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MARSH PLANT ASSOCIATIONS OF SOUTH SAN FRANCISCO BAY: 2008 COMPARATIVE STUDY

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EXECUTIVE SUMMARY

Report In Brief

Within the Main Study Area, 76.5 acres of net conversion from brackish to salt marsh habitat has occurred since 1989. Within the Reference Area, there were 14.34 acres of net conversion from salt marsh habitat to brackish marsh habitat since 1989. Vegetation shifts and conversions between marsh types in the Main Study Area since 1989, and particularly between 2006 and 2008 (during a period when WPCP discharges have remained relatively constant), indicate that natural and region-wide events, such as interannual variations in rainfall, surface water salinities, temperature, mean sea level, and changes in tidal prism play a large role in species distribution in the South Bay.

Executive Summary

Large-scale plant community changes in the remaining 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. 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. This study is the continuation of the WPCP monitoring program.

The 2008 plant association mapping was done on digital 1-meter Multi-spectral (4-bands) color infrared (CIR) & True Color IKONOS® satellite imagery. The extent and distribution of vegetation associations in segments 1, 2, and 8 have remained relatively consistent from year to year. Consequently, these segments were mapped in-house in 2007 and field-verified in the field. The remainder of the segments were mapped in the field by H. T. Harvey & Associates biologists. As part of quality assurance/quality control (QA/AC), the vegetation mapping area was then field-verified by senior biologists. Acreage calculations by plant associations, dominant species and habitat type maps and acreage tables were produced in Geographic Information Systems (GIS) software. Comparisons were made between the 2008 mapping and the 1989 and 2007 mapping.

Large-scale plant association shifts from brackish dominated to saline dominated marshes were observed throughout the Main Study Area in 2007. Similar but less extensive shifts noted in the Reference Area in 2007. The shifts observed in 2007 persisted into 2008. This was particularly evident in the Transition Reach segments of the Main Study Area, where a substantial shift from brackish to saline marshes occurred in 2007, which persisted into 2008. The Lower Reach segments of the Main Study area continue to be primarily dominated by salt marsh plant species. An increase in saline marsh species occurred in the Reference Area in 2007, and in 2008 the Reference Area is now dominated by salt marsh species in the lower segments, brackish marsh species in the mid-segments and by freshwater species in the upper segments.

The total marsh area mapped in 2008 was 1818 acres for the Main Study Area and 281 acres for the Reference Area. The surface area of marsh habitat within the Main Study Area (Upper, Transition and Lower Reaches combined), increased by 396.1 acres between 1989 and 2008. During the same period, 90.2 acres of new marsh formed in the Reference Area. This equates to a 30% increase in marsh acreage in the Main Study Area and a 54% increase in marsh acreage in the Reference Area between 1989 and 2008.

Between 1989 and 2007, there has been a net conversion from salt to brackish marsh, with decreases in this conversion between 1994 and 1995, and again in 2002. However, for the first time in 2007, a large-scale conversion of brackish marsh to salt marsh (122.7 acres) occurred across the entire Main Study Area, and a similar conversion in the Reference Area, with a conversion of brackish to salt marsh of 5.2 acres in 2007 (H. T. Harvey & Associates 2007). In 2008, this conversion continued, but to a smaller extent with the conversion with a total of 149.8 acres converting from brackish to salt marsh in the Main Study Area and a corresponding conversion from brackish to salt marsh of 7.7 acres in the Reference Area.

Marsh conversion in both the Main Study Area and the Reference Area in 2007 and 2008 appears to be related to a combination of factors. The major dieback of alkali bulrush observed in 2007 persisted, and these areas of dieback revegetated primarily by pickleweed in 2008. The combination of very low winter/spring rains, low local tributary freshwater flows, increased tidal prism from the Island Pond breaching, low mean sea level, and decreased soil moisture are all potential contributing factors affecting germination and plant establishment. These factors appear to have contributed to the dieback observed in 2006 and 2007, and the subsequent marsh conversions in 2007 and 2008. In the more saline and transition marshes, pickleweed continues to flourish in 2008 in areas dominated by alkali bulrush prior to 2007. In the fresher/upstream areas of the brackish marshes, spearscale and pepperweed dominated the marsh conversion by colonizing areas previously occupied by alkali bulrush. The large-scale vegetation shifts and conversions between marsh types in the Main Study Area between 2006 and 2008 (during a period when WPCP discharges have remained relatively constant), indicate that interannual variations in rainfall, surface water salinities, temperature, mean sea level, and changes in tidal prism play a large role in species distribution in the South Bay.

