habitat of the salt or transitional marshes. In order to decisively conclude whether brackish marshes constitute sink habitat for CCR, the survival and reproduction of individual birds in the various marsh types would need to be measured (*e.g.*, Breininger and Carter 2002), which is beyond the scope of this study.

4.2. METHODS

Two general types of surveys, winter surveys and spring breeding-season surveys, have historically been conducted to estimate numbers of CCR in the San Francisco Bay. The USFWS and the CDFG typically conduct annual winter surveys from airboats at extreme high tides (*e.g.*, Foerster 1989). Breeding-season surveys are based on listening for calling pairs and individuals.

We conducted breeding season surveys in 2006 for comparison with breeding season surveys conducted in 1989 and 1990 (H. T. Harvey & Associates 1989, 1990a). Except as noted, survey methods in 2006 were consistent with the most recent protocol established by the USFWS and PRBO Conservation Science (J. Albertson, pers. comm.). This protocol has evolved over time, and methods in 2006 varied somewhat from methods used in 1989 and 1990. Differences in survey methods among different years are outlined in Table 1.

Table 1. Comparison of Survey Methods for California Clapper Rails in 1989, 1990, and 2006.

Methodological Considerations	**Year**		
	1989	1990	2006
Call Playback	Used if no spontaneous calls heard by sunset	Always	Never
Season	April 4-May 18	April 12-June 21	February 9-May 27
Time Between Surveys	1 day	1 day	≥6 days
Time of Day	Evening	Evening	Evening or Morning
Length of Survey	Up to 90 minutes walking on transect	4-5 minutes at each station	10 or 90 minutes at each station

The breeding-season surveys were conducted at eight marsh locations (Figure 1), all of which were previously surveyed in 1990 and seven of which were surveyed in 1989, and which represent a range of vegetation types from salt to transitional to brackish. Surveys were conducted from levees adjacent to marshes. In 2006, survey methods varied somewhat for marshes expected to have high CCR densities (sites 1-3) as compared to marshes expected to have low to medium CCR densities (sites 4-8). These differences, and other methodological differences between historic and current surveys, were dictated by the most recent USFWS protocol for the species. The determination as to which marshes would be considered low-density marshes and which were high-density marshes was made based on the assumption that pickleweed and cordgrass-dominated salt marsh would support greater densities of CCR than brackish marshes, per the results of the 1989 and 1990 surveys.

Marshes that were expected to have low to medium CCR densities (Transects 4-8) were surveyed along transects partitioned with listening stations at 200-meter intervals. These "low-density marshes" were surveyed with 10-minute passive listening sessions at each station along a transect on four separate days. Each survey of transects in low-density marshes was conducted by a single observer who walked from one station to the next between the 10-minute survey periods.

Marshes expected to have high CCR densities (Transects 1-3) were surveyed from stationary listening positions. Observers at these "high-density marshes" were present at each listening station for the entire 1.5-hour survey period. Stations again were placed at 200-meter intervals along a transect. High-density marshes were surveyed passively on three separate days. Some of these surveys at high-density sites were conducted by five surveyors simultaneously, but others were completed by fewer observers, on two sequential survey periods within 24 hours (usually within 12 hours).

In addition, several additional 90-minute surveys were conducted in certain low-density marshes. These surveys were conducted out of concern that conducting only 10-minute surveys at each station might miss CCR detections if densities were very low. These additional surveys were not conducted to aid in density estimation, but merely to determine if CCR may have been present in marshes where no other detections were made, or may have been more abundant that thought based on a few limited detections. Two additional 90-minute surveys were conducted at Transects 4, 6, and 7, and 3 additional surveys were conducted at Transect 8 (Appendix A).

At stations along transects in both low- and high-density marshes, surveyors listened for any CCR calls, and recorded the type of call, time, direction (using a handheld compass), and estimated distance to the call. Weather conditions were also recorded. No taped calls were used to elicit calls from CCR, since the USFWS protocol only allows taped calls prior to March 31, and only at sites at which at least two prior surveys have failed to detect CCR. As described below, weather delays forced us to survey into early May, preventing us from using taped calls. CCR call types noted in the surveys followed Massey and Zembal (1987) and included the *clapper*, which is characteristic of a bird of either sex; the *duet* (alternating clapper calls), designating a mated pair; the *kek*, usually from an unmated male; and the *kek-burr*, usually from an unmated female.

4.3. CCR SURVEY LOCATIONS

Eight marshes were surveyed in 2006 (Figure 1). These marshes (Mowry Slough West, Calaveras Point East I and II, Mud Slough West, Goose Point Marsh, Triangle Marsh, Warm Springs Marsh and South Coyote Slough) constitute a subset of the thirteen marshes surveyed in 1990. Warm Springs Marsh and South Coyote Slough are classified as brackish marshes, Triangle Marsh, Mud Slough West, and Goose Point are classified as transitional marshes, and Mowry Slough West and Calaveras Point East I and II are classified as salt marshes; these classifications have not changed since the 1989/1990 surveys. For all marshes, transect length was approximately 1000 meters, and five stations were established on each transect approximately 200 meters apart.

4.3.1 CCR Survey Timing

Surveys were conducted between 9 February and 9 May 2006. Because the optimal calling period is mid-January through March, every effort was made to complete the surveys prior to the end of March in accordance with the USFWS protocol. However, rain prohibited surveys on many dates due to the inability of surveyors to drive on salt-pond levees within 72 hours of rain and due to restrictions on the performance of surveys when rain and wind hamper the detectability of CCR. In March and the first half of April, there were no periods of greater than

72 hours without measurable precipitation, effectively eliminating our ability to conduct surveys between March 1 and late April. In addition, the new survey protocol calls for at least one week between surveys, a greater number of surveys at each station than previous protocols, and at high-density marshes, a much greater intensity of survey effort, with one person at a single location for 90 minutes. As a result, it was necessary to extend the survey period into early May to allow for an adequate number of surveys at each station.

Because poor weather precluded the completion of surveys within the season specified in the protocol (mid-January through March), H. T. Harvey & Associates senior wildlife ecologist Steve Rottenborn contacted Joy Albertson and Jim Browning of the USFWS on 27 April 2006 to discuss the appropriateness of continuing the surveys after March. Ms. Albertson confirmed that poor weather had plagued a number of CCR survey attempts in 2006. During these conversations, it was agreed that surveys conducted so late in the breeding season might underestimate CCR numbers, and could not be used to prove the absence of CCR from a particular area. The use of tapes would not be permitted so late out of concern that tape playbacks might adversely affect the CCR. However, it was generally agreed that surveys conducted in April and May should still allow for at least qualitative comparisons of CCR abundance among different transects.

Each site was surveyed on three (high-density) or four (low-density) separate days at dawn or dusk. All surveys were conducted between 1 hour before and after sunrise or sunset. At least one week passed between successive surveys at any given location, except on two occasions when only six days elapsed between surveys, once at Transect 1, and once at Transect 2 (Appendix A). Surveys were not conducted under heavy rain conditions, and heavy wind conditions (> 10 mph) were avoided if possible. Surveys were conducted at tides in which tidal sloughs were no more than bank full, and high (flood) tides were avoided. Tide height, wind speed, moon phase, and weather conditions were noted for each survey.

Observers were experienced ornithologists very familiar with the calls of CCR and other marsh birds. Before surveys commenced survey personnel received refresher training in the field, listening to calls of CCR, Virginia Rails (*Rallus limicola*), and other marsh birds. Survey personnel were also trained in how to estimate distances to calls in the marsh. Survey personnel included Scott Terrill, Ph.D., Steve Rottenborn, Ph.D., David Johnston, Ph.D., David Ainley, Ph.D., Laird Henkel, M.S., Kriss Neuman, M.S., Larry Spear, M.S., John Sterling, B.A., and Mike Mamoser, B.S.

4.3.2 Data Analysis

CCR detections were mapped (based on direction and distance from survey stations) for each survey. If two observers at adjacent stations along transects in high-density marshes detected the same type of call at the same time in the same approximate location, this was considered to be one detection. At low-density marshes, if an observer moving along a transect recorded two or more detections in the same area within the marsh, but from two adjacent stations, this was considered a single detection. In some cases, during surveys of both low- and high-density marshes, a single observer detected a single bird at one location within the marsh, then later detected another single bird at a location nearby; such detections could pertain to different individuals, or to the same bird moving through the marsh. In this case, the decision whether to combine detections was somewhat subjective, depending on distance between detections and time elapsed. For example, generally, detections within 20 m of one another but more than 20 minutes apart were considered to be the same bird (because a CCR could easily move 20 m within 20 minutes), whereas detections greater than 20 m from each other less than 20 minutes apart were considered different birds. Detections within 20 m of each other but less than 20 minutes apart may be considered different birds if birds were consistently heard calling from two different locations. Thus, estimates of the total number of birds detected were conservative. Consistent with the current protocol, "duet" calls were considered to represent two paired birds. All other calls ("clapper", "kek", "agitated kek", "kek-burr", "purr" and "churr") were considered to represent single birds, although no determination was made as to whether these were members of pairs or were unmated birds.

Based on mapped locations, the total number of CCR per survey per station was calculated. Several different methods have been used in the past to estimate density. Traditionally, sightings from one or more surveys were combined to map estimated locations of single birds and pairs in a given marsh, and density was calculated as the total estimated number of CCR divided by the total area of the marsh (H.T. Harvey & Associates 1989, Foerster et al. 1990). This method assumed that all of the marsh was effectively sampled, an assumption that may not always be easy to meet, and that certainly could not be met in broad marshes (*e.g.*, at transects 1-3). Prior to 1990, researchers often walked out into marshes to get closer to potential CCR detections; this is no longer permitted by the USFWS. CCR may not be detected effectively at great distances, and if surveys are conducted from levees adjacent to marshes, some CCR may be missed. To allow for the possibility that some CCR were missed, density estimates from the 1990 surveys were calculated using maximum detection distances of 500 ft., 800 ft., and no maximum (H.T. Harvey & Associates 1990e). For each category, the area of the marsh within that distance of the survey transect was calculated, and density was calculated as the number of CCR divided by the area of the marsh sampled.

More refined analytical techniques are also available to accurately estimate density. Distance sampling (Buckland et al. 1993), which uses statistical sampling techniques rather than a complete census, is probably the most accurate method to determine density in a given marsh. This method compensates for birds that are not detected at increasing distances from the observer. Currently, CCR survey data for 2006 compiled by the San Francisco Estuary Invasive Spartina Project allow for use of either the complete census technique or distance sampling. We used distance sampling because it is much more accurate, and allows for better comparisons with future surveys. It is expected that distance sampling will become the standard for CCR surveys in the future, since the complete census technique is likely to miss birds far from the observer.

For distance sampling analysis, we combined all data and calculated the density of detections in concentric rings around a hypothetical survey station (N = 120 sightings). We used seven rings, or strata, in 50 m increments: 0-50 m, 50-100 m, etc., out to the maximum distance recorded for a detection. Using the program DISTANCE (version 5.0), we tested a variety of curves to model the decrease in detectability with increasing distance, and chose the model with the best fit based on the lowest Akaike's Information Criterion (AIC) value. DISTANCE uses this curve to determine the effective detection radius (EDR). All missed detections inside the EDR equal the number of observed detections outside the EDR, meaning that density estimates using all observed data, and a sample area based on the EDR, represent 100% actual density. Total area of each marsh sampled using the EDR was calculated using GIS, and these areas were used to convert numbers of CCR detected into densities (i.e., number of CCR divided by the effective area sampled = density).

4.4. RESULTS

4.4.1 Abundance and Density

Number of CCR detected at each station varied from 0 to 12 (Appendix A). Mean number of CCR detected was 1.0 per station (SD = 2.1). The highest numbers of detections were at Stations 2e (12 CCR on May 4) and 3b (11 CCR on April 27). No CCR were detected on Transects 6, 7, or 8, and relatively few CCR were detected on Transect 4.

As noted above, the survey protocol dictated three 90-minute surveys per station at high-density marshes (Transects 1-3), and four 10-minute surveys at low-density marshes (Transects 4-8). At transects in low-density marshes, we did not know to what degree 10-minute surveys at each station limited our ability to detect CCR (compared to 90 minute surveys, which had 800% more survey effort), so two additional 90-minute surveys were conducted at single stations on Transects 4, 6, and 7, and three additional 90-minute surveys were conducted at stations on Transect 8. These additional surveys did not change results: no CCR were ever detected on Transects 6, 7, or 8, and few were detected on Transect 4 (Appendix A). Because these additional surveys did not provide new or different information from the standard surveys, the results of these additional surveys were not used in any other analyses.

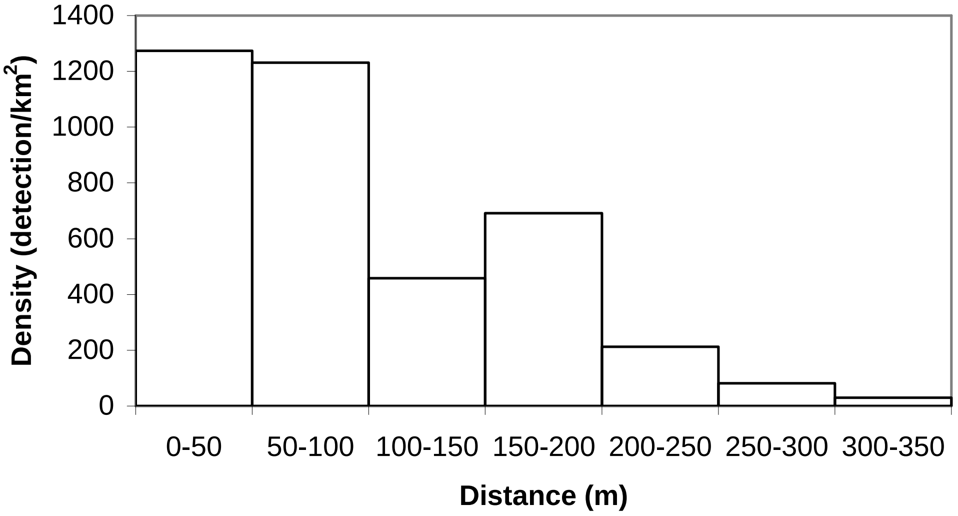
Total numbers of CCR per survey on each transect ranged from 0 to 24 (24 CCR were detected on Transect 3 on April 27; Table 2). Mean number of CCR per transect was 4.7 (SD = 6.9). The number of CCR detected varied considerably among survey dates on a given transect. For example, totals from Transect 3 ranged from 4 to 24, and totals on Transect 5 ranged from 0 to 14 (Table 2). There was no clear pattern of seasonality of maximum counts; instead maximum counts at different Transects occurred throughout the study period. For example, the maximum count on Transect 5 occurred on February 13, whereas on Transect 2 the maximum was on May 2. As a result, we did not consider it inappropriate to determine mean numbers of detections for each transect across surveys (Table 2). The maximum number of CCR detected on a transect on a single survey was at Transect 3, with 24 CCR detected on April 27; the maximum mean number of CCR per survey was greatest at Transects 2 and 3, which tied with 13.67 CCR each.

Table 2. Number of Clapper Rails Detected per Transect per Survey, Using Actual Data (90-Minute Surveys at Transects 1-3, 10-Minute Surveys at Transects 4-8).

Transect	Date	Pairs	Number of Individuals	Total
1	24-Apr	3	10	16
1	1-2 May	2	5	9
1	8-May	0	7	7
1	***Mean***	***1.67***	***7.33***	***10.67***
2	20-21 Apr	3	7	13
2	27-Apr	3	4	10
2	4-May	5	8	18
2	***Mean***	***3.67***	***6.33***	***13.67***
3	20-Apr	1	2	4
3	27-Apr	4	16	24
3	4-May	2	7	13
3	***Mean***	***2.33***	***8.33***	***13.67***
4	16-Feb	0	0	0
4	24-Feb	0	0	0
4	25-Apr	0	4	4
4	5-May	0	0	0
4	***Mean***	***0.00***	***1.00***	***1.00***
5	13-Feb	5	4	14
5	23-Feb	1	1	3
5	22-Apr	0	2	2
5	6-May	0	0	0
5	***Mean***	***1.50***	***1.75***	***4.75***
6	13-Feb	0	0	0
6	23-Feb	0	0	0
6	22-Apr	0	0	0
6	6-May	0	0	0
7	9-Feb	0	0	0
7	22-Feb	0	0	0
7	26-Apr	0	0	0
7	9-May	0	0	0
8	11-Feb	0	0	0
8	25-Feb	0	0	0
8	22-Apr	0	0	0
8	6-May	0	0	0

When the density of CCR was plotted against distance from the observer, it was apparent that detections at each station dropped off dramatically at distances greater than 100 m from the observer (Figure 2). The detection model provided by DISTANCE for this decline was a hazard-rate curve, with 2nd and 3rd order cosine adjustments. The EDR from this model was 147 meters (95% confidence interval = 111-194 m).

Figure 2. Detection Function of California Clapper Rails (all data combined).



Using this detection function, we calculated the density of CCR at each marsh (*i.e.*, along each transect) for each day surveyed (Table 3). CCR abundance and density were considerably higher on Transects 1-3 than on Transects 4-8. Although habitat conditions may have been better on Transects 1-3 (these were the high-density marshes), these transects were also surveyed for much longer time periods, 90 minutes per station versus 10 minutes per station on the other transects. Greater survey time likely resulted in a greater number of detections per station. Although this should not necessarily affect the calculations of density at each transect, it does complicate comparisons of presence/absence between the high-density and low-density transects.

To compensate for differences in survey effort among transects, we sampled the 90-minute surveys on Transects 1-3 as if they were 10-minute surveys. We did this two ways: 1) we used data from the first 10 minutes of each survey, and 2), we used data from sequential 10-minute blocks of time from each station along a transect, as if a person were walking the transect and surveying each station for 10 minutes. We used these two different methods because both methods may have been biased: use of sequential time periods is the same as the low-density marsh method, and may compensate for a bias associated with time of day, whereas use of the first 10 minutes of each survey may compensate for a potential bias created by the initial disturbance caused by an observer arriving at a station.

Table 3. Density[1] of Clapper Rails Detected (rails/hectare) per Survey, Using Actual data (90-Minute Surveys at Transects 1-3, 10-Minute Surveys at Transects 4-8).

Transect	Date	Pairs	Number of Individuals	Total
1	24-Apr	0.23	0.73	1.15
1	1-2 May	0.15	0.38	0.65
1	8-May	0.00	0.50	0.50
1	***Mean***	***0.13***	***0.53***	***0.78***
2	20-21 Apr	0.23	0.53	0.98
2	27-Apr	0.23	0.30	0.75
2	4-May	0.38	0.60	1.38
2	***Mean***	***0.28***	***0.48***	***1.03***
3	20-Apr	0.08	0.15	0.30
3	27-Apr	0.30	1.15	1.75
3	4-May	0.15	0.50	0.95
3	***Mean***	***0.18***	***0.60***	***1.00***
4	16-Feb	0.00	0.00	0.00
4	24-Feb	0.00	0.00	0.00
4	25-Apr	0.00	0.53	0.53
4	5-May	0.00	0.00	0.00
4	***Mean***	***0.00***	***0.13***	***0.13***
5	13-Feb	0.33	0.28	0.93
5	23-Feb	0.08	0.08	0.20
5	22-Apr	0.00	0.13	0.13
5	6-May	0.00	0.00	0.00
5	***Mean***	***0.10***	***0.13***	***0.33***
6	13-Feb	0.00	0.00	0.00
6	23-Feb	0.00	0.00	0.00
6	22-Apr	0.00	0.00	0.00
6	6-May	0.00	0.00	0.00
7	9-Feb	0.00	0.00	0.00
7	22-Feb	0.00	0.00	0.00
7	26-Apr	0.00	0.00	0.00
7	9-May	0.00	0.00	0.00
8	11-Feb	0.00	0.00	0.00
8	25-Feb	0.00	0.00	0.00
8	22-Apr	0.00	0.00	0.00
8	6-May	0.00	0.00	0.00

[1] Density is calculated using DISTANCE, with an Effective Detection Radius of 147 meters for each station.

Abundance estimates using only 10-minute sampling periods are presented in Table 4. These abundance estimates are similar using the two sampling methods; in fact, maximum counts vary by only one bird, on Transect 2. However, when we used linear regression to test for a relationship between sampled data from each survey on Transects 1-3 and the original 90-minute data from these surveys, the method using the first 10 minutes was far more accurate than the other method. Only 2% of the variability in the new 10-minute data was explained by the 90-minute data using sequential 10-minute periods ($r^2 = 0.02$), whereas 45% of the variability in 10-minute data was explained by the original 90-minute data when using the first 10 minutes of each survey ($r^2 = 0.45$).

At a given station along high-density transects, data from the entire 90-minute survey at each station resulted in more than twice as many CCR detected compared to data from the first 10 minutes of each survey. Thus, in order to allow comparisons of CCR abundance between high-density transects and low-density transects, abundance estimates using the first 10 minutes of each survey are probably better to assess *relative* abundance among transects than original data based on the two very different survey methods. These converted values assume a consistent level of effort (10 minutes at each station) for all transects. This conversion does not account for potential differences stemming from the different *number* of surveys in different marshes (4 surveys at high-density marshes, and 3 surveys at low-density marshes). Indeed, at Transect 4, CCR were only detected on one of four surveys; thus, if only three surveys were conducted, there is the possibility that no CCR would have been detected. Nevertheless, we feel that the adjusted data in Table 4, using only the first 10 minutes of each survey, provide a good index of relative use of each transect that can be used for at least qualitative comparisons with data from 1989 and 1990.