TABLE OF CONTENTS

TABLES:

APPENDICES:

LIST OF CONTRIBUTORS

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INTRODUCTION

Large-scale plant community changes in the marshes of South San Francisco Bay were first observed in the 1970s (H. T. Harvey & Associates 1984). At that time, brackish marsh plants were colonizing areas that had previously been vegetated with salt marsh plants. Based upon those observations, causal mechanisms for the vegetation change were reviewed. A potential cause of that change was freshwater input from the San Jose/Santa Clara Water Pollution Control Plant (WPCP).

Subsequent studies confirmed the observed changes in plant species composition described in the 1970s (H. T. Harvey & Associates 1984). Efforts were made to determine the extent of these changes through time by examining historical aerial photography (CH2MHill 1989). These studies relied on aerial photographs of different scales, were not rectified, and could not be field-truthed. However, the historic photos documented that large-scale vegetation changes (both marsh type conversion and new marsh formation) were occurring in the marshes of South San Francisco Bay.

In 1989, as part of a monitoring program required by the San Francisco Bay Regional Water Quality Control Board (RWQCB), the City of San Jose commissioned a more detailed study of the marshes potentially affected by the freshwater discharge from the WPCP (H. T. Harvey & Associates 1990). Simultaneously, and also at the behest of the RWQCB, the Sunnyvale WPCP commissioned a study of the vegetation of the marshes in Guadalupe and Alviso Sloughs. Both of these studies included the collection of new aerial photography and detailed mapping of dominant plant species in the field. These data provided the baseline for analyzing changes in plant species distribution in the marshes of South San Francisco Bay. Subsequent mapping studies were conducted by the City of San Jose in 1991, 1994, and annually thereafter (CH2MHill 1989, H.T. Harvey & Associates 1990, 1991, 1995, 1997, 1998, 1999, 2000, 2001, 2002a, 2003, 2004, 2005a, 2006, and 2007). These studies documented changes in the distribution and extent of salt, brackish and freshwater marsh. Herein we report the 2008 results of this ongoing monitoring.

Vegetation changes that were noted in the early (1989-1991) mapping efforts could not be definitively tied to discharge from the WPCP as the reference area for those early efforts (Mowry Slough) was not affected by any freshwater stream discharge. Alviso Slough, which had been mapped in 1989 and 1991, and which has freshwater inflow from the Guadalupe River, was therefore chosen as a new reference area. In order for it to be an effective reference area, one that was representative of larger scale changes, changes in that slough vegetation needed to be independent of the flow of the WPCP. A dilution study performed in Alviso Slough found increased dilution of discharge waters with increased distance from the WPCP discharge site and very little entrainment of WPCP waters into Alviso Slough, therefore supporting the selection of Alviso Slough as the Reference Area (CH2MHILL 1990). Mapping efforts since 1995 have included the Main Study Area and this additional reference area (Alviso Slough).

One of the primary reasons to map these marshes was that they support endangered species, and habitat changes could affect these species. The dominant plant species of tidal salt marshes in

South San Francisco Bay includes pickleweed (primarily *Sarcocornia pacifica*, formerly known as *Salicornia virginica*) and cordgrass (*Spartina foliosa*). Pickleweed and cordgrass dominated salt marsh provides habitat for a unique assemblage of animal species including the federally and state-endangered salt marsh harvest mouse (*Reithrodontomys raviventris raviventris*) and California clapper rail (*Rallus longirostris obsoletus*). (An expanded description of the habitat requirements for these wildlife species can be found in the discussion section at the end of the report.) Therefore, it is important to determine the extent of vegetation change and its causes. Specifically, it is important to understand the extent that this conversion is caused by natural, region-wide environmental change versus anthropogenic changes such as freshwater discharge from the WPCP and dry-weather releases from local reservoirs.

A number of variables control the distribution of plant species in coastal marshes. The most obvious of these factors, surface water and soil salinity, correlate significantly with vegetation distributions (Espinar et al. 2005, Reardon 1996, Callaway and Sabraw 1994, Allison 1992, Callaway et al. 1989, Zedler 1983, Zedler and Beare 1986). Zedler (1983) documented the conversion of a pickleweed-dominated salt marsh to a cattail-dominated (*Typha domingensis*) freshwater marsh along the San Diego River. She found that the conversion was highly correlated with reservoir discharges that continued well beyond the normal rainy season, thereby decreasing salinities. Plants are sensitive to such salinity changes during various life history stages. Espinar (2005) found that the timing of fresh or saline inputs, in combination with the timing of inundation, may affect seed germination, plant growth, and the resulting plant species distribution.