Table 4. Number of Rails Detected, Using Converted Data (as described above) for transects 1-3 (as if all surveys were of 10-minute duration).

		Sequential 10-minute periods			**First 10 minutes of each survey**		
Transect	Date	Pairs	Number of Individuals	Total	Pairs	Number of Individuals	Total
1	24-Apr	0	2	2	0	2	2
1	1-2 May	0	1	1	0	2	2
1	8-May	0	2	2	0	1	1
1	***Mean***	***0.00***	***1.67***	***1.67***	***0.00***	***1.67***	***1.67***
2	20-21 Apr	0	0	0	1	2	3
2	27-Apr	1	3	5	0	0	0
2	4-May	0	1	1	2	2	6
2	***Mean***	***0.33***	***1.33***	***2.00***	***1.00***	***1.33***	***3.00***
3	20-Apr	0	1	1	0	0	0
3	27-Apr	1	1	3	0	3	3
3	4-May	0	3	3	0	1	1
3	***Mean***	***0.33***	***1.67***	***2.33***	***0.00***	***1.33***	***1.33***
4	16-Feb	0	0	0	0	0	0

		Sequential 10-minute periods			First 10 minutes of each survey		
Transect	Date	Pairs	Number of Individuals	Total	Pairs	Number of Individuals	Total
4	24-Feb	0	0	0	0	0	0
4	25-Apr	0	4	4	0	4	4
4	5-May	0	0	0	0	0	0
4	***Mean***	***0.00***	***1.00***	***1.00***	***0.00***	***1.00***	***1.00***
5	13-Feb	4	5	13	4	5	13
5	23-Feb	1	1	3	1	1	3
5	22-Apr	0	2	2	0	2	2
5	6-May	0	0	0	0	0	0
5	***Mean***	***1.25***	***2.00***	***4.50***	***1.25***	***2.00***	***4.50***
6	13-Feb	0	0	0	0	0	0
6	23-Feb	0	0	0	0	0	0
6	22-Apr	0	0	0	0	0	0
6	6-May	0	0	0	0	0	0
7	9-Feb	0	0	0	0	0	0
7	22-Feb	0	0	0	0	0	0
7	26-Apr	0	0	0	0	0	0
7	9-May	0	0	0	0	0	0
8	11-Feb	0	0	0	0	0	0
8	25-Feb	0	0	0	0	0	0
8	22-Apr	0	0	0	0	0	0
8	6-May	0	0	0	0	0	0

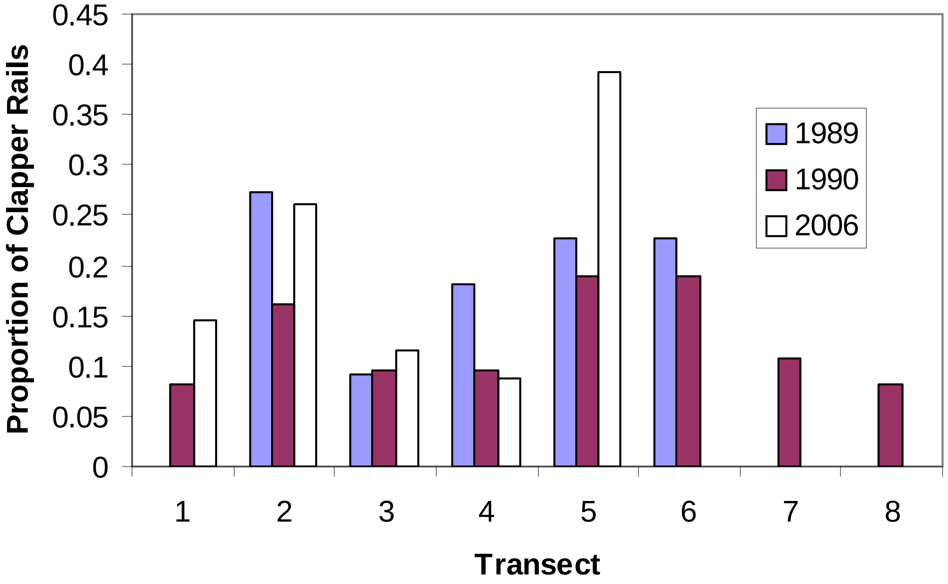
4.4.2 Comparison with 1989/1990 Results

Methods used in 1989 and 1990 differed from methods used in 2006. The two most substantial differences were the use of tape playbacks in 1989 and 1990, which has the potential to substantially increase detectability of CCR by eliciting responses from CCR, and the methods used to calculate density. In 1989 and 1990, density was calculated as the total number of CCR divided by the total area of marsh. This method did not consider decreasing detectability with increasing distance from the observer, and likely resulted in underestimates of true density (since some distant CCR would have been missed). However, some of the marshes (particularly along Transects 2 and 3) were considerably narrower in 1989 and 1990 than they are currently, thus mitigating the issue of poor detection of distant CCR in those earlier years. Nevertheless, the method used to estimate density in 2006 is likely more accurate. The degree to which the more accurate method of calculating densities (which might increase density estimates compared to 1989 and 1990 estimates) was offset by our inability to use tape playbacks (which would decrease detectability of CCR compared to 1989 and 1990 methods) is unknown.

Because of these methodological differences, it is problematic to directly compare densities or numbers of CCR detected in 1989 and 1990 with data collected in 2006. Therefore, we instead compared the relative use of the different transects among years by converting the mean number of CCR detected on each transect using 10-minute surveys (Table 4) to a *proportion* of the combined mean number of CCR detected on all transects during that year. Although this method omits the use of much of the data collected in 2006, it is more appropriate for comparative purposes than using data from 90-minute and 10-minute surveys from 2006 in the same analysis.

Distribution of the proportion of CCR sightings among transects was generally similar among the three years (Figure 3). The most notable differences among years were that CCR were detected on Transects 7 and 8 in 1990, but not in 1989 or 2006, and that CCR were not detected in 2006 on Transect 6, where they were detected in fairly high numbers in 1989 and 1990. The relatively high number of CCR detected on Transect 5 in 2006 is also notable.

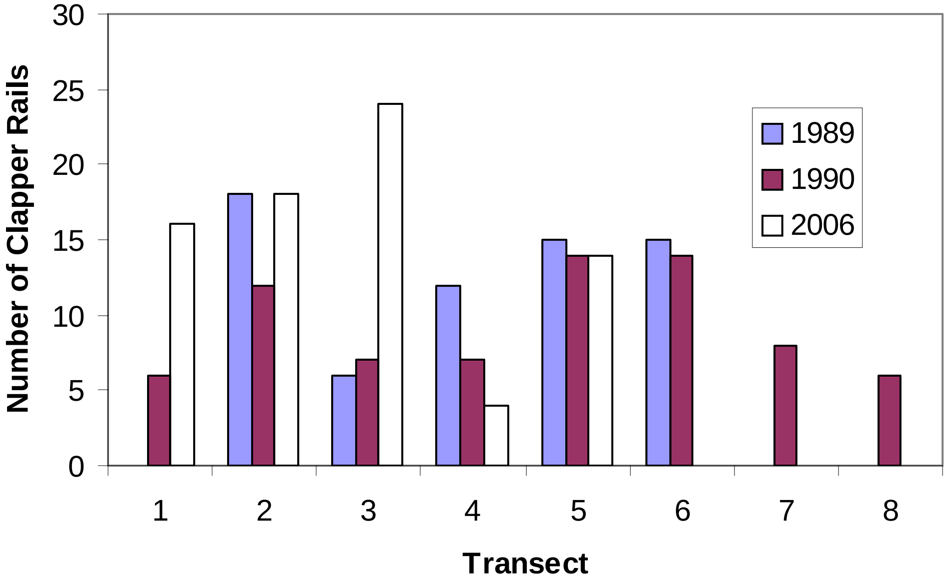
Figure 3. Proportion of Clapper Rails Detected on Eight Transects in South San Francisco Bay, 1989[1], 1990, and 2006.



[1]Transect 1 was not surveyed in 1989. Data from 2006 are based on averages of 10-minute surveys at each transect.

As previously noted, direct comparison of total number of CCR detected or of density of CCR detected among years is not appropriate given the methodological differences. However, for illustrative purposes, we also present the total number of CCR detected per transect during the three survey years (Figure 4). For 2006, we used the maximum number of CCR from any one survey; for previous years totals were compiled by reviewing data from three consecutive surveys and interpreting these data to estimate the likely total number of CCR.

Figure 4. Number of California Clapper Rails Detected on Eight Transects in South San Francisco Bay, 1989[1], 1990, and 2006.



[1] Transect 1 was not surveyed in 1989. Numbers from 1989 and 1990 are based on totals from 3 consecutive days; numbers from 2006 are the maxima from either 90-minute counts (Transects 1-3), or 10-minute counts (Transects 4-8).

4.5. DISCUSSION AND CONCLUSIONS

Despite logistical difficulties related to rainy weather in 2006, we were able to conduct 154 individual station-surveys between 9 February and 9 May. Although the study period was longer than that dictated by the current protocol (which calls for surveys between January 15 and March 31), all surveys were conducted during the breeding season for the species. In addition, we did not detect any obvious seasonal bias of greater detections during any one portion of the study period. Use of distance sampling in 2006 allowed for density estimates that are likely more accurate than those generated in previous years. Overall, we feel that data from these surveys provide an accurate assessment of the relative distribution of CCR in the marshes surveyed during the 2006 breeding season.

In 2006, we detected the greatest overall number of CCR at Transect 3 (Calaveras Point East II Marsh). This marsh is a broad tidal salt marsh, with pockets of brackish marsh. High numbers of CCR were also detected at Transects 1 (Mowry Slough West Marsh), and 2 (Calaveras Point East I Marsh), which are also dominated by salt marsh. At Transects 1, 2, and 3, the marsh is very wide; for example, the edge of the tidal marsh at the intertidal mudflats is more than 500 meters from the levees on which surveys were conducted along Transects 2 and 3. In addition, because the upper marsh plain at these marshes is dominated by pickleweed, whereas the majority of cordgrass-lined channels occur much farther from the levees, most of the highest-quality habitat for CCR along these transects was quite distant from the survey stations. As a result, many of the CCR in the marshes adjacent to Transects 1-3 were likely beyond detection range, and much of the survey area around a given station along these transects consisted of pickleweed-dominated high marsh that supported fewer CCR than the cordgrass-dominated marsh much farther out. Therefore, we expect that CCR densities in the outer, more cordgrass-dominated portions of these marshes are considerably higher than those estimated during our 2006 surveys.

Transect 5, at Goose Point Marsh, also had a high total number of CCR, and when data were normalized to 10-minute survey periods, this site had a substantially greater mean number of CCR than any other site (Table 4). The high average at this site is driven by the results of the first survey, on which 13 CCR were detected using 10-minute surveys at the five survey stations on the transect. This high count occurred on 13 February, and it is not clear why subsequent surveys at this transect had much lower numbers of CCR. In addition, Goose Point Marsh is narrow enough that surveyors were able to detect most or all of the CCR that were calling in this marsh during a given survey (as opposed to the situation along Transects 1-3, where CCR in the highest-quality habitat in the lower/outer marsh were largely undetected due to distance from the observers).

For reasons discussed previously, the density estimates produced by the 2006 surveys may not be directly comparable to those from 1989 and 1990. However, it is worth noting that the mean CCR densities (Table 3) estimated along the salt marsh transects were consistently much higher in 2006 than they were in 1989 or 1990. Densities derived from surveys of the Mowry Slough Marsh (Transect 1) were estimated at 0.21-0.43 CCR/hectare in 1990 and 0.78 CCR/hectare in 2006; this transect was not surveyed in 1989. Densities derived from surveys of the Calaveras Point Marsh (Transects 2 and 3) were estimated at 0.35, 0.27-0.36, and 1.03 CCR/hectare for Transect 2 and 0.35, 0.33-0.42, and 1.00 CCR/hectare for Transect 3 in 1989, 1990, and 2006, respectively.

The 2006 salt marsh CCR densities were also comparable to those reported by PRBO for surveys of various Bay-area locations in 2005 (Herzog et al. 2005). Although estimates of CCR densities in some salt marshes in the Central Bay and San Pablo Bay were as high as 2.3-3.0 CCR/hectare, the majority of density estimates was well below the 0.78-1.03 CCR/ha estimates from Transects 1-3 in 2006. In the South Bay in particular, only one location (East Palo Alto) had CCR density estimates as high as 0.6-1.1 CCR/hectare in 2005 (Herzog et al. 2005).

The greatest differences between results of the 2006 sampling and results of both 1989 and 1990 surveys occurred at Transects 5 (Goose Point Marsh) and 6 (Triangle Marsh; Figure 3). At Goose Point, we detected substantially more CCR in 2006 relative to other transects. In 1989 and 1990, abundance was high at Goose Point, but not substantially higher than at Calaveras Point (Transect 2) or Triangle Marsh. At Triangle Marsh, we did not detect any CCR during the four protocol-level surveys in 2006, whereas substantial numbers of CCR were detected here in 1989 and 1990.

In addition, substantial differences between results of the 1989 and 2006 sampling and results of the surveys conducted in 1990 occurred at Transects 7 (Warm Springs Marsh) and 8 (South Coyote Slough Marsh). At these marshes, no CCR were detected in 1989 or 2006, but CCR were detected in 1990.

Below, we explore three possibilities for these potential differences in relative distribution of CCR among years: 1) changes in habitat suitability, 2) changes in predator abundance and distribution, and 3) changes in CCR populations in the South Bay. It should also be noted that even though three to four surveys were conducted at each site each year, these surveys still only provide a "snapshot" of CCR use of each site. As evidenced by the fairly high variability among surveys at some sites in 2006 (Table 2), some differences among sites or changes among years may be due to natural sampling variability.

Typical habitat for CCR is tidal salt marsh dominated by pickleweed with extensive stands of cordgrass, or alkali bulrush, and a large network of tidal channels. CCR forage on invertebrates such as mussels, clams, and crabs, which they capture primarily in tidal sloughs and mudflats (Albertson and Evens 2000), and networks of tidal channels allow CCR to forage for prey while relatively obscured from predators. During the breeding season, CCR also require suitable nesting habitat. Most nests occur near tidal channels, in areas where there is abundant cover from predators, usually in the form of cordgrass, alkali bulruh, gumplant or large clumps of pickleweed (Albertson and Evens 2000). We have no quantitative information on changes in prey availability or quality of foraging habitat over time, but we do have information on changes in marsh vegetation, which relate directly to potential nesting habitat and cover from predators.

As detailed in the 2006 comparative study of marsh plant associations in the South Bay (H. T. Harvey & Associates 2006), habitat conditions have changed since 1989, particularly at transitional marshes. Figure 5 indicates the percentage of each marsh dominated by fresh, brackish, and saltmarsh vegetation in 1989 and 2006, based on data collected within these individual marshes along transects that ran perpendicular to the levees, throughout the entire marsh. Figure 6 indicates the percentage of alkali bulrush and cordgrass along these same transects. Among the eight marshes where we surveyed for CCR, vegetation at Goose Point Marsh (Transect 5) has changed the most since 1989 (Figure 5). At this site, there has been a dramatic shift from saline to brackish vegetation, which has resulted in a dramatic increase in the amount of alkali bulrush present (Figure 6). At the adjacent Triangle Marsh (Transect 6), overall habitat conditions changed relatively little from 1989 to 2006 (Figures 5 and 6), although the proportion of marsh that was not dominated by alkali bulrush has shifted from primarily pickleweed to primarily invasive perennial peppergrass (*Lepidium latifolium*; H. T. Harvey & Associates 2006). In addition, the amount of pickleweed at Triangle Marsh, albeit relatively small, decreased substantially between 1989 and 2006. Although vegetation at some sites changed very little over time, other sites at which there was a substantial shift in vegetation were Transect 2 (Calaveras Point), where cordgrass and alkali bulrush cover increased as did overall acreage of tidal marsh, and Transects 7 and 8 (Warm Springs Marsh and South Coyote Slough Marsh), where alkali bulrush cover decreased, and perennial peppergrass and spearscale (*Atriplex triangularis*) increased. At South Coyote Slough Marsh (Transect 7, at Newby Island), the percentage of California bulrush (*Scirpus californicus*) also increased.

Figure 5. Marsh Characteristics at the Eight Clapper Rail Survey Transect Locations in 1989 (top) and 2006 (bottom).

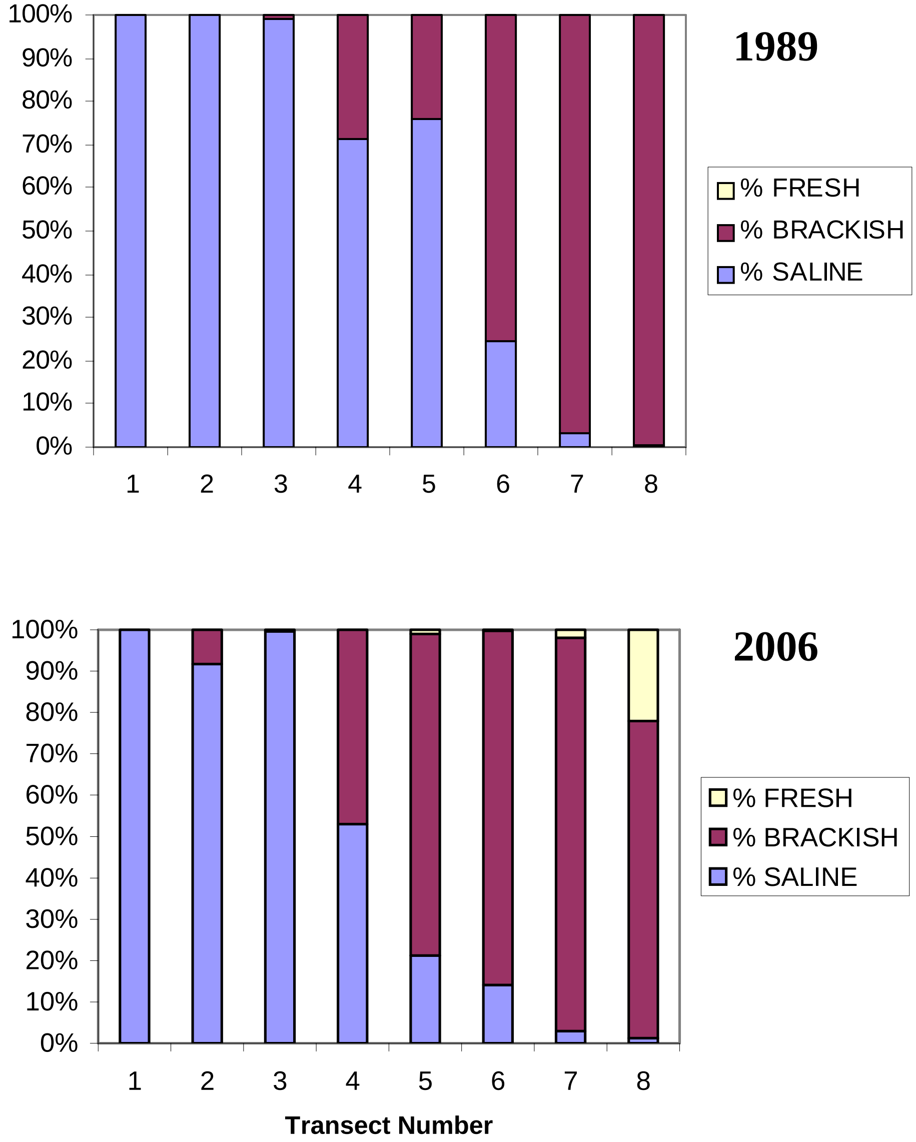
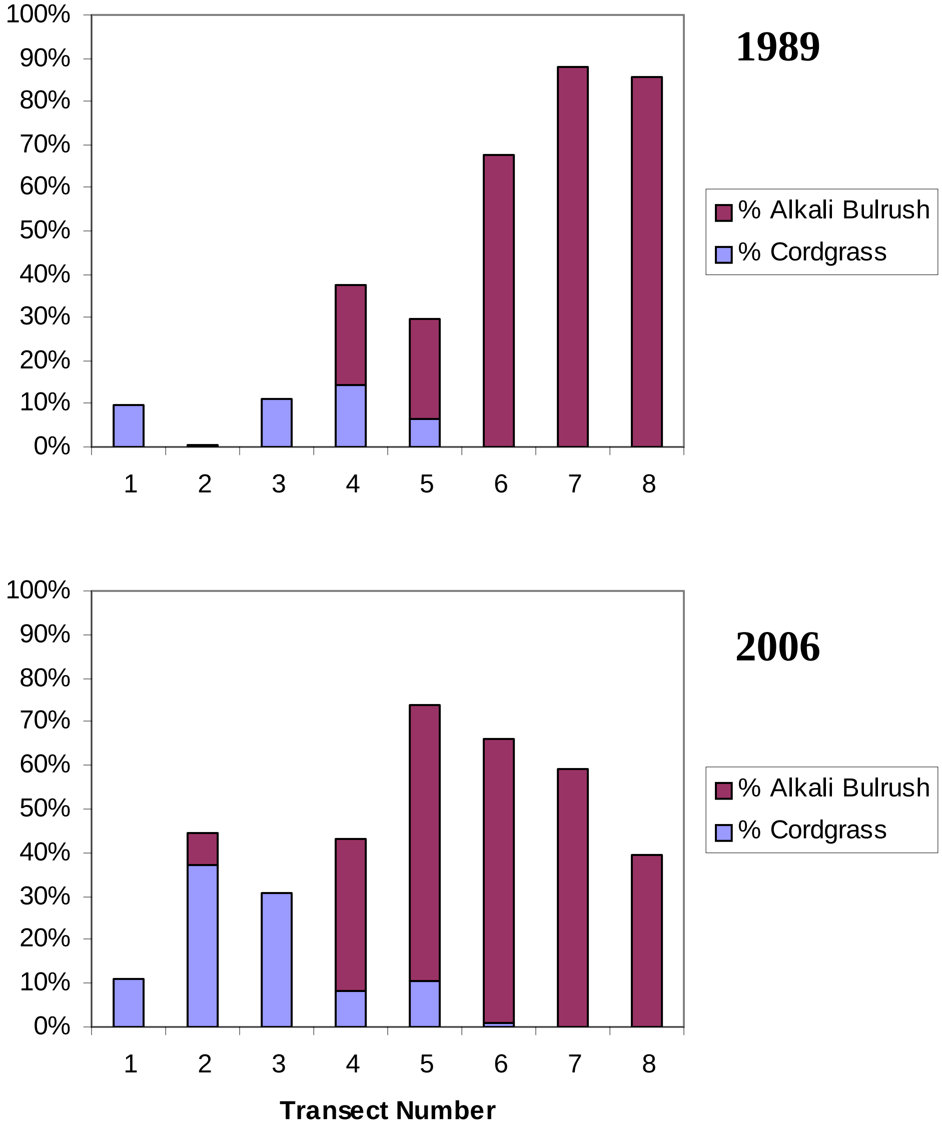


Figure 6. Percentage of Alkali Bulrush and Cordgrass (including pickleweed/cordgrass intergrade areas) at the Eight Clapper Rail Survey Sites in 1989 (top) and 2006 (bottom).