Many other factors also influence marsh species composition including: depth and duration of flooding over the marsh surface (Webb and Mendelssohn 1996, Webb et al. 1995, Pennings and Callaway 1992, Mendelssohn and McKee 1988, Mall 1969); accumulation of phytotoxins such as hydrogen sulfide in marsh soils (Webb and Mendelssohn 1996, Webb et al. 1995, Koch and Mendelssohn 1989, DeLaune et al. 1983, King et al. 1982); interstitial nutrient concentrations (Koch et al. 1990, Bradley and Morris 1980, Koch and Mendelssohn 1989, Morris 1980), and soil mineral and organic matter content (Nyman et al. 1990, DeLaune et al. 1979). Natural variability in abiotic factors, such as precipitation, tidal fluctuation, and evapotranspiration, have similar influences. Anthropogenic changes to freshwater discharges, non-point source pollution (nutrients and sediments), and regional/global climate changes (drought, temperature, sea level) also influence these variables. Alexander and Dunton (2002) found that timing and quantity of freshwater inputs strongly dictated halophyte response to precipitation in two marshes in Louisiana. Warren and Niering (1993) found increased flooding frequency from sea level rise altered tidal marsh plant associations in the northeastern United States. Wisser et al (2006) used an 18-year record of end-of season biomass to evaluate multiple stressor effects (flooding duration, salinity, air temperature, precipitation deficits, nutrient availability and cloud cover) in Louisiana salt marshes and found that when surface water and cloud cover were optimal, larger flooding durations reduced peak biomass of the marsh species. Other research shows that changes in dynamic systems such as tidal salt marshes may be driven at the local scale by a number of factors that can only be detected by studies conducted over a long time period (Higginbotham and others 2004). Similarly, yearly mapping of marshes for this study allowed us to detect inter-annual vegetation shifts that less-frequent surveys would have masked.

Competition between different plant species (interspecific) with similar environmental tolerances also influences their distributions. Although environmental tolerance and competitive ability are inversely related (Grace and Wetzel 1981, Zedler 1982, Bertness 1991), competition still plays a role among species with similar tolerances. Zedler (1982) found that competitive interactions occur in salt marshes, and concluded that pickleweed does compete with cordgrass for light and to some extent, nutrients. Leininger (2006) used a model to examine rain, drought, and disturbance scenarios along with marsh conditions at three marsh study sites in San Francisco Bay and found that invasion potential of perennial peppergrass (*Lepidium latifolium)* varies with site disturbance and rainfall conditions. In particular, perennial peppergrass spread was inhibited in years of increased moisture and also with increased salinity.

This year's monitoring results are reported, and analyzed in light of a number of factors, including a lack of late season rainfall contributing to higher ambient Bay salinities, lower overall precipitation resulting in decreased freshwater runoff from both local inputs and Delta flows, lower mean sea level, and the localized effect of the SBSP restoration in the Island Ponds area on tidal prism.

SURVEY METHODS

STUDY AREA

We divided the study area into 28 segments as defined in the 1989 study (H. T. Harvey & Associates 1990; Figure 1). We then sub-divided the study area into four Reaches (Upper Reach segments, Transition Reach segments, Lower Reach segments, and Alviso Slough segments [Reference Reach]) to provide a more easily comprehensible method of analyzing the data and presenting the results (Figure 1). The Upper (approximately 460 acres), Transition (approximately 390 acres), and Lower Reach (approximately 850 acres) segments, referred to as the Main Study Area are located within the Coyote Creek watershed and include Segments 1-5 and 8-26 (Figure 1). Segments 27-30 (Reference Area - approximately 275 acres) are located along the lower Guadalupe River, also known as Alviso Slough (Figure 1). This study assumes that the WPCP discharge does not significantly influence the Reference Area, and therefore provides a suitable control site for documenting vegetation changes in South San Francisco Bay.

BASE IMAGERY

The City of San Jose acquired IKONOS® imagery from a satellite pass that occurred at 10:30 a.m. on June 20, 2008. The tidal elevation at this time was 0.2 feet Mean Lower Low Water (MLLW) near the Calaveras Point Station. The 1-meter multispectral (4-bands) color infrared (CIR) & true color orthorectified IKONOS® satellite imagery is projected in StatePlane NAD83 Zone III (feet).

VEGETATION ASSOCIATION MAPPING AND AREA CALCULATIONS

Habitat mapping was based upon the imagery obtained and completed at a scale to 1:2400 (one inch = 200 feet) using the IKONOS® imagery as a base layer. Habitat mapping was assisted using two laptop computers (Panasonic Toughbook 18) equipped with geographic information systems (GIS) software (ArcView 9.1). These computers and software allow the IKONOS® imagery to be used for mapping in the field or in the office.

The initial mapping was conducted in-house; habitat boundaries and classifications were identified using the IKONOS® imagery and were based on the signatures of the photographic imagery. Topographic features, marsh boundaries, and tentative habitat types (based on photographic signatures) were mapped in the office prior to field visits.

Ground-truthing of the preliminary mapping was conducted during site visits to the project area during July and August 2008. Because of the habitat consistency seen in Segments 1, 2, and 8 during past mapping years, these three segments were mapped in-house in 2008. Marsh vegetation was observed primarily from areas directly adjacent to the marshes, consistent with methods employed in previous years and in compliance with U.S. Fish and Wildlife Service (USFWS) guidelines and regulations. Therefore, marshes were observed primarily from levee roadways, railroad beds, unimproved salt pond levees and Pacific Gas and Electric (PG&E) walkways. We also surveyed the marsh edge in Segments 1, 2, 11, 12, 13, 15, 21, 22, and 30 by boat. Only when necessary and allowed by USFWS regulations were vegetation associations verified by walking in those marshes areas that were not clearly visible from adjacent levees and upland areas. Access to the Study Area was obtained from the USFWS San Francisco Bay National Wildlife Refuge (Cheryl Strong 510.557.1271), Cargill Salt Division, Newark, CA (Pat Mapelli 510.790.8610), Tri-Cities Landfill (Terry Medeiros 510.624.5910), and the Newby Island Landfill (Rick King 408.945.2802).

The GIS database was downloaded and backed-up weekly. The digitized boundaries of habitat areas were reviewed for consistency and quality. Plant association acreages and color-coded figures for the entire Study Area were generated in GIS (ArcView 9.2). Plant association acreages and color-coded figures for the entire Study Area were generated by GIS systems ArcInfo and ArcView.

VEGETATION ASSOCIATION CATEGORIZATION METHODS

Any species that occurred as a dominant, co-dominant or sub-dominant as defined below, in any portion of the study area was mapped. For the purposes of this study a dominant species had a percent cover of 51-100%, co-dominant species have roughly equal percent coverage, and sub-dominant species have between 15 and 49 percent cover.

Each species was then assigned to a vegetation association comprised of one dominant, a dominant and subdominant, or two or more co-dominant species. The three types of vegetation associations are described below:

Dominant – An area that consists of one dominant species that comprises approximately 85-100% of the cover is named solely for that species, so that the vegetation association called pickleweed consists of from 85-100% pickleweed and less than 15% of other unspecified species.

Dominant/sub-dominant – If one species comprises between approximately 51-85% of the cover in a particular area, and another species comprises 15-49% cover in that same area, then this is dominant/sub-dominant vegetation association. The association is named for both species, with the more abundant species listed first. The category called pickleweed/alkali bulrush could therefore consist of 51-85% cover of pickleweed and 15-49% cover of alkali bulrush.

Co-dominant – Two co-dominant associations were identified in 2007: Pickleweed-Cordgrass Mix and Spearscale-Pickleweed Mix. Co-dominant mixes are defined as having approximately equal amounts of each species with combined total coverage of the two species exceeding 85%.

The upland species category consists of species not considered by the USFWS (1988) to be wetland indicators. These include ruderal species such black mustard (*Brassica nigra*), ripgut grass (*Bromus diandrus*), sweet fennel (*Foeniculum vulgare*), and coyote brush (*Baccharis pilularis*). The peripheral halophyte category consists of a patchwork of species that occur along salt marsh edges, such as levee slopes. This mixture, in which no one species generally exceeds 15% of the cover, includes pickleweed and various peripheral halophyte species such as alkali

Figure 1. Segment Locations

heath (*Frankenia salina*), Australian saltbush (*Atriplex semibaccata*) and slender-leaved iceplant (*Mesembryanthemum nodiflorum*).

Plant species associations were grouped into dominant species categories (e.g., alkali bulrush/peppergrass association is an alkali bulrush dominant species category). These dominant species categories were then assigned to one of four habitat types: salt marsh, brackish marsh, freshwater marsh and upland. In addition, stands of dead vegetation were also included in the 2008 mapping as a distinct habitat type. A number of assumptions about grouping dominant species into appropriate habitat types were made. These include:

- Relative salt tolerance of dominant plant species;
- Edaphic characteristics of the South Bay Marshes that may control plant species distribution;
- Historic relationships within this study, and;
- Relationships between dominant plant species and wildlife use.

Certain plant species for which salinity tolerance data are lacking (e.g., spearscale) were categorized into habitat types based on relative location in the marsh plain or known wildlife use. This assumption and the potential uncertainties related to assigning plant species to habitat type categories has been understood throughout the study period and was stated in the 1989 (baseline) study (H. T. Harvey & Associates 1990). The habitat classification scheme first used in the baseline study is carried through to this study to collect comparable data.