The greatest change in CCR abundance and the greatest change in vegetation both occurred at Goose Point Marsh (Transect 5). Here, alkali bulrush has increased in dominance, while cordgrass has decreased, since 1989 (Figures 5 and 6). Thus, CCR abundance at Goose Point Marsh has apparently increased while the plant community of this marsh has become more brackish (less saline). However, because the more traditionally brackish marshes (along Transects 6, 7, and 8) lacked CCR altogether in 2006, there is no clear linkage between the increase in alkali bulrush and the increase in CCR at Goose Point Marsh (compared to 1989/1990 conditions). Thus, the mechanism responsible for the apparent increase in CCR abundance at Goose Point Marsh is unknown. The second greatest change in CCR abundance occurred at Triangle Marsh (Transect 6). Here, relatively high densities of CCR were detected in

1989 and 1990, but no CCR were detected in 2006. Although vegetation changed relatively little here on a broad scale (Figures 5 & 6), the proportion of pickleweed decreased by about 50% and the amount of peppergrass increased by about 50%. No quantitative data are available regarding the effects of peppergrass on CCR, but Spautz and Nur (2004) theorized that by altering channel morphology, peppergrass may decrease the quality of tidal marsh habitat for CCR.

Relative CCR abundance also increased at Transect 2 (Calaveras Point), where both cordgrass and alkali bulrush cover increased as did overall acreage of tidal marsh. It is likely that some of the changes in marsh vegetation since 1989/1990 have resulted in changes in CCR distribution in the South Bay. However, the extent to which vegetation changes have affected the distribution and abundance of CCR in the study area is unclear. The most obvious evidence suggesting that factors other than vegetation changes are responsible for a substantial portion of interannual variability in CCR numbers is the dramatic change in CCR abundance in the brackish marshes along Transects 6, 7, and 8 between 1989 and 1990, despite fairly consistent vegetation conditions in those marshes during the two years.

Surveys conducted during the 1980s and 1990s indicated that CCR were decimated by non-native red foxes (*Vulpes vulpes regalis*), and probably reached historic low population levels around the time that mammalian predator management was implemented on Refuge lands in 1991 (Harding et al. 1998, Albertson and Evens 2000). This predator management plan has been successful in reducing the abundance of predators, and the effects of mammalian predators on CCR, resulting in an increase in CCR populations (Harding et al. 1998). From spring 1991 to fall 1996, the average number of individuals removed from Refuge lands per year included 90 red foxes, 27 feral cats (*Felis catus*), 26 striped skunks (*Mephitis mephitis*), and two raccoons (*Procyon lotor*) (Harding et al. 1998. In addition, 38 non-native opossums (*Didelphis virginiana*) and 25 native gray foxes (*Urocyon cinereoargenteus*) were captured and released. The numbers of red foxes trapped were consistent from 1991 to 1996, but trapping rates declined because more traps were used in successive years. Successful trapping required 46 traps/fox in 1991-92 and 83 traps/fox in 1995-96, indicating that the trapping program was successful in reducing fox populations. Between 1991 and 1996, CCR population size within a given marsh showed a significant negative relationship with the number of red foxes removed the prior year, and CCR population growth rates were significantly related to red fox trapping success the prior year. The Refuge's predator management plan continues to be implemented, and sightings of red foxes on the Refuge are far less frequent than they were before predator management was initiated (Joy Albertson, pers. comm.). The most recent population estimate for CCR was approximately 1,040 to 1,264 birds in 2000; this estimate is two to four times the population estimate in 1991 (Alberston and Evens 2000).

It is unlikely, however, that changes in predator populations in the South Bay are responsible for the observed use of brackish marshes at Transects 7 and 8 in 1990, but not in 1989 or 2006. It could be that intense pressure from predators forced CCR to abandon historically used high-quality habitat in 1990, and to disperse into marginal brackish habitat near Transects 7 and 8 to avoid predation. That hypothesis would be supported if the primary predators at the time, non-native red foxes, were differentially successful in their attempts (*i.e.*, they were more readily able to detect and prey upon CCR in the pickleweed/cordgrass marshes than in the comparatively denser habitats dominated by alkali bulrush). There are no studies to support that hypothesis, however, and the differences in detections in the brackish marshes in 1989 and 1990, when there presumably would have been no difference in predation rates, provides contrary evidence.

In contrast, avian predator abundance has increased considerably since 1990. In particular, numbers of breeding California Gulls (*Larus californicus*) in the South Bay have increased from approximately 3,850 pairs in 1990 (Strong 2004) to 16,475 pairs in 2006 (Strong 2006). Corvids, particularly Common Ravens (*Corvus corax*), have increased considerably as breeders in the immediate South Bay since the early 1990s as well (S. Rottenborn, pers. obs.). Given the abundance of both species, their heavy use of South Bay landfills, and the proximity of the Newby Island Landfill to the brackish marshes in the South Bay, it is possible that avian predation on eggs or chicks may be at least partially responsible for declines in CCR numbers in brackish marshes in the South Bay since 1990.

If 2006 CCR numbers in the South Bay were low in response to one or more factors unrelated to habitat (*e.g.*, predation, low food supplies, or poor productivity in previous years), it is also possible that CCR distributed themselves according to habitat preference, so that preferred salt marsh and transitional habitats were occupied first, and no "excess" of CCR was present to occupy brackish marshes along Transects 6, 7, and 8.

With only three years of survey effort over a period of 17 years, and very different estimates of CCR density in brackish marshes between 1989 and 1990, it is difficult to draw firm conclusions regarding the potential effects of changes in marsh vegetation on CCR populations in the South Bay. Transitional marshes with a combination of tidal pickleweed habitat and alkali bulrush, as well as salt marshes, appear to provide fairly good habitat for CCR. Although brackish marshes were occupied by moderate numbers of CCR in 1990, the frequency with which these marshes are used, and their value to CCR (*e.g.,* whether they support successful breeding or serve as population sinks) when occupied is still unknown. Further surveys of these marshes would undoubtedly shed more light on the distribution and abundance of CCR in the South Bay, particularly in brackish marshes.

5.0 SALT MARSH HARVEST MOUSE SURVEYS

5.1. BACKGROUND

The subspecies of the SMHM endemic to the marshes of central and southern San Francisco Bay (*Reithrodontomys raviventris raviventris*) is listed as Endangered by both the United States Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG). These listings are based on the small population size of the mouse due primarily to habitat loss (Shellhammer et al. 1982). In the southern San Francisco Bay, the SMHM occurs in low numbers in tidal marshes and occasionally in adjoining diked salt marshes. Historically, tidal salt marsh dominated by pickleweed has been considered the prime habitat for this species (Fisler 1965, Shellhammer et al. 1984, Shellhammer 2000).

As salinity levels have changed in the southern San Francisco Bay (South Bay), so too have marsh plant communities (H.T. Harvey & Associates, 1984, 1990d, 1997, 1998, 1999, 2000, 2001, 2002a, 2002b, 2003, 2004, 2005, 2006). Decreased salinity has altered the composition and abundance of marsh plants, exacerbating the loss of SMHM habitat. The goals of this study were to set up a monitoring plan to establish baseline population estimates of the mouse within the potentially affected areas and attempt to determine the possible effects of salt marsh conversion on the SMHM. The present study was carried out to help the City update these baseline population numbers and further examine the mouse’s potential presence in brackish marshes of the South Bay.

5.1.1 1990 Baseline SMHM Surveys

H. T. Harvey & Associates classified South Bay marshes into three categories: salt marshes composed primarily of pickleweed and Pacific cordgrass (*Spartina foliosa*), brackish marshes dominated by alkali bulrush, and transitional marshes composed of a mixture of these three species (H.T. Harvey & Associates 1990). The study was divided into two phases: spring/summer and late summer/fall (H.T. Harvey & Associates 1990a, 1990b) and involved three marshes: Calaveras Point Marsh (hereafter called the Calaveras Marsh, a salt marsh), Triangle Marsh (a transitional marsh), and Newby Island Marsh (a brackish marsh). The Newby Island Marsh is located a short distance from the Warm Springs Marsh (Figure 1). The study tested the hypotheses that 1) SMHM do not use areas dominated by alkali bulrush and 2) SMHM are more abundant in salt marshes than in transitional marshes.

To gather data, live traps were set in each of these marshes during the spring through early summer and late summer through early fall when tidal cycles permitted trapping on the marsh plain, low in the tidal zone. Data from the late spring were compared to those from the early fall to determine whether the mouse population was relatively static or fluctuated seasonally. During the August to October period, the brackish marsh site was moved from Newby Island to the nearby Warm Springs Marsh.

In the spring-summer 1990 trapping of Calaveras Marsh, 59 SMHM were captured on the marsh plain in 500 trap nights (TN) for a capture efficiency of 11.8; one of the highest capture efficiencies ever recorded from the South Bay. The marsh plain of Triangle Marsh produced 14

SMHM in 500 TN for a capture efficiency of 2.8 while no SMHM were captured on the marsh plain at Newby Island in 392 TN. Two SMHM were captured, however, on a levee within the brackish Newby Island Marsh that was covered by scattered, salt-tolerant vegetation, including a narrow fringe of scattered pickleweed. During the late summer-fall trapping, the same general relationship of capture efficiency among the marshes was observed, although the number of SMHM captured was generally lower. In fact, Calaveras Marsh yielded 22 SMHM in 400 trap nights (a capture efficiency of 5.5), or less that half the number captured in the spring-summer trapping of the same area. Triangle Marsh trapping produced a total of 10 mice in 500 TN (a capture efficiency of 2.0), and no SMHM were captured at Warm Springs. It is this data from the late summer/fall surveys that are compared to the 2006 data in Phase One of the present study.

These results were interpreted as supporting our two hypotheses proposed at that time: 1) SMHM usually do not use brackish water marshes (such as Newby Island and Warm Springs marshes) and if they are found there, they gain access via some route that contains more salt-tolerant vegetation than the rest of the brackish marsh, and 2) salt marshes contain more SMHM than transitional marshes.

Population numbers could not be estimated with mark-recapture techniques because the low capture rates and recapture frequency in these studies do not meet the minimum requirements for reliable estimates with these techniques. Trapping larger grids for a greater number of nights might allow such estimates, but this would be a difficult and expensive process to undertake.

5.1.2 Habitat Use of SMHM in Marshes in the South San Francisco Bay

The work of Shellhammer (1982, 2000) and Shellhammer et al. (1982), along with numerous unpublished data and project reports, suggests that SMHM primarily use pickleweed but are also found in spearscale, alkali heath (*Frankenia salina*), and gumplant. They are also known to utilize mixtures of pickleweed and other species (Fisler 1965; Shellhammer 1982, 2000; Shellhammer et al. 1982). SMHM have not been found to use solid stands of salt grass (*Distichlis spicata*), though when it occurs within pickleweed-dominant habitat along with other salt-tolerant plants, they may use it. Bulrushes (*Scirpus robustus, S. californicus, S. acutus, and S. maritimus*) had not been found to support SMHM as of 2005. The alkali bulrush of the South Bay has not been trapped extensively since the 1970's, when trapping on the substrate beneath the vegetation yielded extremely few SMHM (Shellhammer trapping records).

Fisler (1965) and Shellhammer et al. (1982) found that SMHM moved up into the mixed halophyte-grassland in the late spring and early summer, in marshes where there was adjoining upland vegetation. SMHM are regularly found in grasses intermixed with pickleweed and other halophytes (salt-tolerant plants) and are occasionally found in grasses at the edge of marshes in the late spring and early fall. SMHM also were found to use bulrush when it was associated with pickleweed, as was the case in the previous study of the South Bay marshes for the City of San Jose (H. T. Harvey & Associates 1990a, 1990b, 1990c, 1990d). The hypothesis developed during the 1990 study was that while SMHM appeared to not use monocultures of bulrush (*Scirpus* spp.), the mice may venture into brackish vegetation from adjacent areas of pickleweed or areas of pickleweed combined with various brackish species. In the 1990 study it was unclear whether the SMHM that were captured in the bulrush area of Triangle Marsh were residents of the bulrush itself or were transients from adjacent areas of either solid pickleweed or in mixtures of pickleweed and bulrush.

5.1.3 Habitat Use by SMHM in Brackish Marshes in the Suisun Marsh

The CDFG and the Department of Water Resources (DWR) have been performing yearly SMHM surveys in a series of SMHM reserves in the Suisun Marsh. Laureen Barthmann-Thompson of the CDFG and Patty Quickert of the DWR (pers. comm.) have discovered patterns of habit utilization by the northern subspecies of SMHM (*Reithrodontomys raviventris halicoetes*) that differ from the consensus regarding SMHM habitat use in brackish marshes. In Suisun Marsh, SMHM are most often captured in pickleweed, as is expected. However, trapping done in 2005 in bulrush-dominated brackish marsh habitat revealed much greater captures rates of SMHM than expected. Trap lines were placed in an area dominated by bulrush (*Scirpus Olneyii)* that had almost no pickleweed. The trap lines extended 140 meters into the bulrush, and SMHM were caught throughout this grid, up to 140 meters from the nearest pickleweed. It should be noted that a different trapping technique was utilized in these bulrush dominated areas of Suisun Bay; the traps were placed approximately one meter above the substrate, on the thatch layer of the bulrush, and the trapping was done at high tides when the marsh plain was inundated; trapping in the South Bay has not been conducted in this manner. In the South Bay, trapping has not occurred expressly in areas where there has been heavy thatch, nor has it occurred high in the vegetation (*e.g.*, on top of deep thatch or on bent stems of bulrush with the marsh plain covered by water). The Suisun Marsh has little of the dominant bulrush species found in the South Bay (*S. robustus* and S. *maritimus*), while the South Bay has little of the dominant species of bulrush found in the Suisun Marsh (*S. americanus*). However, the respective species of bulrush found at both ends of the bay have similar architecture, and are both associated with brackish or fresh environments, so it is presumed that the capturing of SMHM in bulrush in the Suisun Marsh may be relevant to brackish habitat use by SMHM in the South Bay.

5.1.4 Changes in Marsh Vegetation Between 1990 and 2006

The vegetation at each of the three marshes surveyed in this study, and elsewhere in the South Bay, has been mapped at regular intervals between 1990 and 2006 (H. T. Harvey and Associates 1984, 1990c, 1990d, 1991, 1994, 1995, 1997, 1998, 1999, 2000, 2001, 2002a, 2002b, 2003, 2004, 2005, 2006). This monitoring has shown a change in the vegetation at each of the marshes. High sedimentation rates at Calaveras Marsh have lead to the width of the marsh from the levee to the Bay roughly doubling between 1990 and 2006. This wide marsh has formed the types of higher-order channels associated with maturing marshes, and the plant diversity has increase in correspondence to the increasing complexity of the marsh. The vegetation in 2006 at Calaveras Point Marsh was nearly entirely saline, just as it was in 1990. Triangle Marsh shifted toward a greater percent cover of brackish marsh plants (19% cover alkali bulrush in 1990 to 45% in 2006), and a lower percentage of saline marsh plants (58% cover pickleweed in 1990 to 31% in 2006). Warm Springs in 2006 was still dominated by alkali bulrush and was just as brackish as it was in 1990, but it had acquired a greater percent cover of the invasive peppergrass.

5.1.5 Design of the 2006 Study

The 2006 South Bay SMHM study was designed to answer two questions: 1) whether the densities of SMHM in the South Bay have changed over the last 16 years, and 2) whether SMHM preferentially utilize the higher portions of brackish alkali bulrush habitat during high tide events. The study was composed of two phases, each of which was designed to answer one of these questions. In Phase One we surveyed the same three marshes trapped in the 1990 study with the same trapping technique, and compared the capture efficiencies between years. In Phase Two we trapped two of the same grids as in Phase One, utilizing the alternative trapping technique of placing the traps above the thatch layer a during high tide, as was done in Suisun Marsh. Phase Two took place three weeks after Phase One, and the trapping was only performed at Triangle and Warm Springs Marshes because they are the marshes dominated by brackish vegetation.

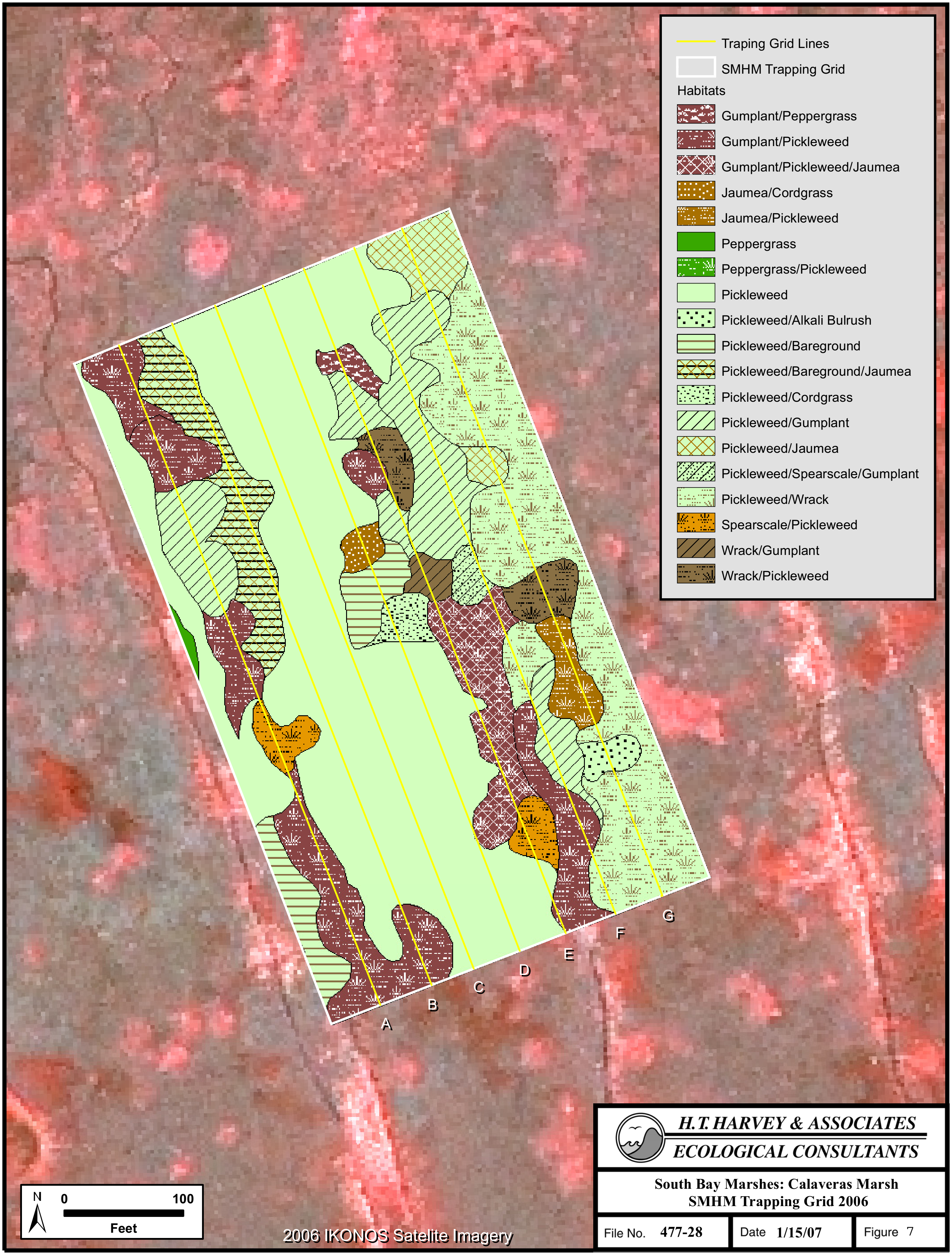
5.2. METHODS

5.2.1 Trapping Procedures

Phase One trapping was performed between August 28 and September 1, 2006. Trap locations are shown on Figures 7, 8, and 9. Traps were placed on the soil surface of the marsh very close to the same locations as in 1990, with the exception of Calaveras Marsh, where the trapping grid was moved approximately 100 meters closer to the Bay (Figure 10). The evolution of Calaveras Marsh between 1990 and 2006 resulted in changes to the drainage patterns, with higher portions of the marsh near the levee, including the 1990 trapping grid area, experiencing longer inundation. Even during low tides this area was covered with water, and the pickleweed was not tall or dense enough to support traps. Therefore, we moved the grid to a portion of the marsh with better drainage to prevent inundation of the mice while in the traps, which would have led to a numbers of deaths of this endangered species due to drowning and/or hypothermia. Even at the new grid location the marsh plain did not always drain completely, so as a further precaution we used wooden pedestals to support live traps at lower elevation trap locations (photo – Appendix B).

Trapping in Phase Two was carried out between September 17 and 21, 2006 at Triangle and Warm Springs Marshes. Traps were placed approximately 1 meter above the soil of the marsh plain, and at least one foot above the nocturnal high tide level. Traps were placed either on the thatch beneath the bulrush stems, on vegetation “platforms” made by bending and tying together bulrush stems, or on wooden pedestals as used in Phase One.

Small mammals were trapped using Sherman™ live-traps stocked with nesting material and baited with a mixture of crushed walnuts and birdseed. The traps were placed ten meters apart and covered with vegetation or wrapped in insulating bubble wrap when they were exposed (*e.g.*, when placed on top of bulrush thatch). Traps were set each night at approximately sunset and checked at or near sunrise the following morning, as required in our federal permit and CDFG Memorandum of Understanding. Where necessary, traps were completely removed from the marsh after checking them each morning and replaced in the evening when there was no chance that they might be flooded. All small mammals were identified to species, and lightly blazed on one or more places on the body. Blazing is defined as snipping the fur on the dorsal surface of

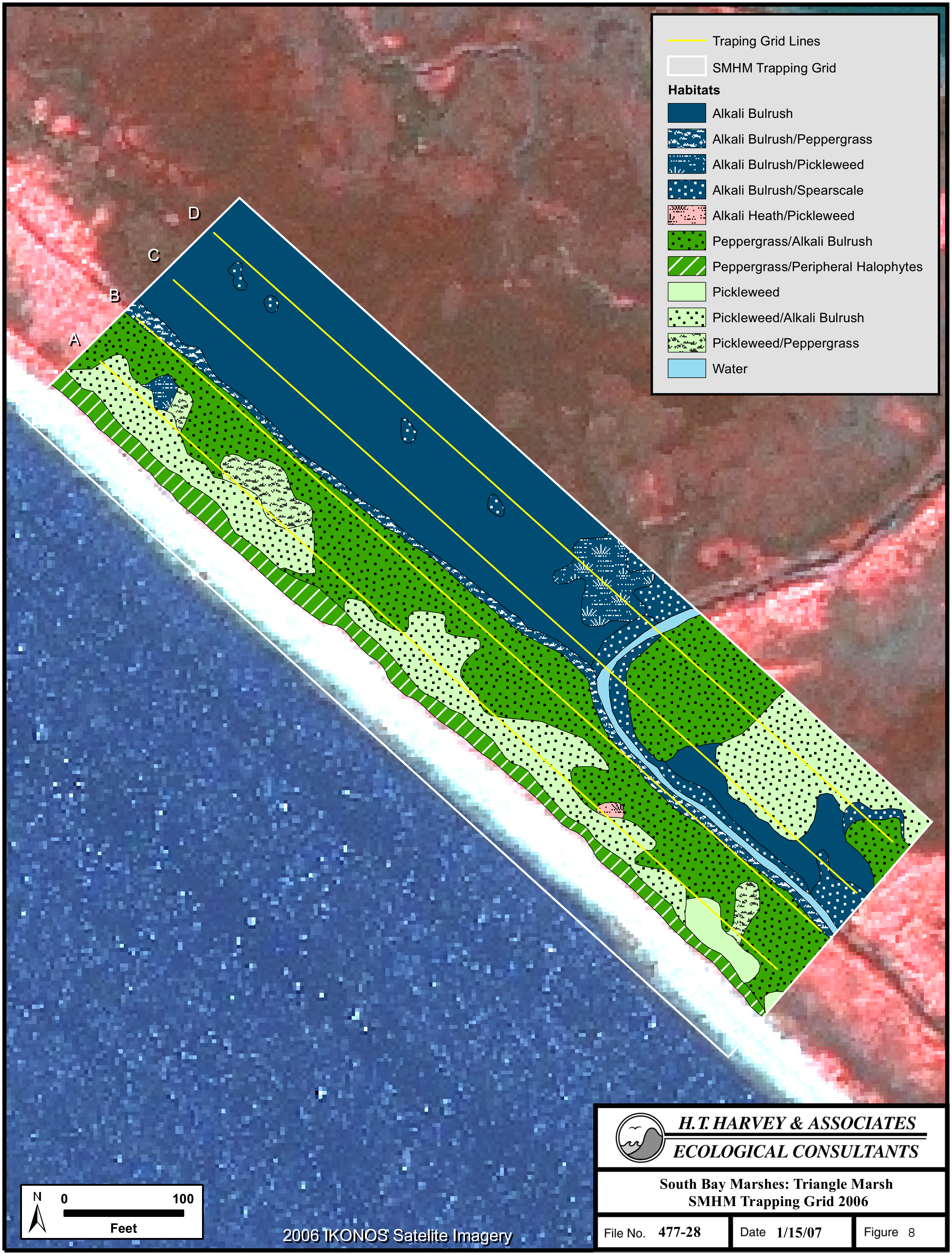


H.T. HARVEY & ASSOCIATES

ECOLOGICAL CONSULTANTS

South Bay Marshes: Calaveras Marsh
SMHM Trapping Grid 2006

File No. 477-28	Date 1/15/07	Figure 7



2006 IKONOS Satelite Imagery

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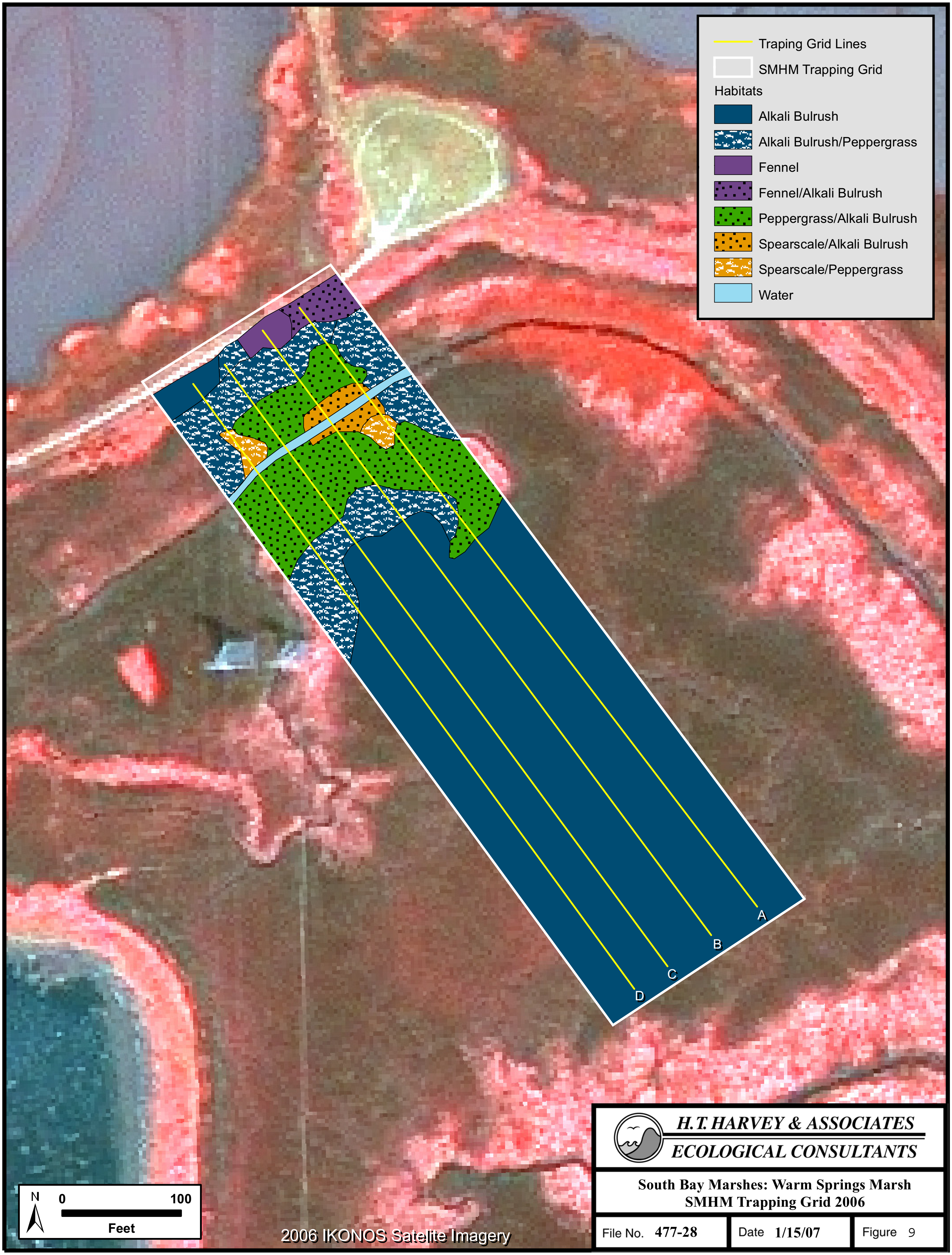
ECOLOGICAL CONSULTANTS

South Bay Marshes: Triangle Marsh
SMHM Trapping Grid 2006

File No. **477-28**	Date **1/15/07**	Figure 8



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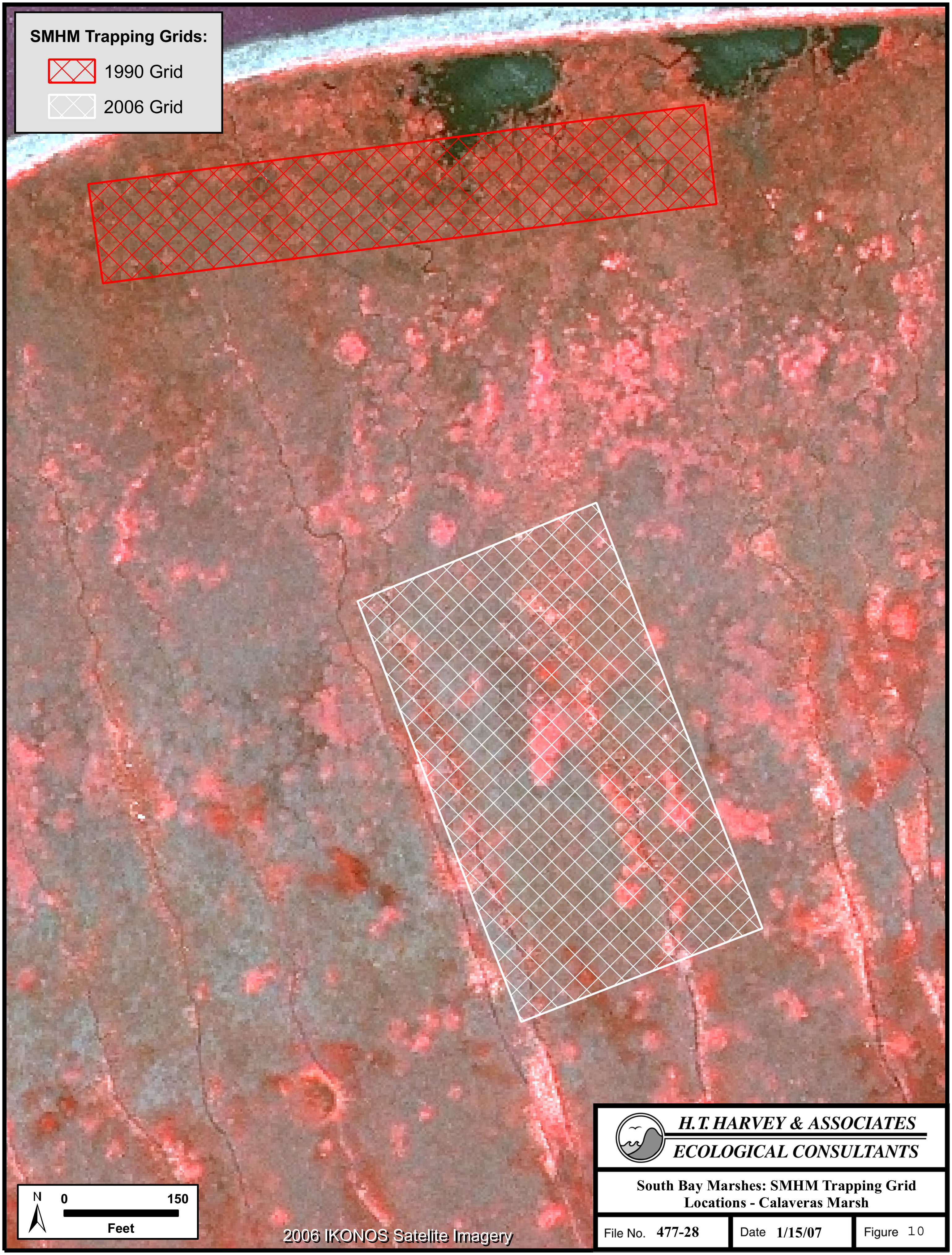
ECOLOGICAL CONSULTANTS

South Bay Marshes: Warm Springs Marsh
SMHM Trapping Grid 2006

File No. **477-28**
Date **1/15/07**
Figure 9



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ECOLOGICAL CONSULTANTS

South Bay Marshes: SMHM Trapping Grid Locations - Calaveras Marsh

File No. 477-28	Date 1/15/07	Figure 10

the animal in a unique pattern such that individuals can be recognized upon recapture. Data and trap locations were recorded on data sheets. SMHM were identified using the characteristics described in the following section.

5.2.2 Determination of Tidal Elevations

To ensure the safety of the mice during trapping in a fully tidal marsh system, trapping periods were selected to coincide with low tides during the night so that the marsh plain would not be flooded. As a first step, tidal charts were consulted to select an appropriate week for trapping. However, prior to any actual trapping, field verification of the accuracy of the tidal charts was performed at each of the three trapping grid locations. Wooden stakes were chalked and placed throughout the trapping grid prior to a moderately high tide. The following day, the water line on each of the stakes was measured and the depth of water inundating the marsh was compared to the predicted tides. These measurements were then used to refine the trapping dates.

5.2.3 Species Identification of Harvest Mice

The SMHM is difficult to identify in the field due to similarities with the western harvest mouse. Fisler (1965) described criteria used in their identification and Shellhammer (1984) described a numerical technique to identify these species in the field. Both SMHM and western harvest mice are very small rodents similar in size, shape, and overall coloration and both possess grooved incisors. However, SMHM have relatively fat, blunt-tipped, unicolored tails that lack white hairs, while western harvest mice have narrower, pointed tails that are bicolored and possess white hairs. In addition, SMHM typically are placid when held while western harvest mice are usually very active, similar to house mice (*Mus musculus*) in their frantic and biting behavior. It is their tail characteristics, though, that are most easily measured: the diameter of the tail 20 mm from the body, the overall color pattern, presence of white hairs on the ventral side of the tail, and the pointedness of the tip of the tail. Shellhammer (1984) described a numerical value from 0 to 2 for each of these characteristics (Table 5).

Table 5. Traits of the Tail Used to Differentiate Between Salt Marsh and Western Harvest Mice.

Trait	Score		
	0	1	2
Tip of Tail	Blunt	Intermediate	Pointed
Tail Pattern	Unicolor	Intermediate	Bicolor
Ventral Tail Hair Color	No white hairs	Few white hairs	More than a few white hairs
Diameter of Tail 20 mm from Body	2.1 mm or more	2.0 mm	1.9 mm or less

Total scores of these tail characteristics have been effective in differentiating the two species in most cases, especially when used in conjunction with behavior and, in some localities, the coloration of the venter (belly). The total score obtained for an individual mouse ranges from 0 to 8. SMHM generally score from 0 to 3, while western harvest mice typically score from 6 to 8.

Animals with total tail scores of 4 or 5 are listed as unidentified harvest mice, especially when their behavior and/or venter coloration do not aid in the diagnosis.

While venter (belly) coloration is not diagnostic, it often helps observers make a diagnosis when used in conjunction with tail traits and behavior, especially in the South San Francisco Bay where cinnamon-colored bellies are frequently found. Fisler (1965) noted seven gradations of venter coloration, which Shellhammer (1984) numbered (*i.e.* coded for brevity). They are (1) white or grayish white venter, (2) cinnamon pectoral spot, (3) band of color across chest, (4) ventral band with ¾ of the venter white, (5) color and white mixed, ½ of venter white, (6) trace of (¼) white, and (7) venter all cinnamon of varying intensity.

5.2.4 Vegetation Analysis

Vegetation was characterized in a one-meter square around each of the trap sites. Vegetation parameters measured were species present, percent cover of those species, and their average height. The vegetation of each of the marshes trapped was also mapped in 2006 as part of a long-term vegetation monitoring study, and these data were used in larger scale analyses of habitat use by SMHM, described below.

5.2.5 Capture Efficiency Calculations

Capture efficiency is a relative measure of number, or abundance, of small mammals. Capture efficiency is the number of SMHM captured divided by the number of total trap nights (TN) expended to capture them, multiplied by the number of traps in the grid, which in this case is 100. It can be used to compare trapping efforts of a varying number of trap-nights in different locations and/or at different times.

5.2.6 Statistical Methods

Comparisons of SMHM densities between trapping grids were performed utilizing a Chi-square test. Because the Chi-square test is considered less reliable at lower frequencies, these tests were performed on the total capture numbers directly, not on the calculated capture efficiencies.

Patterns in habitat use by SMHM were discerned by measuring correlations between SMHM captures and vegetation characteristics. These correlations were measured at three different spatial scales of vegetation data, the local scale ($1m^2$), the home range scale (grid, 1 hectares), and the marsh scale (34 to 149 hectares) For the home range scale and marsh scale analyzes, the relationship between SMHM habitat use and vegetation type was analyzed utilizing simple linear regression. The total number of SMHM or other rodents captured in each grid was plotted as a function of the vegetation characteristics within the entirety of the given grid or marsh. Only the data from Phase One was used, because the trapping methods were comparable between all three trapping grids in those samples. The vegetation characteristics utilized were percent cover of pickleweed species, percent cover of bulrush species, and percent cover of perennial peppergrass.

Interspecific covariation correlation matrices were developed to measure habitat use by SMHM with respect to the local scale vegetation data (*i.e.* $1m^2$ around each individual trap). Both the

Pearson product-moment correlations and the Spearman Rank correlations were calculated (see Ludwig and Reynolds 1988). A total of six correlation matrices were developed: one correlation matrix that pools data from all 3 girds and both phases (n = 500), and five correlation matrices (n=100) for the five separate grids and trapping phase (Calaveras Phase One, Triangle Phase One and 2, Warm Springs Phase One and Two). Because the purpose of this fine scale vegetation analysis was to ascertain small-scale habitat selection by SMHM and other rodent species, each individual animal capture was considered a data point. The three plant species that are assumed crucial to defining the habitat quality of a marsh for SMHM, pickleweed, alkali bulrush, and perennial peppergrass, are used in the covariance correlation matrices.

5.3. RESULTS

5.3.1 Small Mammal Captures and Vegetation Summaries

The numbers of SMHM captured are shown in Table 6a and Table 6b. Vegetation summaries, presented as percent cover overall and percent cover at SMHM capture sites, are presented in Table 7a and Table 7b. Trap areas for the three marshes are superimposed on vegetation maps mapped for the City of San Jose in 2006 in Figures 7-9.

Comparisons of SMHM capture rates between 1990 and 2006 indicate that there was no significant difference between SMHM captures at Calaveras Marsh (p=0.24) or Triangle Marsh (p=0.46). The Chi-square test cannot be performed when any observed frequencies are less than one, which precluded the use of a statistical test comparing 1990 to 2006 SMHM captures at Warm Springs Marsh because 0 animals of this species were captured on the site in 1990, whereas 2 were captured in 2006 (Phase One).

Comparison of SMHM captures between Phases One and Two of the current study shows that there was no change in the number of SMHM captured at Triangle Marsh (p=0.25), but there was a marginally significant increase in SMHM at Warm Springs Marsh (p=0.056). Likewise, there was no significant difference between Phases 1 and 2 in the number of California voles captured at Triangle Marsh (p=0.68), but there was a significant decline in the number of voles at Warm Springs Marsh (p=0.021).

No western harvest mice were captured in any of the three marshes in 1990, none have been identified in any of the studies carried out by H. T. Harvey and Associates in the vicinity of these marshes, and the marshes involved in this study do not consist of western harvest mouse habitat. Of the harvest mice captured in 2006, a few individuals had tail characteristics that measured out as intermediate between western harvest mice and SMHM (Appendix C). Nearly all of these individuals were juveniles or subadults, the smaller size of which precludes the accurate application of the tail characteristics for species identification. While technically these are "unidentifiable" harvest mice, based on our previous knowledge of these sites, we considered all harvest mice captured in this project, including the few unidentified harvest mice, to be SMHM.

Table 6a. Rodent Trapping Results, Phase One.