AREA COMPARISONS

Analysis of marsh conversion within the Main Study and Reference Areas involved a multi-step process that began at a total marsh area level and proceeded to a more specific, segment-level analysis. The first task involved comparing the relative acreage change in marsh type and dominant species categories between years. The current year's results are compared to baseline year 1989. When a significant shift in marsh acreage occurred, the dominant species categories responsible for that shift were also identified.

The reaches and segments described earlier are depicted in Figure 1 and detailed in Table 1 below.

Table 1. South Bay Marsh Segments and Their Reaches.

Reaches	Segments
Lower (Mouth of Coyote Creek)	1, 2, 3, 4, 8, 22 and 23
Transition (Drawbridge)	5, 9, 10, 11, 14 and 20
Upper (Newby Island)	12, 13, 15, 16, 17, 18, 19, 21, 24, 25 and 26
Reference (Alviso Slough)	27, 28, 29 and 30

Marsh habitat acreage data from all years (1989, 1991, 1994, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007 and 2008) was also compared by Reach.

The final step in the analysis involved overlaying the habitats from the 1989 mapping onto 2008 data in ArcView to determine, with confidence, the location and size of change in marsh area and habitat type. The habitats for 2007 were also overlaid onto 2008 data to determine the changes between 2007 and 2008. Dominant species and habitat maps were produced for each of the four Reaches. The maps were produced from an ArcView database and the full mapping for all segments by plant species association is available electronically.

EDAPHIC CHARACTERISTICS

Edaphic characteristics were studied in 2006 and 2007 in an attempt to determine the processes resulting large-scale die-offs (lack of new growth) of alkali bulrush observed in 2006 and 2007 in both the Main Study Area and in the Reference Area. In addition to the die-offs observed in those years, subsequent species shifts were observed in many of the areas of dead vegetation. Soil cores were collected and analyzed for soil bulk density and interstitial soil salinity in 2006 and 2007. No such cores were collected in 2008.

RESULTS

Detailed habitat maps and raw data are presented in the Appendices of this report:

- Appendix A. Vegetation and Marsh Habitat Maps from 2008 (Figures A1-A8)
- Appendix B. Spatial Analysis (marsh conversion and gain/loss) from 1989 to 2008 (Figures B1-B12)
- Appendix C. Detailed Acreage Matrices by Segment and Species (Tables C1-C28)
- Appendix D. Plant List of Species Observed During Vegetation Mapping
- Appendix E. Dominant Species Categories, Marsh Type and Vegetation Associations for 1989 and 2008.

GENERAL SPECIES DISTRIBUTION, DOMINANT SPECIES CATEGORY AND HABITAT ACREAGES FOR 2008

Main Study Area

This year, 82 vegetation associations (e.g., alkali bulrush/peppergrass) were mapped. The vegetation associations were grouped by dominant species into 24 vegetation categories (e.g., alkali bulrush) (Figures A1-A4). The spatial distribution of dominant plant species and habitat types (see Appendix E for habitat classifications) for the 2008 data are presented in Appendix A for each of the three marsh Reaches (figure scales vary). The acreages of habitat types and associated dominant plant species are shown in Table 2.

The dominant plant species is pickleweed, comprising approximately 49% of the marsh (Table 2). Alkali bulrush, which is the dominant plant species of brackish marsh associations in South San Francisco Bay, declined from approximately 27% in 2006 to approximately 6% in 2008. Peppergrass (*Lepidium latifolium*) and spearscale (*Atriplex prostrata*) are most abundant in the Upper and Transition Reach segments and they comprise approximately 11% and 9%, respectively of the marsh (Figures A-1 through A-3).

Lower Reach. The segments within the Lower Reach (nearest San Francisco Bay; Figures A-1 and A-5) are comprised primarily of single-species stands or mixtures of salt marsh plant species dominated by pickleweed and cordgrass. Cordgrass and pickleweed are most abundant in the Lower Reach segments.

Transition Reach. The Transition Reach, intermediate to the furthest upstream and downstream Reaches, supported substantial amounts of both salt and brackish species, which sometimes occurred in mixed associations (both brackish and salt marsh plant species) (Figures A-2 and A-6). However, this reach has become dominated by large stands of pickleweed (especially in the Segments north of Coyote Creek) over the last two years. Large areas of pickleweed also occurred in segments south of Coyote Creek (Segments 9 and 11), but these pickleweed-dominated areas are also intermixed with spearscale, peppergrass, and alkali bulrush dominated associations (Figure A-2). Cordgrass is also found in the Transition Reach along the northern and southern marsh fringes of Coyote Creek (Figure F-5).