	Salt Marsh Harvest Mice	House Mice	California Voles
Calaveras Marsh			
August 29, 2006	3	1	0
August 30, 2006	7 + 3[1]	1+0	0
August 31, 2006	2 + 5	1+0	4+0
September 1, 2006	3 + 4	1+1	2+0
Total	**15 [3.75]** [2]	**4+1**	**6+0**
1990 Results	**22 [5.5]**	**0**[3]	**1**[3]
Triangle Marsh			
August 29, 2006	4	7	4
August 30, 2006	2+0	4 + 0	13 + 1
August 31, 2006	2+3	5 + 2	6 + 4
September 1, 2006	3+5	3 + 8	6 + 9
Total	**11 [2.75]**	**19 + 10**	**30 + 14**
1990 Results	**10 [2.00]** [4]	**8**	**18**
Warm Springs Marsh			
August 29, 2006	1	5	0
August 30, 2006	0	4+2	6+0
August 31, 2006	1+1	1[5]+3	3+2
September 1, 2006	0+1	0+6	11 + 6
Total	**2 [0.5]**	**10+11**	**20+8**
1990 Results	**0 [0.0]**	**27**	**38**

[1] = Number after the plus signs are the numbers of recaptures.

[2] = Capture efficiency (number of captures per 100 trap-nights) is in brackets.

[3] = 1990 results for voles and house mouse are displayed as total captures, including recaptures, whereas 2006 results differentiate between new and recaptured individuals for these species.

[4] = Trapping efforts in 1990at Triangle and Warm Springs were for five nights rather than four, hence the numbers marked are for a larger effort than in the present study.

[5] = Includes one rat, *Rattus rattus*.

Table 6b. Rodent Trapping Results, Phase Two.

	Salt Marsh Harvest Mice	House Mice	California Voles
Triangle Marsh			
September 18, 2006	6	8	6
September 19, 2006	2 + 4	6+3	8+2
September 20, 2006	7 + 5	2+8	7+5
September 21, 2006	2 + 9	2+10	2+9
Total	**17[4.25]**	**18**	**23**
Warm Springs Marsh			
September 18, 2006	5	1	3
September 19, 2006	0	5+0	3+0
September 21, 2006[1]	1+0	2+1	1+2
September 22, 2006	2+0	0+2	2+1
Total	**8 [2.0]**	**8**	**9**

[1] Trapping was not carried on evening of 20-Sept-06 because of raccoon trap vandalism. A large raccoon was trapped on the grid by predator control on the night of 19-Sept-06, and trapping resumed the evening of 20-Sept-06.

Table 7a. Local Scale Vegetation[1] Summary for 2006 and 1990 by Relative Percent Cover by Plant Species

	Triangle Marsh 2006a	Triangle Marsh 2006b	Triangle Marsh 1990	Calaveras 2006	Calaveras 1990	Warm Springs 2006	Warm Springs 1990
Atriplex triangularis (spearscale)	0.8	0.8	7.8	2.5		6.0	5.2
Distichlis spicata (saltgrass)	0.02	0.02	0.6		0.8		
Foeniculum vulgare (fennel)						1.9	
Frankenia salina (alkali heath)	4.2	1.9	9.2				
Grindelia hirsutula (gumplant)				13.7			
Jaumea carnosa (fleshy jaumea)				4.7			
Lepidium latifolium (perennial peppergrass)	18.7	18.2	3.3	1.3		13.7	6.9
Salsola soda (Russian thistle)	0.2	0.2	0.4	1.8	0.2		
Salicornia virginica (pickleweed)	31.3	26.1	57.6	60.9	99.0		
Scirpus maritimus (alkali bulrush)	44.8	52.7	19.4	2.0		72.1	87.9
Spartina sp. (cordgrass)				1.1			
Total Veg. Cover	99.9	99.9	98.3	88.0	100.0	93.7	100.0
Sample Size (n)	100	100	50	100	50	100	50

[1] Averaged vegetation composition as measured at 1 m2 around each trap location.

Table 7b. Local Scale Vegetation[1] Summary at SMHM Capture Sites for 2006 and 1990 by Relative Percent Cover by Plant Species

	Triangle Marsh 2006a	**Triangle Marsh 2006b**	**Triangle Marsh 1990**	**Calaveras 2006**	**Calaveras 1990**	**Warm Springs 2006a**	**Warm Springs 2006b**	**Warm Springs 1990**
Atriplex triangularis (spearscale)	3.0	0.6	11.3	3.8			5.7	
Distichlis spicata (saltgrass)					1.9			
Foeniculum vulgare (fennel)								
Frankenia salina (alkali heath)	6.0	1.3	4.7					
Grindelia hirsutula (gumplant)				10.3				
Jaumea carnosa (fleshy jaumea)				5.0				
Lepidium latifolium (perennial peppergrass)	14.4	22.0		2.0		32.5	31.4	
Salsola soda (Russian thistle)		0.6		0.5				
Salicornia virginica (pickleweed)	47.6	36.4	70.7	60.0	98.1			
Scirpus maritimus (alkali bulrush)	29.0	39.0	11.3	2.5		62.5	58.6	
Spartina sp. (cordgrass)				4.8				
Total Veg. Cover	100.0	100.0	98.0	88.8	100.0	95.0	95.7	n/a
Sample Size (n)	15	24	12	20	26	4	6	0

[1] Averaged vegetation composition as measured at 1 m^2 around each SMHM capture site.
(Note: 2006a trapping = marsh plain, 2006b trapping = up in the vegetation)

5.3.2 SMHM Captures in Relation to Vegetation at Capture Sites

Overall Patterns. The interspecific covariation correlation matrix for the combined data from all the grids showed that SMHM were significantly positively correlated with pickleweed, and significantly negatively correlated with bulrush on the local ($1m^2$) scale (Appendix D). California voles were significantly positively correlated with bulrush and with perennial peppergrass, and the non-native house mouse was also significantly positively correlated with peppergrass. All of the plant species were strongly negatively correlated with each other, which is to be expected because they represent different marsh types. The lack of strong correlations between the various rodent species should not be interpreted as a lack of competitive interactions between them because the covariation correlation technique is less able to detect interactions when capture rates are low (Ludwig and Reynolds 1988).

The larger scale analyses (home range and marsh segment scales) generally corroborate the results of the local scale analysis (Appendix E). The slopes of the regression lines generally show that the density of SMHM is greater where the percent cover of pickleweed is higher, and lower where the percent cover of bulrush or perennial peppergrass is lower. California voles show the opposite pattern; their densities are greater where the percent cover of bulrush and perennial peppergrass is greater, and lower where the percent cover of pickleweed is greater. The small sample size in these regression analyses ($n=3$) makes achieving statistical significance difficult, so many of the patterns described above are not statistically significant. However, there were a few correlations that were marginally statistically significant ($0.05<p<0.10$). The SMHM showed a negative association with alkali bulrush ($p=0.074$) and with perennial peppergrass ($p=0.053$). The California vole showed a positive association with alkali bulrush ($p=0.099$) and with perennial peppergrass ($p=0.056$).

The individual marshes each displayed unique relationships between SMHM and vegetation characteristics. These often differ from the overall pattern, indicating that SMHM habitat selection can be idiosyncratic and is a function of the vegetation present at any given site. The results from the interspecific covariation correlation matrices for each individual marsh are presented below. Note that within this discussion two factors are termed “correlated” where $p<0.05$, and “associated” where $0.05<p<0.10$.

5.3.3 Calaveras Marsh

Eighty-five percent of the captures (23 of 27) of SMHM at Calaveras Marsh were at trap sites dominated by pickleweed. Gumplant was present at 6 capture sites and dominant at one. Other capture sites included one with 50% cordgrass, 30% bulrush, and 10% pickleweed; one with 70% jaumea and 30% cordgrass; and one site with 45% pickleweed, 35% cordgrass, and 10% jaumea. Percentages of plant species overall and at all capture sites are presented in Tables 3a and 3b. Detailed information in reference to vegetation at each trap site and the identification of capture/recapture sites are shown in Appendices F and G. A more detailed visual representation of the grid and associated vegetation can be seen in Figure 2.

The interspecific covariation correlation matrix for Calaveras Marsh (Appendix D) did not show any significant correlations between SMHM and local scale vegetation. This implies that the SMHM in this high-quality salt marsh did not exercise habitat selection at the local scale. California voles were significantly positively associated with perennial peppergrass in Calaveras Marsh.

5.3.4 Triangle Marsh

During the first phase of trapping at Triangle Marsh, 58% (11 of 19) of the SMHM capture sites were dominated by pickleweed, whereas 26% (5) were dominated by bulrush. Two capture sites were dominated by a near-equal mixture of bulrush and alkali heath and one by alkali heath and perennial peppergrass (Table 7b and Figure 8). During Phase Two trapping at Triangle Marsh, when the traps were placed higher in the vegetation, 49% (17) of SMHM trap sites were dominated by pickleweed, 17% (6) by bulrush, and 14% (5) by perennial peppergrass. Two capture sites had an equal amount of pickleweed and bulrush. We note that two captures occurred at sites covered by 100% perennial peppergrass.

During the first phase of trapping at Triangle Marsh, the interspecific covariation correlation matrix indicates that SMHM were positively associated with pickleweed ($0.05<p<0.10$), and significantly negatively correlated with alkali bulrush ($p<0.05$). This suggests that SMHM were actively selecting the more salt-marsh associated vegetation within this transitional marsh. California voles were significantly positively correlated with alkali bulrush ($p<0.05$), and negatively associated with pickleweed ($0.05<p<0.10$). House mice were negatively associated with bulrush ($0.05<p<0.10$), and significantly positively correlated with both pickleweed and perennial peppergrass ($p<0.05$). This pattern is generally consistent with that of the overall interspecific covariation correlation matrix.

The interspecific covariation correlation matrix for the second phase of trapping at Triangle Marsh did not change drastically from that of Phase One for SMHM, although there were changes. SMHM were even more strongly positively correlated with pickleweed, and more negatively correlated with bulrush. A significant negative correlation ($p<0.05$) between SMHM and perennial peppergrass emerged during the second trapping session at Triangle Marsh. In addition, the California vole and the house mouse did not show any significant correlation with plant type, unlike in Phase One.

5.3.5 Warm Springs Marsh

Phase One trapping at Warm Springs Marsh, which was conducted both on the marsh plain and beneath the thatch layer, resulted in 2 individuals, each of which were recaptured one time. Two of the four total captures (captures and recaptures) occurred in a location covered entirely by bulrush, with a 10% cover thatch layer. One capture occurred in an area of 60% perennial peppergrass/ 40% bulrush. A fourth mouse was captured in 70% perennial peppergrass/ 30% bulrush (Table 3a and Figure 9). Phase Two trapping, which occurred on or above the thatch layer in this bulrush-dominant marsh, resulted in 8 total SMHM being captured; 5 in bulrush-dominated sites, 2 in perennial peppergrass-dominated sites with sparse bulrush, and 1 at perennial peppergrass/ spearscale dominated site with 20% bulrush present.

Warm Springs marsh differed from the other marshes in that there was no pickleweed present on the grid; alkali bulrush and perennial peppergrass were the dominant plant species. During Phase One of trapping, the interspecific covariation correlation matrix indicated that there was no significant correlation or association either positive or negative between SMHM and vegetation type. However, there was a positive association between California voles and bulrush ($0.05<p<0.10$), as seen in other marshes. House mice were positively associated with perennial peppergrass and negatively associated with bulrush ($0.05<p<0.10$).

During Phase Two of trapping at Warm Springs, SMHM likewise did not show any significant correlations or associations with vegetation in the interspecific covariation correlation matrix. However, in contrast to Phase One, California voles showed a negative association with bulrush, (0.05<p<0.10). Both house mice and voles showed a significant positive correlation ($p<0.05$) with perennial peppergrass in the second phase. The results imply that the competitors of SMHM, voles and house mice, shifted their vegetation use during the second phase of trapping at Warm Springs Marsh from bulrush to peppergrass.

Trap Vandalism. On the second night of Phase Two trapping in Warm Springs Marsh, a raccoon disturbed 35 traps in the grid. Trapping was halted for one night, during which Brian Popper, a wildlife biologist and trapper from the United States Department of Agriculture working with the San Francisco Bay National Wildlife Complex, captured a 22-pound male raccoon. Popper's trapping occurred concurrently with our own for the remainder of the session, and there were no other raccoon problems.

Mouse Movements. Three SMHM moved across the wide sloughs in Triangle Marsh, and one of these mice was documented crossing the slough twice. Even though the water level in both sloughs was low during those nights in which movement occurred, the mice still apparently swam across at least 2 meters of water. It is possible that one of the mice actually traveled the distance to the other side of the slough on land, but this seems unlikely as it would have had to move 80+ meters to the edge of the grid, 10- 20 meters to a small bridge we erected to cross the slough east of the grid, and then at least 100 meters back up the other side to the location where it was trapped. There was a similar situation in the same marsh in 1990 (H.T. Harvey 1990a), though at that time it was reported that the only possible set of events capable of producing the observed results was that several mice swam the width of the slough. Although we present a possible alternative, it appears most likely that all mice in question did, in fact, swim across the slough.

5.4. DISCUSSION AND CONCLUSIONS

5.4.1 Comparison of 1990 and 2006 Vegetation and Trapping Baselines

No significant decline in SMHM densities were observed at any of the marshes in 2006 as compared to 1990. This suggests that the various changes that have occurred in the vegetation of the marshes of the South Bay over the last 16 years have not adversely affected the relative densities of the SMHM in the South Bay, presuming the three marshes we sampled are sufficiently representative. More detailed discussions of the results for each marsh follow below.

5.4.2 Calaveras Point Marsh

This marsh has changed considerably since 1990. The 1990 trapping area in this marsh was essentially fully covered by pickleweed (99% pickleweed in 1990 versus 61% in 2006; Table 3a). Spearscale, gumplant, jaumea, alkali bulrush, and cordgrass were all absent from the trapping area in 1990, but were present in 2006. In combination with the much greater width of the marsh, this greater plant diversity, particularly the 14% cover by gumplant, indicate that this marsh is maturing and perhaps increasing in quality for SMHM. Higher areas along small marsh channels are building and these higher areas support gumplant, a favorite escape cover of SMHM in broad salt marshes.

The 2006 capture locations reflected this change in vegetation. While 85% of the capture sites were dominated by pickleweed, 22% were gumplant-dominant. Cordgrass appeared in several capture sites, and dominated at some of them (Appendix F). This is somewhat unexpected as cordgrass usually occurs so low in the marsh that it is inundated too frequently to support SMHM. The interspecific covariation correlation matrix did not show a significant correlation between SMHM and any of the vegetation types, which implies that this species was not actively selecting habitat on the local scale within this salt marsh. This may be because the high-quality salt marsh habitat at Calaveras Marsh is essentially uniform in its suitability for this species.

While the number of SMHM captured did not differ significantly between 1990 and 2006, there were fewer mice trapped in 2006 (15 vs. 22). The pickleweed in the grid was short, thinner, and less structurally complex in 2006 as opposed to 1990, likely due to the greater amount of standing water from the less efficient drainage of this now much broader marsh. This shift in the structure of the pickleweed in this area could have caused a decline in capture rates. Also, the 2006 study utilized wooden platforms to elevate the traps because there was often standing water in the marsh plain, even at low tide. While care was taken to ensure that vegetation led up onto the platforms to allow harvest mice to readily access the traps, it is still possible that the platforms slightly reduced the capture efficiency of SMHM because the traps were slightly more difficult to access than they were when sitting directly on the marsh plain in the 1990 study. The use of platforms could therefore also have been a factor in the lower capture efficiency rates for this marsh in 2006 as compared to 1990, although clearly this effect was not sufficient to cause a statistically significant decline in SMHM captures.

We surmise that there are more SMHM in the Calaveras Marsh in 2006 than in 1990, primarily because the marsh is more than twice its 1990 size. Although the greater pooling of water may reduce the quality of the vegetation for SMHM in the back of the marsh near the levee, the middle portions of the marsh are expected to continue to mature and develop the type of vegetation strongly associated with high quality SMHM habitat, such as internal escape cover in the form of gumplant and deeper, thicker pickleweed as well as large patches of alkali bulrush and cordgrass. The SMHM population in Calaveras Marsh is considered to be secure into the foreseeable future, and may even increase in size as the evolution of the marsh proceeds.

5.4.3 Triangle Marsh

This marsh has become more brackish since 1990. The area beyond the tidal slough, where two lines of our traps were placed, is almost entirely covered with alkali bulrush. In 1990, while this area was predominantly bulrush, it still contained patches of pickleweed. The area between the levee and the parallel slough, where our two inner trap lines were located, is still mostly pickleweed, intermixed with patches of perennial peppergrass and alkali bulrush. Perennial peppergrass has become more common, rising from about 3% cover in 1990 to almost 19% in 2006. The lack of significant difference in the capture efficiency of SMHM at this marsh between 1990 and the 2006 (2.00 vs. 2.75) implies that these changes in the marsh vegetation have not adversely affected the SMHM population within Triangle Marsh. In fact, a greater number of SMHM were captured in 2006 as opposed to 1990, which indicates that not finding a decline cannot be attributed to a lack of statistical power.

Twice as many harvest mice were captured at pickleweed-dominated trap sites as at pure alkali bulrush sites or at perennial peppergrass dominated sites during Phase One of trapping. The positive correlation between SMHM and pickleweed and the negative association between SMHM and alkali bulrush as shown in the interspecific covariation correlation matrix indicate that SMHM are actively selecting the salt-marsh vegetation within this transitional marsh. California voles showed a positive association with alkali bulrush and a negative correlation with pickleweed, indicating that this species, which is less adapted to saline environments than the SMHM, was actively selecting the brackish marsh vegetation within Triangle Marsh. This pattern is consistent with what is known about the relative salt-tolerances of these two rodent species.

5.4.4 Warm Springs Marsh

Two animals were captured during the Phase One trapping, when traps were placed on the mud surface and beneath the live vegetation and thatch, and none were captured in 1990 (Table 6a and Figure 9). The appearance of SMHM in this marsh suggests that some aspect of the marsh structure or the larger scale metapopulation dynamics of the species changed between 1990 and 2006 that allowed this habitat to be utilized by this species. No change occurred in the vegetation of this marsh between 1990 and 2006 that would be expected to increase its suitability for SMHM; the only changes were a slight decrease in the percentage of bulrush from 88% to 72%, and an increase in perennial peppergrass from 7% to 14%.

The lack of any significant correlation between SMHM and vegetation type in the interspecific covariation correlation matrix suggests that this species was not actively selecting habitat on the local scale during Phase One of the study. California voles showed a positive association with alkali bulrush during Phase One of trapping at Warm Springs, which is consistent with patterns observed in Triangle Marsh, in the overall covariation matrix, and in the marsh-scale regression analyses.

5.5. PHASE TWO

5.5.1 Triangle Marsh

The number of SMHM captured in Phase Two was not significantly different than in Phase One (11 vs. 17, p=0.25). This indicates that placing the traps above the alkali bulrush thatch did not significantly increase capture rates of SMHM in this marsh. It should be noted that the water did not actually cover the marsh plain during this second trapping session at Triangle Marsh. This was an idiosyncratic effect that occurred in spite of both tide tables and reconnaissance tidal height measurements indicating that the marsh plain should have been covered with water during this second phase of trapping. This result suggests that simply putting the traps higher in the vegetation will not necessarily increase SMHM capture efficiencies. However, even though the difference between the two phases was not significant, there was an increase in the number of SMHM, and this trend is consistent with the pattern observed at Warm Springs in Phase Two. Overall, the number of SMHM captured at transitional Triangle Marsh during Phase Two was higher than expected given the moderate habitat suitability normally assigned to transitional marsh environments, and was actually greater than the number of SMHM captured at saline Calaveras Marsh in Phase One (15 vs. 17).

During the second trapping session, some of the traps in this grid were moved from where they had been in the first trapping session to areas with more alkali bulrush. Traps could be placed higher in the bulrush than in pickleweed, and hence we could provide more safety for captured mice from the anticipated tidal inundation. These changes in placement increased the amount of bulrush at the trap site by approximately 18% and reduced the amount of pickleweed by about 12% (Table 7a). There was no significant difference between SMHM correlations with vegetation at the local between Phase One and Phase Two of trapping, which indicates that moving some of the traps to taller bulrush vegetation during the second phase did not bias the measured habitat use by this species. SMHM continued to be positively correlated with pickleweed and negatively correlated with bulrush, as in Phase One.

5.5.2 Warm Springs Marsh

The most striking difference between phases was at the Warm Springs Marsh. The number of SMHM increased by a factor of four from Phase One to Phase Two (2 vs. 8), and this difference constituted a marginally significant increase ($p = 0.056$). These results indicate that some factor was sufficiently different between the two trapping phases to cause a significant effect on SMHM capture rates. This could have been due to either higher trap placement in the vegetation, or flooding of the marsh plain causing the mice to move up into the bulrush, or simply the mice being more active and thereby more likely to enter a trap. The fact that the difference was not observed at Triangle Marsh where no water was on the marsh plain (*i.e.*, the highest tides during the evenings did not flood the trapping grid) suggests that it is the presence of the water in the marsh that makes SMHM capture rates higher, not simply the position of the traps higher in the vegetation. Our results from trapping above the thatch layer mirrors that of the CDFG and DWR trappers in the Suisun Marsh, where significantly more harvest mice and other species were captured higher in the thatch layer than on the soil surface.

The number of SMHM captured in Phase Two might have been higher if it were not for the raccoon vandalism in the middle of the trap sequence. Trapping was interrupted for one night when a large raccoon was captured and removed by USDA trappers working in association with the Refuge. We cannot assess what impact the raccoon damage and the subsequent delay in trapping had on capture numbers, but we expect there was probably a lower capture rate subsequent to the raccoon vandalism. Capturing just one more SMHM during Phase Two would have been sufficient to make this a significant ($p<0.05$) rather than merely marginally significant ($p=0.056$) difference between the two phases.

The increase in the number of SMHM captured at Warm Springs between Phase One and Phase Two of the study was accompanied by several other significant changes. The number of California voles significantly declined during the second phase (30 vs. 9, $p=0.021$). In addition, the association between voles and alkali bulrush went from being positive during Phase One to negative during Phase Two, and voles were positively correlated with perennial peppergrass during the second phase, whereas they showed no significant correlation with peppergrass during the first phase. This suggests that the voles shifted the criteria by which they selected habitat on the local scale, from preferring areas dominated by bulrush to avoiding these areas and preferring areas where perennial peppergrass exists. Within Warm Spring Marsh, the bulrush portions of the site were lower in elevation and were the portions covered in water during the high tides, where as perennial peppergrass occupied the higher, drier ground. The results from this study suggest that the voles were vacating the lower lying bulrush portions of the site to move to the high, drier perennial peppergrass portions of the marsh during the high tide. It was been indicated in previous studies that voles are strong competitors with SMHM, and behaviorally exclude SMHM from habitat (Geissel et al. 1998). It is possible that the increase in SMHM densities in Warm Springs Marsh was due to competitive release from the voles vacating the bulrush portion of the marsh.

Capturing 8 SMHM during the second phase at Warm Springs Marsh was a very surprising result. This is a much greater density of SMHM that has ever been documented in a brackish marsh before. The 1990 results of no SMHM captured on the flood plain at Warm Springs were also found at a nearby, similar marsh (Newby Island) trapped during that year (H. T. Harvey 1990a), and extensive trapping surveys of brackish marshes in the South Bay in the 1970's also yielded no SMHM (Shellhammer, unpublished data). This result suggests that the use of brackish marsh habitat by SMHM is greater than previously thought. Further implications of this intriguing result are discussed below.

5.5.3 Questions Raised by the Phase Two Trapping of Warms Springs Marsh

How are SMHM able to utilize brackish, bulrush habitat? This study shows that SMHM are using the thatch layer more than the surface of the marsh plain, and that the species is present in brackish marsh habitat where it has not been previously found. There are multiple hypotheses regarding why we found SMHM in considerable densities in a brackish, bulrush-dominated marsh, and these are explored in more detail below. At this point all of these ideas are speculative, and it will take future study to confirm any of these hypotheses.

In the 1960s and 1970s, when the bulrush marshes were less mature and had essentially no thatch, SMHM did not utilize this habitat. It is quite possible that the development of a thatch layer with the maturation of the bulrush marsh vegetation is what allows SMHM to utilize this habitat now. In past decades when the bulrush marshes of the South Bay were younger, the lower parts of alkali bulrush marshes had open areas between the stems with an upper canopy well above the marsh plain. It was an environment in which CCR and other harvest mouse predators could traverse as easily as harvest mice. Mature bulrush, with its thick layer of thatch, excludes predators and provides cover for the mice, and if the thatch layer is thick enough it also provides escape cover for the mice during almost all high tides. The bulrush also provides seeds as a potential seasonal food source for the mice. Although we do not have data to confirm that SMHM eat parts of alkali bulrush, we presume they do. Fisler (1965) suggested, based on his relatively small amount of diet analysis, that the scat of SMHM contained fibrous plant material, especially in seasons when green, leafy plant material was less available, and bulrush would provide ample amounts of this kind of forage. We also do not have measurements of the size of a mouse's home range within stands of alkali bulrush, but they have been trapped more than 60 meters from the nearest non-bulrush food source in this study and as far as 90 meters away in a similar species of bulrush in the Suisun Marsh (Bathmann-Thompson, pers. comm.). Thus mice appear to be present within the bulrush for a longer time period than they could physiologically handle without eating.

The results of this study suggest that SMHM are more heavily utilizing the thatch layer higher up in the bulrush during high tide events when the marsh plain is flooded. This could be due to either the harvest mice escaping the high tide, or due to competitive release because the California voles avoid the bulrush when the marsh plain is flooded. It is possible that, at least in some cases, significant tidal action in addition to a thick thatch layer is necessary for a brackish marsh to support SMHM. Further study is needed before this can be confirmed.

While SMHM use bulrush during high tide events when the marsh plain is flooded, the value of bulrush to SMHM will probably remain the same with predicted sea level rise. Given a moderate level of sea level rise and continued sediment availability, the bulrush marsh plain elevations will likely remain consistent with sedimentation rates.

It is possible that the use of brackish, bulrush-dominated habitat by SMHM is mediated by competitive interactions. Geissel et al. (1988) found in the diked, saline New Chicago Marsh that SMHM used pickleweed more often when the much larger California voles were less numerous, and moved into areas of lesser quality when vole numbers were high due to behavioral exclusion. A similar process may occur in brackish marshes, where SMHM utilize this marginal habitat when their densities, or densities of competing species, in neighboring higher-quality habitat are high. However, at Warm Springs there are no large areas of high-quality pickleweed habitat nearby, so this is not likely the situation in this specific instance. The results of our study suggest that SMHM utilize the thatch layer higher up in the bulrush during high tide events when the marsh plain is flooded. This could be due merely to the mice escaping the high tide, however, our data suggest that there may be a competitive process at work as well. At Warm Springs, SMHM utilized the bulrush more when vole densities were lower, perhaps due to competitive release because the California voles actively avoided the bulrush when the marsh plain was flooded. Voles are not as good at climbing vegetation as are the smaller, more agile SMHM. These competitive considerations suggests that tidal action regularly covering the marsh plain, in addition to a thick thatch layer, may be necessary for a brackish marsh to support SMHM in high numbers. In any case, it is quite likely that the effects of competition, especially with the California vole, play a role in the use of brackish marsh habitat by SMHM.

Another possible explanation for the presence of SMHM in the brackish marshes at Warm Springs is that they are in transit between patches of vegetation with which they are more commonly associated. Such vegetation would be more salt-tolerant plants with more succulent or less fibrous leaves such as pickleweed, spearscale, or alkali heath. Warms Springs Marsh is made up of large patches of alkali bulrush and perennial peppergrass and smaller patches of pickleweed, pickleweed and perennial peppergrass, spearscale and bulrush, pickleweed and bulrush, and others (Figure 9). Most of the brackish marshes in the South Bay are lined with narrow bands of halophytes and grasses. These strips of non-brackish vegetation may allow SMHM to move throughout the brackish marshes and into patches of more saline vegetation. However, it should be noted there are no large patches of salt marsh habitat located near Warm Springs Marsh, and the marshes near this end of the South Bay are nearly entirely brackish, so these SMHM are still existing in a largely brackish environment.

What are the conservation implications of the high number of SMHM found in the alkali bulrush of a brackish marsh? Our study documented a much greater density of SMHM in a brackish marsh than has ever been reported before in the South Bay. The capture of 2 SMHM in Phase One was unexpected, but the capture of 8 individuals during Phase Two is surprising enough to call for a reexamination of the suitability of brackish, bulrush-dominated marsh habitat for this species. It should be noted that 8 individuals is approximately half of the density of SMHM captured at saline Calaveras Marsh or transitional Triangle Marsh. If such comparatively high capture rates for SMHM can be found consistently in other brackish marshes as well, it would suggests that brackish marsh habitat is of higher value to this endangered species that has previously considered. It is very possible that the value of a brackish marsh as habitat for SMHM is dependent certain key characteristics, particularly with respect to existence of a thatch layer, or the presence of vigorous tidal action, or the proximity to pickleweed habitat. The results of this study are not sufficient to conclude precisely what the value of brackish marsh habitat is for SMHM, or under what conditions it has value. Rather, it merely indicates that it likely has more value that previously thought. Further study is needed to address this question, and ultimately determine what the value of brackish marsh habitat is for SMHM.

What are the implications for SMHM of the spread of perennial peppergrass through the marshes of the South San Francisco Bay? Based on this study, the spread of perennial peppergrass in tidal marshes might potentially be of concern for the SMHM, although the data are far from conclusive at this point. Since 1990, perennial peppergrass has spread throughout the more brackish South Bay marshes, and there was more of it in and near our trapping grids in 2006 as compared to1990. The results of the vegetation correlation analyses in our study show that SMHM are negatively correlated with perennial peppergrass at the marsh scale and local scale, and that its competitors the California vole and the house mouse are positively correlated with perennial peppergrass on both the grid scale and the local scale. These results suggest that the spread of perennial peppergrass within the marshes of the South Bay could reduce the habitat quality of those marshes for SMHM, and thereby potentially the densities of SMHM within these marshes. However, the fact that SMHM densities increased between 1990 and 2006 at both of the brackish marshes in this study in spite of the greater presence of perennial peppergrass on these grids suggests that this invasive species is not necessarily strongly detrimental to SMHM. In any case, the negative effect of perennial peppergrass on SMHM would probably result from peppergrass being advantageous to the competitors of the endangered mouse. Two SMHM were captured in nearly pure stands of perennial peppergrass, so it is less likely that this invasive plant species is directly detrimental to the endangered mouse. It is possible that the negative correlation between SMHM densities and perennial peppergrass is merely due to this plant being an indictor of less saline, and perhaps less frequently inundated, marsh conditions that do not favor SMHM. Multiple previous trapping projects performed by Howard Shellhammer (unpublished data) indicate that the number of SMHM captures declines as perennial peppergrass cover increases, especially in areas of pure perennial peppergrass. These observations, however, are few in number and based on trapping the sides and lower portions of levees. If peppergrass were to spread throughout the brackish marshes of the South Bay, it is uncertain what the effects would be on SMHM. The negative correlations between SMHM and perennial peppergrass in this study suggest that the spread of this invasive plant species may have negative consequences for the endangered mouse, but this data is not sufficient for a definitive conclusion because other possible explanations for this pattern exist as well.

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APPENDIX A.
CALIFORNIA CLAPPER RAIL SURVEY DATA

Appendix A. Number of California Clapper Rails detected at each station on each survey in 2006.

Transect	Station	Date	AM/PM	# Rails Detected	Length of Survey (min)
1	a	24-Apr	am	2	90
1	b	24-Apr	am	0	90
1	c	24-Apr	pm	4	90
1	d	24-Apr	pm	4	90
1	e	24-Apr	pm	7	90
1	a	1-May	am	0	90
1	b	1-May	am	1	90
1	c	1-May	am	3	90
1	d	2-May	am	0	90
1	e	2-May	am	5	90
1	a	8-May	am	0	90
1	b	8-May	am	1	90
1	c	8-May	am	2	90
1	d	8-May	am	2	90
1	e	8-May	am	2	90
2	a	20-Apr	pm	0	90
2	b	20-Apr	pm	2	90
2	c	21-Apr	am	8	90
2	d	21-Apr	am	4	90
2	e	21-Apr	am	4	90
2	a	27-Apr	pm	2	90
2	b	27-Apr	pm	0	90
2	c	27-Apr	pm	0	90
2	d	27-Apr	pm	4	90
2	e	27-Apr	am	4	90
2	a	4-May	pm	0	90
2	b	4-May	pm	0	90
2	c	4-May	pm	0	90
2	d	4-May	am	7	90
2	e	4-May	am	12	90
3	a	20-Apr	am	0	90
3	b	20-Apr	pm	0	90
3	c	20-Apr	am	0	90
3	d	20-Apr	am	1	90
3	e	20-Apr	am	3	90
3	a	27-Apr	am	6	90
3	b	27-Apr	am	11	90
3	c	27-Apr	pm	0	90
3	d	27-Apr	am	3	90
3	e	27-Apr	am	6	90
3	a	4-May	am	4	90
3	b	4-May	pm	0	90

Appendix A. Number of California Clapper Rails detected at each station

3	c	4-May	pm	0	90
3	d	4-May	am	3	90
3	e	4-May	am	5	90
4	a	16-Feb	am	0	10
4	b	16-Feb	am	0	10
4	c	16-Feb	am	0	10
4	d	16-Feb	am	0	10
4	e	16-Feb	am	0	10
4	a	24-Feb	am	0	10
4	b	24-Feb	am	0	10
4	c	24-Feb	am	0	10
4	d	24-Feb	am	0	10
4	e	24-Feb	am	0	10
4	a	25-Apr	pm	1	10
4	b	25-Apr	pm	1	10
4	c	25-Apr	pm	1	10
4	d	25-Apr	pm	0	10
4	e	25-Apr	pm	1	10
4	a	5-May	am	0	10
4	b	5-May	am	0	10
4	c	5-May	am	0	10
4	d	5-May	am	0	10
4	e	5-May	am	0	10
4	c	11-May	am	1	90
4	e	11-May	am	3	90
5	a	13-Feb	pm	6	10
5	b	13-Feb	pm	3	10
5	c	13-Feb	pm	5	10
5	d	13-Feb	pm	3	10
5	e	13-Feb	pm	0	10
5	a	23-Feb	pm	2	10
5	b	23-Feb	pm	0	10
5	c	23-Feb	pm	1	10
5	d	23-Feb	pm	0	10
5	e	23-Feb	pm	0	10
5	a	22-Apr	am	1	10
5	b	22-Apr	am	0	10
5	c	22-Apr	am	1	10
5	d	22-Apr	am	0	10
5	e	22-Apr	am	0	10
5	a	6-May	am	0	10
5	b	6-May	am	0	10
5	c	6-May	am	0	10
5	d	6-May	am	0	10
5	e	6-May	am	0	10
6	b	13-Feb	pm	0	10

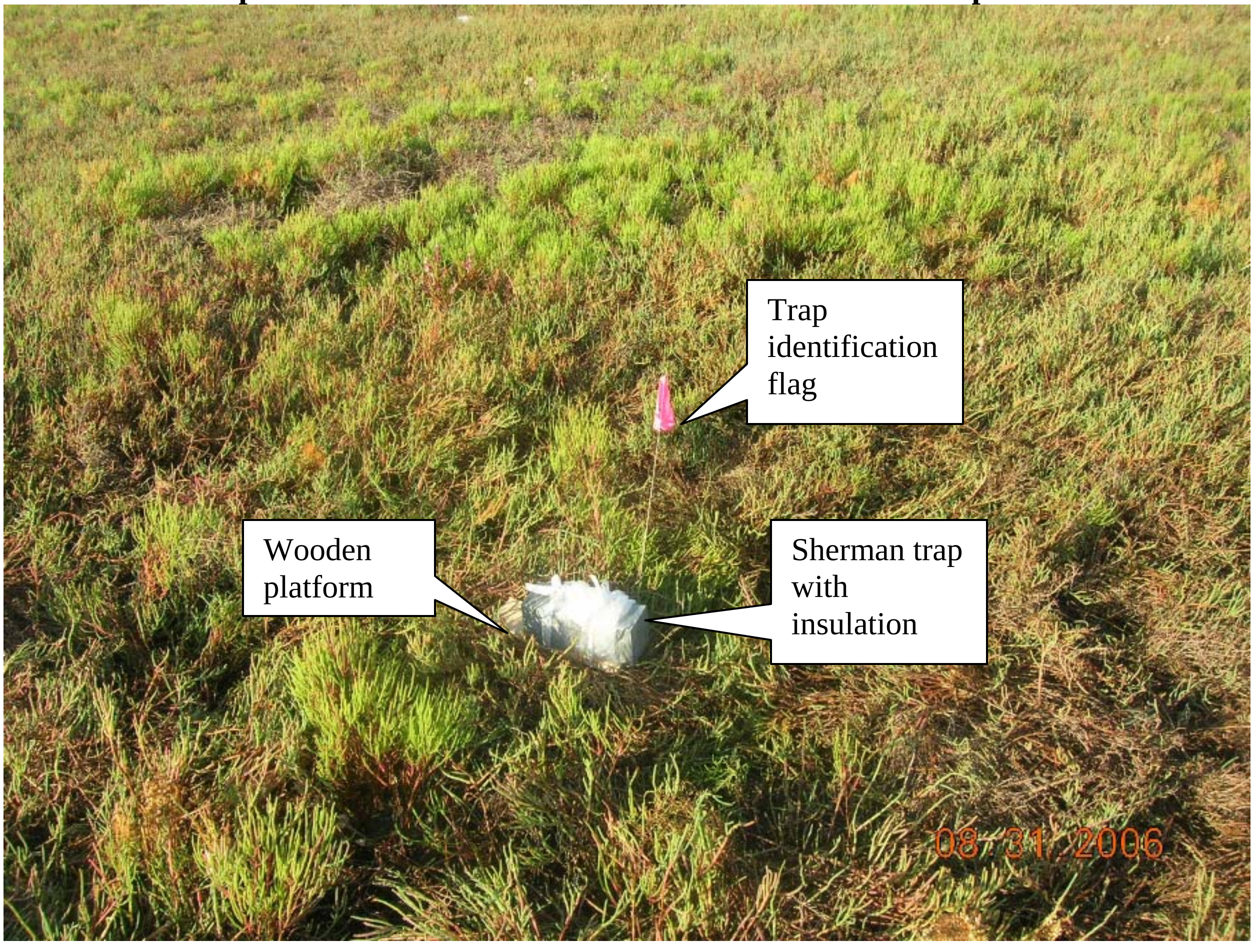
Appendix A. Number of California Clapper Rails detected at each station

6	c	13-Feb	pm	0	10
6	d	13-Feb	pm	0	10
6	e	13-Feb	pm	0	10
6	f	13-Feb	pm	0	10
6	b	23-Feb	pm	0	10
6	c	23-Feb	pm	0	10
6	d	23-Feb	pm	0	10
6	e	23-Feb	pm	0	10
6	f	23-Feb	pm	0	10
6	b	23-Apr	pm	0	10
6	c	23-Apr	pm	0	10
6	d	23-Apr	pm	0	10
6	e	23-Apr	pm	0	10
6	f	23-Apr	pm	0	10
6	b	6-May	am	0	10
6	c	6-May	am	0	10
6	d	6-May	am	0	10
6	e	6-May	am	0	10
6	f	6-May	am	0	10
6	c	10-May	pm	0	90
6	e	10-May	pm	0	90
7	a	9-Feb	pm	0	10
7	b	9-Feb	pm	0	10
7	c	9-Feb	pm	0	10
7	d	9-Feb	pm	0	10
7	e	9-Feb	pm	0	10
7	a	22-Feb	pm	0	10
7	b	22-Feb	pm	0	10
7	c	22-Feb	pm	0	10
7	d	22-Feb	pm	0	10
7	e	22-Feb	pm	0	10
7	a	26-Apr	pm	0	10
7	b	26-Apr	pm	0	10
7	c	26-Apr	pm	0	10
7	d	26-Apr	pm	0	10
7	e	26-Apr	pm	0	10
7	a	9-May	am	0	10
7	b	9-May	am	0	10
7	c	9-May	am	0	10
7	d	9-May	am	0	10
7	e	9-May	am	0	10
7	c	10-May	pm	0	90
7	c	24-May	am	0	90
8	a	11-Feb	pm	0	10
8	b	11-Feb	pm	0	10
8	c	11-Feb	pm	0	10

8	d	11-Feb	pm	0	10
8	e	11-Feb	pm	0	10
8	a	25-Feb	pm	0	10
8	b	25-Feb	pm	0	10
8	c	25-Feb	pm	0	10
8	d	25-Feb	pm	0	10
8	e	25-Feb	pm	0	10
8	a	22-Apr	pm	0	10
8	b	22-Apr	pm	0	10
8	c	22-Apr	pm	0	10
8	d	22-Apr	pm	0	10
8	e	22-Apr	pm	0	10
8	a	6-May	pm	0	10
8	b	6-May	pm	0	10
8	c	6-May	pm	0	10
8	d	6-May	pm	0	10
8	d	6-May	pm	0	90
8	e	6-May	pm	0	10
8	d	27-May	pm	0	90
8	e	27-May	pm	0	90

APPENDIX B.
PHOTO OF TRAP
AT CALAVERAS MARSH

Photo of wooden platform used at lower elevation Calaveras Marsh trap locations



APPENDIX C.
HARVEST MOUSE IDENTIFICATION DATA

Morphological Data of Harvest Mice Captured at Calaveras Point, Triangle and Warm Springs Marshes, August and September 2006.

C = Calaveras Point Marsh, T = Triangle Marsh, W = Warm Springs

ID #	Tail Tip Score	Tail Pattern Score	Tail Ventral Hair Color Score	Tail Diameter (mm)	Total Tail Score	Behavior	Venter (belly color)	Weight (gm)	Tail/ Body (%)	Sex
C-1	0	0	0	0	0	D	7	12	1.01	F
C-2	0	1	1	0	2	I	6	N/A	1.13	F
C-3	0	1	0	0	1	I	7	9	1.09	M
C-4	0	0	1	0	1	D	5	12	1.17	M
C-5	0	0	0	0	0	D	6	13	1.00	M
C-6	0	1	1	0	2	I	5	18	1.03	F
C-7	2	0	0	0	2	I	7	12	1.01	M
C-8	0	1	0	1	2	I	6	13	0.97	F
C-9	0	0	0	0	0	I	3	12	1.01	M
C-10	2	0	0	0	2	I	6	11	0.98	M
C-11	0	0	0	0	0	D	7	12	1.08	F
C-12	0	0	0	0	0	D	4	22	0.89	F
C-13	0	0	1	0	1	D	6	12.5	1.06	F
C-14	0	0	0	0	0	D	7	10	1.02	M
C-15	0	0	0	0	0	I	7	14	1.05	M
T-1	1	1	1	1	4	I	2	12	1.02	F
T-2	0	0	0	0	0	D	7	11	1.05	M
T-3	0	1	1	0	2	D	7	11	0.11	M
T-4	1	0	0	1	2	I	7	10.5	0.94	M1.0
T-5	0	0	1	0	1	D	7	7.5	0.93	M
T-6	0	1	0	0	1	D	7	11.5	0.88	F
T-7	1	0	1	0	2	I	7	12	0.98	F
T-8	1	0	0	0	1	D	7	11	1.03	M
T-9	1	2	2	0	5	I	7	14.5	N/A	F
T-10	2	0	1	0	3	D	4	19	1.04	F
T-11	1	0	0	1	2	D	7	15.5	1.00	F
T-12	1	0	0	0	1	D	7	13	0.93	M
T-13	1	0	1	0	2	D	5	14	0.94	M
T-14	0	0	0	0	0	I	2	17.5	0.94	F
T-15	1	1	0	0	2	D	5	12.5	0.96	F
T-16	1	0	0	0	1	I	7	14	0.94	F
T-17	0	1	1	0	2	D	6	11	0.88	F
T-18	1	1	1	2	5	D	2	7.5	1.08	M
T-19	2	0	1	2	5	D	3	5	N/A	F
T-20	1	1	1	0	3	A	3	16	1.02	F
T-21	0	0	0	2	2	D	7	8	0.88	F
T-22	0	1	0	0	1	I	7	N/A	N/A	M
T-23	1	0	0	2	3	I	7	7.5	N/A	F
W-1	0	0	0	0	0	D	6	11	0.99	M
W-2	0	0	0	0	0	D	7	N/A	1.1	F
W-3	0	0	1	0	1	I	5	N/A	0.8	M

Morphological Data of Harvest Mice Captured at Calaveras Point, Triangle and Warm Springs Marshes, August and September 2006.