Upper Reach. The uppermost segments within the Upper Reach (Figures A-3 and A-7) consist primarily of brackish marsh associations dominated by either pure stands or mixtures of alkali bulrush, peppergrass, and spearscale. However, the lower segments (Segments 19 and 21) of the Upper Reach are dominated by pure stands or mixtures of pickleweed, alkali bulrush, or spearscale. Both cordgrass and pickleweed occur at low abundance even in the furthest upstream segments (although sometimes in patches too small to map). The upstream reach of Artesian Slough (Segments 25 and 26) is dominated by freshwater species such as California bulrush and cattail.

Table 2. Summary of Acreages of the Main Study Area by Dominant Species Categories for Each Habitat Type for 2008.

Dominant Species Category	2008 (Acres)
Salt Marsh Categories	
Cordgrass	185.4
Pickleweed	885.2
Pickleweed-Cordgrass Mix	91.3
Alkali Heath	14.9
Gumplant	20.6
Jaumea	1.2
Saltgrass	4.4
Peripheral Halophytes	27.1
Dead Vegetation	15.8
Sub-Total	**1245.9**
Brackish Marsh Categories	
Alkali Bulrush	116.2
Peppergrass	207.4
Spearscale	161.0
Dead Vegetation	4.5
Sub-Total	**489.1**
Freshwater Marsh Categories	
California Bulrush	66.6
Cattail	16.3
Grass-leaved goldenrod	0.1
Misc. Others	<0.1
Sub-Total	**83.1**
TOTAL	**1818.1**

Reference Area (Alviso Slough)

The spatial distribution of dominant plant species and marsh habitat types in the Reference Area are presented in Figure A8. The 2008 plant association areas for Alviso Slough are presented in Table 3. The distribution of plant species within the Reference Area, similar to the Main Study

Area, progresses upstream from salt marsh to brackish to freshwater species. Segment 30 (nearest Coyote Creek) is comprised primarily of cordgrass and pickleweed dominated associations. The lower portions of Segment 29 are dominated by cordgrass, pickleweed, and alkali bulrush associations, which generally transition in the upper portions of Segment 29 to alkali bulrush, peppergrass, and spearscale associations. With the exception of the lower portion of Segment 28, Segments 27 and 28 are comprised primarily of freshwater vegetation including California bulrush (*Schoenoplectus americanus*, formerly known as *Scirpus californicus*), *Typha* sp., and grass-leaved goldenrod (*Euthamia occidentalis*) (Figures 1 and A-4).

Salt marsh habitat in Alviso Slough has increased gradually since 2000, largely in the form of new marsh created near the confluence with Coyote Creek. Much of this new marsh at the mouth of Alviso Slough was dominated by cordgrass in recent years and this continues to be the case in 2008. Salt marsh associations dominate the downstream areas, with brackish marsh associations occurring primarily upstream of Segment 30. Freshwater marsh associations are concentrated in the upstream portions of the slough (nearest the Union Pacific Railroad [UPRR] crossing).

Table 3. Summary of Acreages of the Reference Area (Alviso Slough) by Dominant Species Categories for Each Habitat Type for 2008.

Dominant Species Category	2008 (Acres)
Salt Marsh Categories	
Cordgrass	39.4
Pickleweed	69.7
Peripheral Halophytes	1.5
Saltgrass	0.1
Gumplant	0.2
Jaumea	0.1
Alkali Heath	0.5
Dead Vegetation	0.0
Sub-Total	**111.5**
Brackish Marsh Categories	
Alkali Bulrush	57.9
Peppergrass	60.0
Spearscale	8.3
Dead Vegetation	2.0
Sub-Total	**128.2**
Freshwater Marsh Categories	
California Bulrush	18.7
Cattail	15.3
Grass-leaved goldenrod	6.9
Smartweed	<0.1
Sub-Total	**41.0**
TOTAL	**280.7**

Vegetation Die-Back

Between 2005 and 2007, large areas of standing dead alkali bulrush were observed. However, corms may remain dormant under conditions of low water levels and high salinity for at least 2 years. In 2007, approximately 28 acres of dead vegetation were mapped in the Main Study Area and approximately 26 acres of dead vegetation were mapped in the Reference Area. This dead brackish vegetation was generally found in saline or brackish habitats and was replaced by pickleweed-dominated habitat in 2008. Other (fresher) areas converted primarily to spearscale and peppergrass. In 2008, the only substantial remaining patches of dead vegetation occur in the Transition Reach in Segments 5, 14, and 20.

Dominant Species Summary

The Upper Reach of the Main Study Area is dominated by brackish marsh species (74%) with the remainder of the vegetation comprising saline (19%) and freshwater species (7%). The Transition Reach is dominated by salt marsh species (75%) and brackish (25%) marsh habitats. The Lower Reach is dominated by saline marsh species (99%), with the remaining marshes composed of brackish marsh species (0.01%). In 2008, the Main Study Area is dominated by saline species (72%), with the remaining areas comprising brackish (26%) and fresh (2%) marsh species. A similar distribution of habitats is noted in the Reference Area; brackish marsh habitats only slightly dominate a greater proportion of the Reference Area (48%), than salt (43%), with freshwater (9%) habitats in the upper reach near the Alviso Marina.

TEMPORAL AND SPATIAL CHANGES IN MARSH HABITAT ACREAGES FROM 1989 THROUGH 2008

This comparison does not include data from Segments 24, 25 and 26 (Artesian Slough) of the Main Study Area and Segment 27 (vicinity of the Gold Street Bridge) of the Reference Area since those segments were not mapped in 1989. Additionally, the Reference Area was not mapped in 1994; therefore only data from the Main Study Area in 1994 is included in the temporal and spatial evaluation. Data from 1991, 1994 and 1996 – 1999 are not derived from orthorectified images. In 2003, baseline data (1989) was digitized and rectified to the 2001 orthophotos to improve area comparisons and precision of the baseline data (H.T. Harvey & Associates 2003).

New Marsh Formation (Salt, Brackish, and Freshwater Marsh Combined)

Within the Main Study Area (Upper, Transition and Lower Reaches combined) the surface area of marsh habitat increased by 396.1 acres between 1989 and 2008 (Table 4). During the same period, 90.2 acres of new marsh formed in the Reference Area (Table 5). This equates to a 30% increase in marsh acreage in the Main Study Area and a 54% increase in marsh acreage in the Reference Area. Within the Main Study area, marsh area remained relatively stable from 1989 to 1996, but new marsh formed in the Lower Reach after 1996, and in the Transition reach primarily between 1996 and 1998 (Figure 2).

Lower Reach. Gains in marsh area between 1989 and 2008 were greatest in the Lower Reach (approximately 307 acres). The majority of new marsh formation continues to occur in the

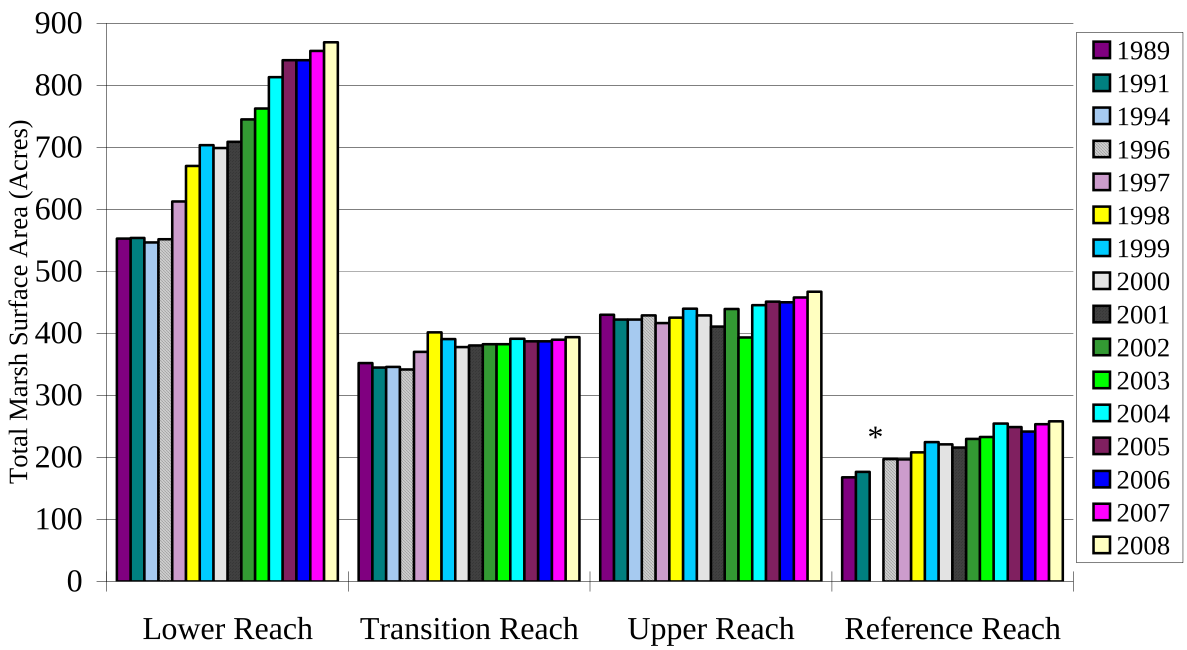
Lower Reach along the north and south sides of Coyote Creek, immediately upstream of Calaveras Point. While little new marsh was created between 2005 and 2006, marsh area in the Lower Reach has steadily increased between 1996 and 2008 (Figure 2).