ID #	Tail Tip Score	Tail Pattern Score	Tail Ventral Hair Color Score	Tail Diameter (mm)	Total Tail Score	Behavior	Venter (belly color)	Weight (gm)	Tail/ Body (%)	Sex
W-4	0	2	2	1	5	I	1	11	1.19	M
W-5	0	0	0	0	0	I	7	12	1.09	F
W-6	1	0	0	0	1	I	7	15	1.07	M
W-7	0	0	0	0	0	I	7	15	0.98	F
W-8	0	2	0	2	4	D	1	9	1.00	M
W-9	0	0	1	0	1	D	7	10	1.13	F
W-10	0	0	0	0	0	D	6	15	0.93	F

APPENDIX D.
INTERSPECIFIC COVARIATION CORRELATION MATRICES

All Grids and Trapping Sessions Combined

Pearson Product-Moment Correlations

	Pickleweed	Bulrush	Peppergrass	SMHM	CA Vole	Mus
Pickleweed		-0.6674**	-0.2378**	0.2377**	-0.0488	0.0333
Bulrush	-0.7041**		-0.3098**	-0.1955**	0.1378**	-0.0499
Peppergrass	-0.0440	-0.3155**		0.0123	0.0015	0.0953**
SMHM	0.1927**	-0.1633**	0.0414		-0.0377	-0.0630
CA Vole	-0.0698	0.1480**	0.0952**	-0.0215		-0.0233
Mus	0.0605	-0.0276	0.2183**	-0.0279	-0.0016	

Spearman Rank Correlations

* = significant at p<0.1 probability level

** = significant at p<0.05probability level

Calaveras Marsh – Session 1

Pearson Product-Moment Correlations

	Pickleweed	Bulrush	Peppergrass	SMHM	CA Vole	Mus
Pickleweed		-0.1380	-0.1475	0.0342	-0.1037	-0.0285
Bulrush	-0.1513		-0.0857	0.0334	-0.0146	-0.0635
Peppergrass	-0.2166**	-0.1314		0.0255	0.1530	-0.0500
SMHM	-0.0310	0.0810	0.0154		-0.1076	-0.0820
CA Vole	-0.0995	-0.0117	0.2189**	-0.1258		-0.0486
Mus	-0.0150	-0.0854	0.0641	-0.1016	0.0516	

Spearman Rank Correlations

* = significant at 10% probability level

** = significant at 5% probability level

Triangle Marsh – Session 1

Pearson Product-Moment Correlations

	Pickleweed	Bulrush	Peppergrass	SMHM	CA Vole	Mus
Pickleweed		-0.6483**	-0.2973**	0.2105**	-0.1113	0.1554
Bulrush	-0.6631**		-0.4303**	-0.1658*	0.2735**	-0.1894*
Peppergrass	-0.1213	-0.5946**		-0.0866	-0.1478	0.0854
SMHM	0.1591	-0.1684*	-0.0332		-0.0646	-0.0449
CA Vole	-0.1659*	0.2565**	-0.1488	0.0148		-0.1901*
Mus	0.2154**	-0.1883*	0.2676**	0.0510	-0.1619	

Spearman Rank Correlations

* = significant at 10% probability level

** = significant at 5% probability level

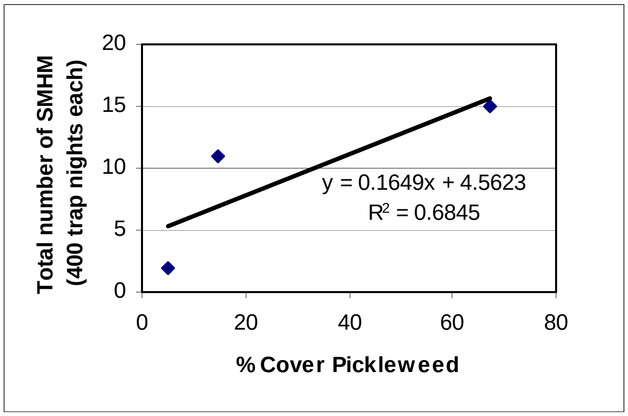
Triangle Marsh – Session 2						
Pearson Product-Moment Correlations						
	Pickleweed	Bulrush	Peppergrass	SMHM	CA Vole	Mus
Pickleweed		-0.6004**	-0.2812**	0.3083**	0.0477	0.0769
Bulrush	-0.6115**		-0.5610**	-0.2780**	0.0511	-0.0339
Peppergrass	0.0937	-0.6931**		0.0226	-0.0755	-0.0582
SMHM	0.2042**	-0.2445**	-0.0077		-0.0705	-0.1831*
CA Vole	0.0308	-0.0089	-0.0131	-0.0355		-0.0667
Mus	0.0616	-0.0302	0.0558	-0.1713	-0.0242	
Spearman Rank Correlations						
* = significant at 10% probability level						
** = significant at 5% probability level						

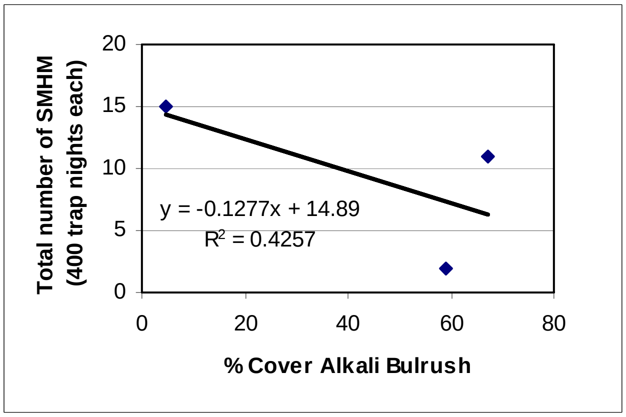
Warm Springs Marsh – Session 1						
Pearson Product-Moment Correlations						
	Bulrush	Peppergrass	SMHM	CA Vole	Mus	
Bulrush		-0.6552**	-0.0638	0.1751*	-0.1758*	
Peppergrass	-0.7400**		0.1479	-0.0584	0.0889	
SMHM	-0.0796	0.1078		-0.0978	0.0161	
CA Vole	0.1472	0.0821	-0.1078		-0.0433	
Mus	-0.1965*	0.1973**	0.0737	-0.0518		
Spearman Rank Correlations						
* = significant at 10% probability level						
** = significant at 5% probability level						

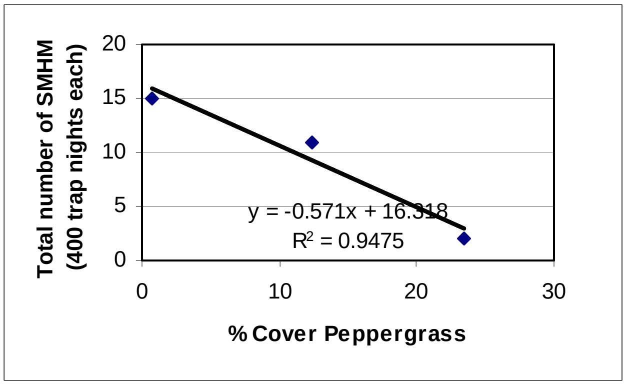
Warm Springs Marsh – Session 2						
Pearson Product-Moment Correlations						
	Bulrush	Peppergrass	SMHM	CA Vole	Mus	
Bulrush		-0.6552**	-0.0817	-0.1332	-0.1172	
Peppergrass	-0.7400**		0.1390	0.2036*	0.1933*	
SMHM	-0.1377	0.1637		0.0891	-0.0724	
CA Vole	-0.1809*	0.2509**	0.0442		0.1108	
Mus	-0.2104**	0.2489**	-0.0808	0.1470		
Spearman Rank Correlations						
* = significant at 10% probability level						
** = significant at 5% probability level						

APPENDIX E.
GRID AND MARSH SCALE VEGETATION CORRELATION ANALYSES

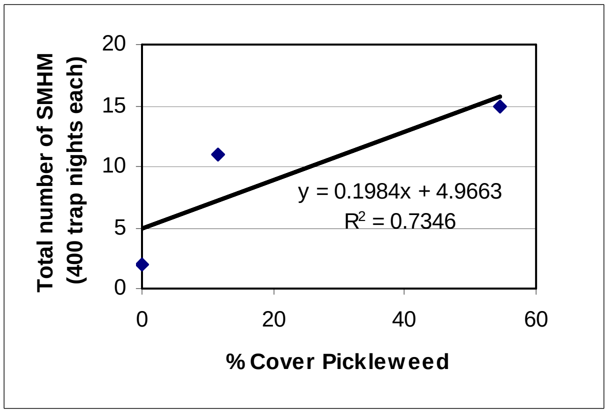
Marsh Scale Analysis - SMHM

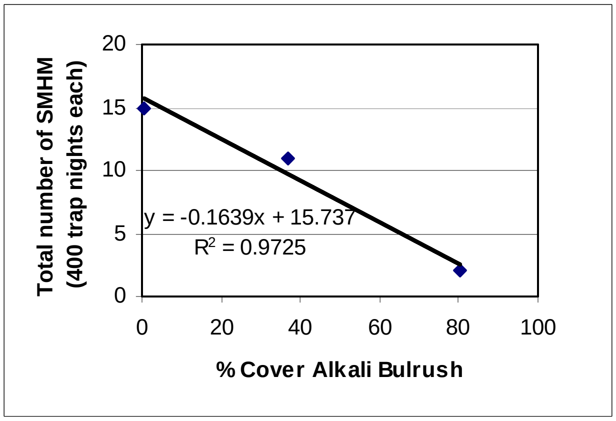


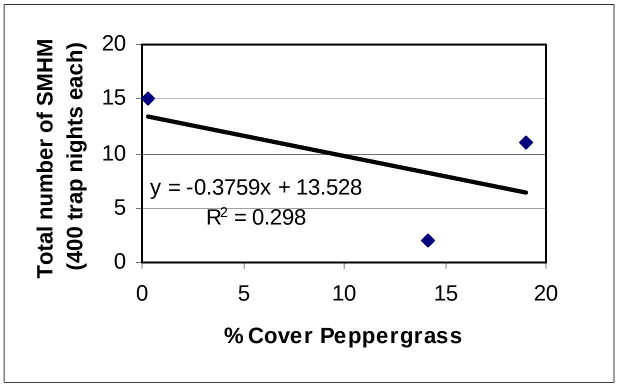




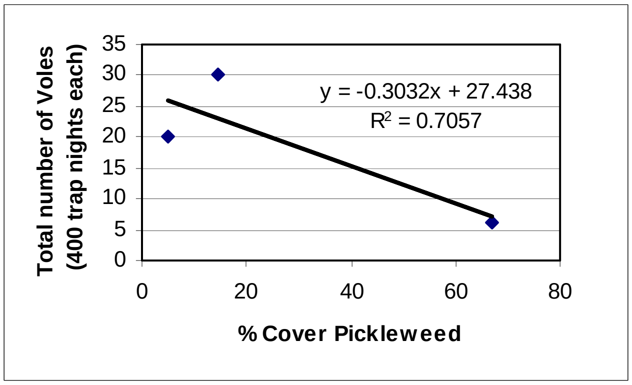
Grid Scale Analysis- SMHM

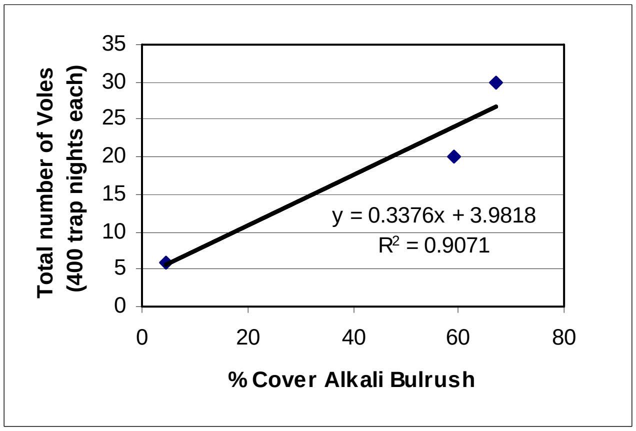


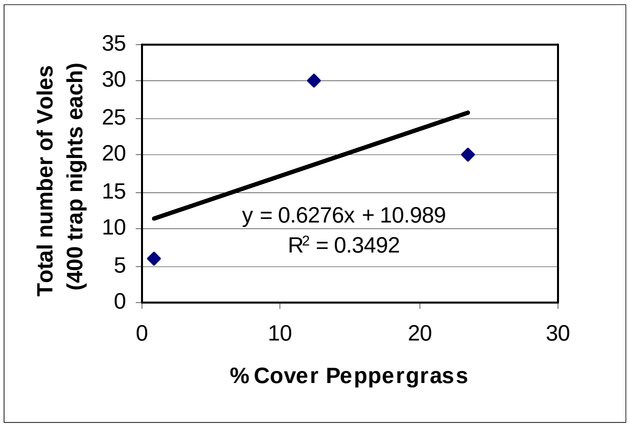




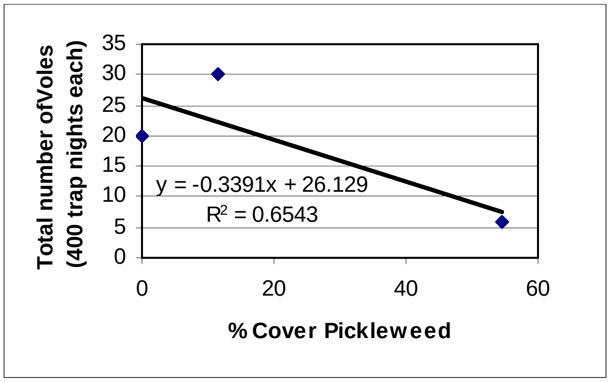
Marsh Scale Analysis – CA Vole

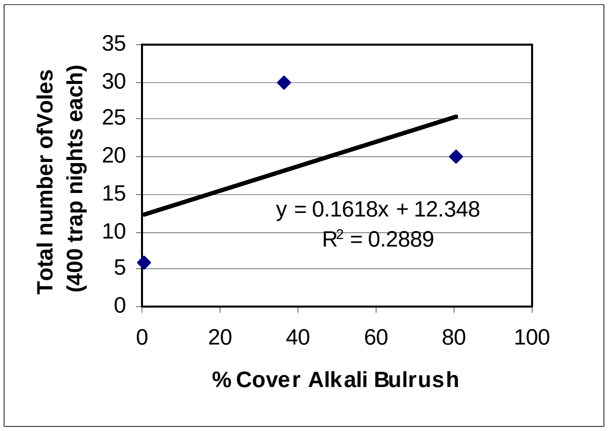


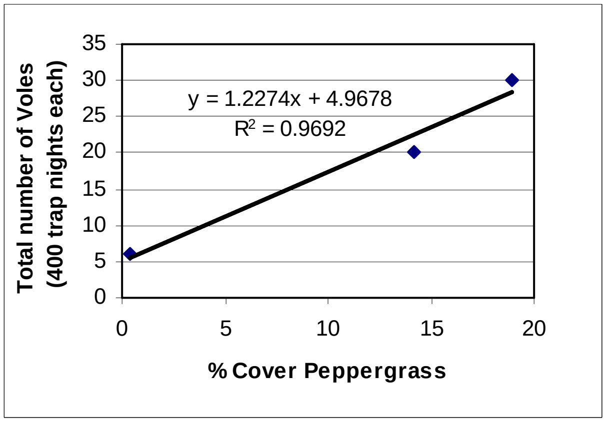




Grid Scale Analysis- CA Vole







APPENDIX F.
VEGETATION AND CAPTURE SITES BY TRAP STATION

KEY:
T=TRIANGLE, C=CALAVERAS, W=WARM SPRINGS
PHASE: 1=1ST TRAPPING EVENT, 2=2ND TRAPPING EVENT
SAVI = *Salicornia virginica* (pickleweed)
SCRO = Scirpus maritimus (alkali bulrush)
LELA = *Lepidium latifolium* (perennial peppergrass)
SALTY SPECIES= Distichlis spicata (saltgrass), Frankenia salina (alkali heath), Grindelia hirsutula (gumplant), Jaumea carnosa (fleshy jaumea), Salsola soda (Russian thistle), Salicornia virginica (pickleweed), Spartina sp. (cordgrass)
BRACKISH SPECIES= *Atriplex triangularis* (spearscale), *Scirpus maritimus* (alkali bulrush), *Lepidium latifolium* (perennial peppergrass)

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
T	1	A01	90	9	1	90	10			2
T	1	A02	95	5	0	95	5	2		
T	1	A03	99	0	1	99	1			
T	1	A04	98	0	2	98	2	1		
T	1	A05	95	5	0	95	5			
T	1	A06	50	50	0	50	50			2
T	1	A07	98	2	0	98	2	3		
T	1	A08	98	2	0	98	2		1	
T	1	A09	97	1.5	1.5	97	3	1	1	
T	1	A10	75	0	25	75	25		1	
T	1	A11	95	0	5	95	5	1		1
T	1	A12	50	50	0	50	50		3	
T	1	A13	80	18	2	80	20			
T	1	A14	60	38	2	60	40		1	
T	1	A15	2	1	97	2	98			
T	1	A16	95	4	1	95	5	1		
T	1	A17	60	38	2	60	40	1	1	1
T	1	A18	40	10	0	90	10			
T	1	A19	1.5	1.5	0	98.5	1.5			
T	1	A20	97	1.5	1.5	97	3			
T	1	A21	95	5	0	95	5			
T	1	A22	60	39	1	60	40			
T	1	A23	70	10	15	70	25		1	1
T	1	A24	99	1	0	99	1			
T	1	A25	75	0	0	96	2			
T	1	B01	0	60	40	0	100			2
T	1	B02	70	10	20	70	30		1	
T	1	B03	0	0	100	0	100		1	
T	1	B04	0	0	100	0	100			
T	1	B05	75	0	25	75	25	1	1	1
T	1	B06	65	20	15	65	35		2	
T	1	B07	85	10	5	85	15			3
T	1	B08	0	20	80	0	100		1	
T	1	B09	1	49	50	1	99	1	1	
T	1	B10	0	0	100	0	100	1		

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
T	1	B11	0	0	100	0	100			
T	1	B12	90	0	10	90	10			
T	1	B13	70	15	15	70	30			
T	1	B14	1	39	60	1	99			1
T	1	B15	0	0	100	0	100			
T	1	B16	0	0	100	0	100		1	
T	1	B17	40	0	60	40	60			1
T	1	B18	85	0	15	85	15			1
T	1	B19	20	40	40	20	80			
T	1	B20	2	0	98	2	98			2
T	1	B21	49	1	50	49	51			
T	1	B22	3	38	59	3	97			1
T	1	B23	5	15	80	5	95			
T	1	B24	80	1	19	80	20			3
T	1	B25	25	25	25	50	50			2
T	1	C01	0	100	0	0	100			
T	1	C02	0	100	0	0	100			
T	1	C03	0	100	0	0	100		1	
T	1	C04	0	100	0	0	100		1	
T	1	C05	0	100	0	0	100			2
T	1	C06	0	100	0	0	100		2	
T	1	C07	0	100	0	0	100		2	
T	1	C08	0	100	0	0	100		2	
T	1	C09	0	100	0	0	100			
T	1	C10	0	100	0	0	100			
T	1	C11	0	100	0	0	100			
T	1	C12	0	100	0	0	100		1	
T	1	C13	0	100	0	0	100		2	
T	1	C14	0	100	0	0	100			
T	1	C15	0	100	0	0	100		1	
T	1	C16	0	100	0	0	100		2	
T	1	C17	0	100	0	0	100		1	
T	1	C18	0	20	80	0	100			
T	1	C19	20	60	20	20	80			
T	1	C20	0	60	30	10	90			
T	1	C21	0	60	40	0	100		1	
T	1	C22	0	100	0	0	100	1	1	
T	1	C23	80	20	0	80	20			
T	1	C24	75	5	0	85	15		1	
T	1	C25	0	75	0	53	95			
T	1	D01	0	100	0	0	100		1	
T	1	D02	0	100	0	0	100		2	
T	1	D03	0	100	0	0	100		1	
T	1	D04	0	100	0	0	100			
T	1	D05	0	100	0	0	100			
T	1	D06	0	100	0	0	100			
T	1	D07	0	100	0	0	100			
T	1	D08	0	60	0	40	60	2		

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
T	1	D09	0	100	0	0	100		1	
T	1	D10	0	100	0	0	100			
T	1	D11	0	100	0	0	100			
T	1	D12	0	80	0	20	80			
T	1	D13	0	100	0	0	100			
T	1	D14	0	100	0	0	100	1		
T	1	D15	0	98	0	1	99			
T	1	D16	50	50	0	50	50		1	
T	1	D17	48	50	0	50	50		1	
T	1	D18	0	40	60	0	100			
T	1	D19	1	17	80	3	97			1
T	1	D20	1	0	0	100	0			
T	1	D21	0	15	30	50	50	1		
T	1	D22	90	8	2	90	10			
T	1	D23	75	15	0	80	20			
T	1	D24	50	50	0	50	50			1
T	1	D25	0	60	0	0	100	1	1	1
C	1	A01	70	0	10	80	10	1		
C	1	A02	90	0	0	95	0			
C	1	A03	10	0	0	100	0			
C	1	A04	80	0	0	100	0	1		
C	1	A05	15	0	0	100	0	1		
C	1	A06	60	0	0	80	20	1		
C	1	A07	50	0	0	95	0			
C	1	A08	30	0	0	90	10			
C	1	A09	60	0	0	75	20			
C	1	A10	60	0	0	100	0	1		
C	1	A11	70	0	30	70	30	1		
C	1	A12	50	0	10	90	10		1	
C	1	A13	80	0	0	100	0			1
C	1	A14	30	0	0	100	0			
C	1	B01	85	0	0	85	0	4		
C	1	B02	90	0	0	90	0			
C	1	B03	80	0	0	80	0			
C	1	B04	70	0	0	70	0			
C	1	B05	65	0	0	65	5	1		
C	1	B06	40	5	0	40	15			
C	1	B07	75	5	0	80	5	1		
C	1	B08	30	0	0	35	40			
C	1	B09	85	0	0	85	0	1		
C	1	B10	90	0	0	90	0			
C	1	B11	75	0	0	75	5			
C	1	B12	90	0	0	90	0	1		
C	1	B13	40	30	0	40	30			
C	1	B14	80	15	0	80	15			
C	1	C01	70	0	0	70	0			
C	1	C02	70	0	0	70	0			
C	1	C03	60	0	0	65	0			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
C	1	C04	70	0	0	70	0	1		
C	1	C05	80	0	0	80	0			
C	1	C06	85	0	0	85	0			
C	1	C07	85	0	0	90	0			
C	1	C08	80	0	0	80	0			
C	1	C09	100	0	0	100	0			
C	1	C10	95	0	0	95	0			
C	1	C11	100	0	0	100	0			
C	1	C12	90	5	0	90	5			
C	1	C13	70	30	0	70	30			
C	1	C14	95	0	0	95	0			
C	1	D01	95	0	0	95	0			
C	1	D02	60	0	0	85	0			
C	1	D03	40	20	0	60	20			
C	1	D04	30	2	0	90	2			
C	1	D05	45	5	0	90	5	2		
C	1	D06	0	0	0	100	0	1		
C	1	D07	60	10	0	60	10	2		
C	1	D08	60	0	0	90	0	1		
C	1	D09	80	0	0	80	0			
C	1	D10	80	0	0	80	0	2		
C	1	D11	100	0	0	100	0			
C	1	D12	97	0	0	97	0			
C	1	D13	100	0	0	100	0			
C	1	D14	97	0	0	97	0			
C	1	E01	5	0	15	60	15		1	
C	1	E02	50	0	0	90	0			1
C	1	E03	40	0	0	60	0			2
C	1	E04	30	0	0	90	10		1	
C	1	E05	45	0	5	95	5			
C	1	E06	50	0	10	90	10			
C	1	E07	5	0	0	40	0			
C	1	E08	25	10	0	75	15			
C	1	E09	15	0	0	95	5			
C	1	E10	20	0	0	100	0			
C	1	E11	20	0	10	90	10			
C	1	E12	65	20	0	65	25			
C	1	E13	10	30	0	15	80	1		
C	1	E14	40	0	30	40	30			
C	1	F01	60	0	0	75	0	1		
C	1	F02	50	0	0	65	10		1	
C	1	F03	65	0	0	95	0			
C	1	F04	70	0	0	100	0			
C	1	F05	70	0	0	95	0			
C	1	F06	75	0	0	95	0			
C	1	F07	60	5	0	80	10			
C	*1*	*F08*	*75*	*0*	*0*	*95*	*0*			*1*
C	1	F09	40	0	0	55	30			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
C	1	F10	60	0	0	90	0			
C	1	F11	10	0	0	85	5			
C	1	F12	10	0	0	100	0			
C	1	F13	40	0	0	85	0			
C	1	F14	60	0	0	95	0	1		
C	1	F15	45	0	5	95	5			
C	1	G01	75	0	0	95	5			
C	1	G02	90	0	0	100	0			
C	1	G03	95	0	0	95	0		1	
C	1	G04	90	0	0	90	0			
C	1	G05	90	0	0	90	0			
C	1	G06	70	0	0	90	0			
C	1	G07	90	0	0	90	0			
C	1	G08	70	0	0	70	5			
C	1	G09	80	0	0	85	0			
C	1	G10	30	0	0	40	0			
C	1	G11	35	0	0	95	5			
C	1	G12	20	0	0	100	0			
C	1	G13	50	0	0	50	0			
C	1	G14	70	10	0	70	10		1	
C	1	G15	85	0	0	85	0			
W	1	A01	0	10	0	0	10			4
W	1	A02	0	60	40	0	100		1	
W	1	A03	0	40	60	0	100			2
W	1	A04	0	1	1	0	100			
W	1	A05	0	10	0	0	100			
W	1	A06	0	0	10	0	100			
W	1	A07	0	20	80	0	100			
W	1	A08	0	40	60	0	100	1		
W	1	A09	0	60	40	0	100			
W	1	A10	0	20	40	0	100			
W	1	A11	0	90	0	0	90	1		1
W	1	A12	0	90	0	0	90			
W	1	A13	0	90	0	0	90			
W	1	A14	0	90	0	0	90			
W	1	A15	0	90	0	0	90		1	
W	1	A16	0	90	0	0	90		2	
W	1	A17	0	90	0	0	90			
W	1	A18	0	90	0	0	90			
W	1	A19	0	90	0	0	90			
W	1	A20	0	90	0	0	90			
W	1	A21	0	90	0	0	90		2	
W	1	A22	0	90	0	0	90			
W	1	A23	0	90	0	0	90			
W	1	A24	0	90	0	0	90			
W	1	A25	0	90	0	0	90			
W	1	B01	0	0	0	0	0			1
W	1	B02	0	60	40	0	100			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
W	1	B03	0	90	10	0	100		1	3
W	1	B04	0	2	8	0	100			
W	1	B05	0	30	70	0	100	1		
W	1	B06	0	40	60	0	100			
W	1	B07	0	90	10	0	100			
W	1	B08	0	95	5	0	100		1	
W	1	B09	0	90	0	0	90		3	
W	1	B10	0	90	0	0	90	1		
W	1	B11	0	90	0	0	90			
W	1	B12	0	90	0	0	90			
W	1	B13	0	90	0	0	90			
W	1	B14	0	90	0	0	90			
W	1	B15	0	90	0	0	90			
W	1	B16	0	90	0	0	90			
W	1	B17	0	90	0	0	90			
W	1	B18	0	90	0	0	90			
W	1	B19	0	90	0	0	90			
W	1	B20	0	90	0	0	90			
W	1	B21	0	90	0	0	90			
W	1	B22	0	90	0	0	90			
W	1	B23	0	90	0	0	90			
W	1	B24	0	90	0	0	90			
W	1	B25	0	90	0	0	90			
W	1	C01	0	50	50	0	100			1
W	1	C02	0	70	30	0	100			1
W	1	C03	0	80	20	0	100		1	1
W	1	C04	0	40	60	0	100			2
W	1	C05	0	0	5	0	100			
W	1	C06	0	10	90	0	100			
W	1	C07	0	20	80	0	100			
W	1	C08	0	40	60	0	100		1	
W	1	C09	0	95	5	0	100		2	
W	1	C10	0	90	0	0	90		1	
W	1	C11	0	90	0	0	90		1	
W	1	C12	0	90	0	0	90			
W	1	C13	0	90	0	0	90			
W	1	C14	0	90	0	0	90			
W	1	C15	0	90	0	0	90			
W	1	C16	0	90	0	0	90			
W	1	C17	0	90	0	0	90			
W	1	C18	0	90	0	0	90			
W	1	C19	0	90	0	0	90			
W	1	C20	0	90	0	0	90			1
W	1	C21	0	90	0	0	90			
W	1	C22	0	90	0	0	90			
W	1	C23	0	90	0	0	90		1	
W	1	C24	0	90	0	0	90			
W	1	C25	0	90	0	0	90			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
W	1	D01	0	100	0	0	100			2
W	1	D02	0	60	40	0	100			
W	1	D03	0	90	10	0	100		1	
W	1	D04	0	1	6	0	100			
W	1	D05	0	4	95	0	100			
W	1	D06	0	5	95	0	100			
W	1	D07	0	10	90	0	100		1	
W	1	D08	0	80	20	0	100		1	
W	1	D09	0	70	30	0	100		1	
W	1	D10	0	50	50	0	100			1
W	1	D11	0	90	0	0	90			
W	1	D12	0	90	0	0	90			
W	1	D13	0	90	0	0	90			
W	1	D14	0	90	0	0	90		1	
W	1	D15	0	90	0	0	90		1	
W	1	D16	0	90	0	0	90		2	
W	1	D17	0	90	0	0	90			
W	1	D18	0	90	0	0	90			
W	1	D19	0	90	0	0	90			
W	1	D20	0	90	0	0	90			
W	1	D21	0	90	0	0	90		1	
W	1	D22	0	90	0	0	90		1	
W	1	D23	0	90	0	0	90			
W	1	D24	0	90	0	0	90			
W	1	D25	0	90	0	0	90			
T	2	A01	90	9	1	90	10			2
T	2	A02	95	5	0	95	5			
T	2	A03	75	20	5	75	25			
T	2	A04	60	30	10	60	40			
T	2	A05	40	60	0	40	60			2
T	2	A06	50	50	0	50	50		2	
T	2	A07	75	25	0	75	25	1	3	
T	2	A08	85	15	0	85	15	2		
T	2	A09	10	30	30	30	60			1
T	2	A10	75	0	25	75	25	1		1
T	2	A11	25	75	0	25	75		3	
T	2	A12	50	50	0	50	50			
T	2	A13	80	18	2	80	20			
T	2	A14	60	38	2	60	40		2	
T	2	A15	2	1	97	2	98	2		
T	2	A16	60	35	5	60	40			
T	2	A17	60	38	2	60	40		2	
T	2	A18	40	50	0	50	50			
T	2	A19	40	35	0	65	35		1	2
T	2	A20	50	50	0	50	50			2
T	2	A21	50	50	0	50	50			
T	2	A22	50	50	0	50	50			1
T	2	A23	50	50	0	50	50		1	3

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
T	2	A24	60	40	0	60	40			
T	2	A25	60	40	0	60	40			1
T	2	B01	0	60	40	0	100			1
T	2	B02	70	10	20	70	30		1	
T	2	B03	0	0	100	0	100			
T	2	B04	0	0	100	0	100		1	
T	2	B05	75	0	25	75	25	3		
T	2	B06	65	20	15	65	35	1		1
T	2	B07	85	10	5	85	15		2	1
T	2	B08	0	20	80	0	100	1	1	
T	2	B09	1	49	50	1	99		1	
T	2	B10	0	0	100	0	100	1	2	1
T	2	B11	0	0	100	0	100			
T	2	B12	10	60	30	10	90			1
T	2	B13	65	30	5	65	35		3	
T	2	B14	1	39	60	1	99			1
T	2	B15	0	0	100	0	100			
T	2	B16	0	0	100	0	100	1		
T	2	B17	40	0	60	40	60			
T	2	B18	55	40	5	55	45			
T	2	B19	20	40	40	20	80			1
T	2	B20	5	90	5	5	95			
T	2	B21	49	1	50	49	51		1	2
T	2	B22	3	38	59	3	97			
T	2	B23	5	15	80	5	95			
T	2	B24	80	1	19	80	20			1
T	2	B25	50	25	25	50	50			1
T	2	C01	0	100	0	0	100	1	3	
T	2	C02	0	100	0	0	100			1
T	2	C03	0	100	0	0	100			1
T	2	C04	0	100	0	0	100			1
T	2	C05	0	100	0	0	100			
T	2	C06	0	100	0	0	100		3	
T	2	C07	0	100	0	0	100		4	
T	2	C08	0	100	0	0	100		2	
T	2	C09	0	100	0	0	100	1	1	
T	2	C10	0	100	0	0	100			
T	2	C11	0	100	0	0	100	1		2
T	2	C12	0	100	0	0	100			
T	2	C13	0	100	0	0	100	1		
T	2	C14	0	100	0	0	100			
T	2	C15	0	100	0	0	100		1	
T	2	C16	0	100	0	0	100			
T	2	C17	0	100	0	0	100			
T	2	C18	0	20	80	0	100			
T	2	C19	20	60	20	20	80			
T	2	C20	0	60	30	10	90			2
T	2	C21	0	60	40	0	100			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
T	2	C22	0	100	0	0	100	1		
T	2	C23	80	20	0	80	20	3		
T	2	C24	75	5	0	85	15	2		
T	2	C25	0	75	0	53	95			
T	2	D01	0	100	0	0	100			
T	2	D02	0	100	0	0	100			2
T	2	D03	0	100	0	0	100			1
T	2	D04	0	100	0	0	100		1	1
T	2	D05	0	100	0	0	100			
T	2	D06	0	100	0	0	100			
T	2	D07	0	100	0	0	100			
T	2	D08	0	60	0	40	60			
T	2	D09	0	100	0	0	100			
T	2	D10	0	100	0	0	100			
T	2	D11	0	100	0	0	100			
T	2	D12	0	80	0	20	80	1		
T	2	D13	0	100	0	0	100			
T	2	D14	0	100	0	0	100	1		
T	2	D15	0	98	0	1	99			1
T	2	D16	50	50	0	50	50	2		
T	2	D17	48	50	0	50	50			
T	2	D18	0	40	60	0	100			
T	2	D19	1	17	80	3	97	1		
T	2	D20	75	10	5	85	15	1		
T	2	D21	0	15	30	50	50			1
T	2	D22	90	8	2	90	10	2		
T	2	D23	75	15	0	80	20	2		
T	2	D24	50	50	0	50	50	2		
T	2	D25	0	60	0	0	100			
W	2	A01	0	10	0	0	0			1
W	2	A02	0	60	40	0	0	1		
W	2	A03	0	40	60	0	0	1		
W	2	A04	0	1	1	0	0			
W	2	A05	0	10	0	0	0			
W	2	A06	0	0	10	0	0			
W	2	A07	0	20	80	0	0	1		
W	2	A08	0	40	60	0	0			
W	2	A09	0	60	40	0	0		1	
W	2	A10	0	20	40	0	0	1		
W	2	A11	0	90	0	0	0			
W	2	A12	0	90	0	0	0			
W	2	A13	0	90	0	0	0			
W	2	A14	0	90	0	0	0			
W	2	A15	0	90	0	0	0			
W	2	A16	0	90	0	0	0			
W	2	A17	0	90	0	0	0			
W	2	A18	0	90	0	0	0			
W	2	A19	0	90	0	0	0		1	

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
W	2	A20	0	90	0	0	0			
W	2	A21	0	90	0	0	0			
W	2	A22	0	90	0	0	0			
W	2	A23	0	90	0	0	0			
W	2	A24	0	90	0	0	0			
W	2	A25	0	90	0	0	0			
W	2	B01	0	0	0	0	0			
W	2	B02	0	60	40	0	0			
W	2	B03	0	90	10	0	0			
W	2	B04	0	2	8	0	0			
W	2	B05	0	30	70	0	0			
W	2	B06	0	40	60	0	0			
W	2	B07	0	90	10	0	0			
W	2	B08	0	95	5	0	0			
W	2	B09	0	90	0	0	0			
W	2	B10	0	90	0	0	0			
W	2	B11	0	90	0	0	0			
W	2	B12	0	90	0	0	0			
W	2	B13	0	90	0	0	0			
W	2	B14	0	90	0	0	0			
W	2	B15	0	90	0	0	0			
W	2	B16	0	90	0	0	0			
W	2	B17	0	90	0	0	0			
W	2	B18	0	90	0	0	0			
W	2	B19	0	90	0	0	0			
W	2	B20	0	90	0	0	0			
W	2	B21	0	90	0	0	0			
W	2	B22	0	90	0	0	0			
W	2	B23	0	90	0	0	0			
W	2	B24	0	90	0	0	0			
W	2	B25	0	90	0	0	0			
W	2	C01	0	50	50	0	0			2
W	2	C02	0	70	30	0	0		1	
W	2	C03	0	80	20	0	0			1
W	2	C04	0	40	60	0	0			2
W	2	C05	0	0	5	0	0			
W	2	C06	0	10	90	0	0			
W	2	C07	0	20	80	0	0			
W	2	C08	0	40	60	0	0		1	
W	2	C09	0	95	5	0	0			
W	2	C10	0	90	0	0	0			
W	2	C11	0	90	0	0	0			
W	2	C12	0	90	0	0	0			
W	2	C13	0	90	0	0	0		1	
W	2	C14	0	90	0	0	0			
W	2	C15	0	90	0	0	0			
W	2	C16	0	90	0	0	0			
W	2	C17	0	90	0	0	0			

Marsh	Phase	Trap #	%SAVI	%SCRO	%LELA	% Salty Sp.	%Brackish sp.	SMHM	Vole	House Mouse
W	2	C18	0	90	0	0	0			
W	2	C19	0	90	0	0	0			
W	2	C20	0	90	0	0	0			
W	2	C21	0	90	0	0	0			
W	2	C22	0	90	0	0	0			
W	2	C23	0	90	0	0	0			
W	2	C24	0	90	0	0	0			
W	2	C25	0	90	0	0	0			
W	2	D01	0	100	0	0	0			
W	2	D02	0	60	40	0	0			2
W	2	D03	0	90	10	0	0		2	1
W	2	D04	0	1	6	0	0		1	
W	2	D05	0	4	95	0	0		2	
W	2	D06	0	5	95	0	0			
W	2	D07	0	10	90	0	0			
W	2	D08	0	80	20	0	0		1	1
W	2	D09	0	70	30	0	0			
W	2	D10	0	50	50	0	0			
W	2	D11	0	90	0	0	0			
W	2	D12	0	90	0	0	0			
W	2	D13	0	90	0	0	0			
W	2	D14	0	90	0	0	0			
W	2	D15	0	90	0	0	0	1		
W	2	D16	0	90	0	0	0			
W	2	D17	0	90	0	0	0			
W	2	D18	0	90	0	0	0			
W	2	D19	0	90	0	0	0			1
W	2	D20	0	90	0	0	0			
W	2	D21	0	90	0	0	0	2	1	
W	2	D22	0	90	0	0	0			
W	2	D23	0	90	0	0	0			
W	2	D24	0	90	0	0	0	1		
W	2	D25	0	90	0	0	0			

APPENDIX G.
SALT MARSH HARVEST MOUSE CAPTURE SITES

Marsh	Phase	Trap #	SMHM Captures	SMHM Recaptures	Total SMHM
C	1	A1	1	1	
C	1	A10	1	0	
C	1	A11	1	0	
C	1	A4	1	1	
C	1	A5	1	0	
C	1	A6	1	0	
C	1	B1	4	2	
C	1	B12	1	1	
C	1	B7	1	1	
C	1	B9	1	0	
C	1	C4	1	0	
C	1	D10	2	1	
C	1	D5	2	1	
C	1	D7	2	1	
C	1	D8	1	0	
C	1	E13	1	0	
C	1	F1	1	0	
C	1	F14	2	1	
C	1	D6	1	1	
C	1	B5	1	1	
C	**1**		**27**	**12**	**15**
T	1	A2	2	1	
T	1	A4	1	1	
T	1	A7	3	2	
T	1	A9	1	1	
T	1	A11	1	1	
T	1	A16	1	0	
T	1	A17	1	0	
T	1	B5	1	0	
T	1	B9	1	0	
T	1	B10	1	0	
T	1	C22	1	0	
T	1	D8	2	1	
T	1	D14	1	0	
T	1	D21	1	1	
T	1	D25	1	0	
T	**1**		**19**	**8**	**11**
T	2	A7	1	0	
T	2	A8	2	1	
T	2	A10	1	1	
T	2	A15	2	2	
T	2	B5	3	3	
T	2	B6	1	1	
T	2	B8	1	1	

Marsh	Phase	Trap #	SMHM Captures	SMHM Recaptures	Total SMHM
T	2	B10	1	0	
T	2	B16	1	0	
T	2	C1	1	0	
T	2	C9	1	0	
T	2	C11	1	0	
T	2	C13	1	0	
T	2	C22	1	0	
T	2	C23	3	2	
T	2	C24	2	1	
T	2	D12	1	0	
T	2	D14	1	1	
T	2	D16	2	1	
T	2	D19	1	0	
T	2	D20	1	1	
T	2	D22	2	1	
T	2	D23	2	1	
T	2	D24	2	1	
T	**2**		**35**	**18**	**17**
W	1	A11	1	0	
W	1	B10	1	1	
W	1	B5	1	1	
W	1	A8	1	0	
W	**1**		**4**	**2**	**2**
W	2	A7	1	0	
W	2	A3	1	0	
W	2	A10	1	0	
W	2	D21	1	0	
W	2	D24	1	0	
W	2	A2	1	0	
W	2	D15	1	0	
W	2	D21	1	0	
W	**2**		**8**	**0**	**8**