Transition Reach. Approximately 42 acres of new marsh formation occurred in the Transition Reach. In contrast to the Lower Reach, marsh area in the Transition Reach remained relatively stable since 2000. The slight increase in marsh area in the Transition Reach in 2008 is primarily due to mapping of increased vegetation interior of the levees in the Island Ponds, particularly in Pond A21.

Upper Reach. The surface area of marsh in the Upper Reach increased only slightly since 1989 with brief declines in 1997, 2001, and 2003. The slight increase in marsh area in the Upper Reach is due to mapping of increased vegetation inside the recently restored Island Ponds (Pond A19 and A20) in 2008 (Figure 2).

Reference Area. A trend of increasing marsh area is apparent from 1989 through 2008 in the Reference Area (Figure 2), with slight declines noted between 1999 and 2001, and again between 2005 and 2006. New marsh in the Reference Area continues to form near the mouth of Alviso Slough along the south sides of Coyote Creek, immediately upstream of Calaveras Point.

Figure 2. Total Marsh Acreage Comparison between 1989 and 2008, by Reach.



* No data collected in 1994 within Reference Area.

Table 4. Summary of Acreages of the Main Study Area[a] by Dominant Species Categories for Each Habitat Type for 1989, 2007, 2008 and Percent Change from 1989-2008.

Dominant Species Category	1989 (Acres)	2007 (Acres)	2008 (Acres)	Percent Change (1989-2008)
Salt Marsh Categories				
Cordgrass	84.2	169.7	185.3	101%
Pickleweed	669.1	854.7	883.4	28%
Pickleweed-Cordgrass Mix[b]	-	90.8	91.3	-
Alkali Heath[b]	-	15.3	14.8	-
Gumplant[b]	-	27.4	20.6	-
Jaumea[b]	-	-	1.2	-
Peripheral Halophytes	25.6	24.1	26.5	4%
Misc. others	0.1	2.0	0.0	0%
Saltgrass		-	4.4	
Dead Vegetation		7.6	15.8	-
Sub-Total	**779.0**	**1191.6**	**1243.3**	**60%**
Brackish Marsh Categories				
Alkali Bulrush	489.6	177.5	102.7	-79%
Peppergrass	66.1	174.7	189.3	186%
Spearscale[b]	-	104.7	160.7	-
Dead Vegetation	-	19.9	4.0	-
Sub-Total	**555.7**	**476.8**	**456.7**	**-18%**
Freshwater Marsh Categories				
California Bulrush	-	21.5	20.3	-
Cattail	-	12.9	10.4	-
Misc. Others	-	<0.1	<0.1	-
Sub-Total	-	**34.4**	**30.8**	-
TOTAL	**1334.7**	**1702.8**	**1730.8**	**30%**

[a] Comparison consists of Segments 1-5 and 8-23 only, since Segments 24-26 were not mapped in 1989.
[b] Not a dominant species category in 1989.

Table 5. Summary of Acreages of the Reference Area (Alviso Slough)[a] by Dominant Species Categories for Each Habitat Type for 1989, 2007, 2008 and Percent Change from 1989-2008.

Dominant Species Category	1989 (Acres)	2007 (Acres)	2008 (Acres)	Percent Change (1989-2008)
Salt Marsh Categories				
Cordgrass	28.3	37.7	39.4	39%
Pickleweed	43.6	45.0	69.4	59%
Peripheral Halophytes	3.1	4.3	1.2	-61%
Alkali heath[b]	-	-	0.4	-
Gumplant[b]	-	-	0.2	-
Jaumea[b]	-	-	0.1	-
Misc. Others	-	0.1	0.1	-
Dead Vegetation	-	10.8	0.0	-
Sub-Total	**75.0**	**97.9**	**110.8**	**48%**
Brackish Marsh Categories				
Alkali Bulrush	72.3	50.9[b]	56.1	-22%
Peppergrass	20.4	53.0	59.5	192%
Spearscale[b]	-	8.5	7.8	-
Dead Vegetation	-	15.1	1.9	-
Sub-Total	**92.7**	**127.5**	**125.3**	**35%**
Freshwater Marsh Categories				
California Bulrush	0.3	15.0	11.6	>100%
Cattail	-	6.4	3.5	-
Grass-leaved goldenrod	-	5.7	6.9	-
Misc. Others	-	0.1	0.1	-
Sub-Total	**0.3**	**27.2**	**22.1**	**>100%**
TOTAL	**168.0**	**252.6**	**258.2**	**54%**

[a] Comparison consists of Segments 28-30.
[b] Not a dominant species category in 1989.

Changes in Surface Area of Salt, Brackish, and Freshwater Marsh Habitats

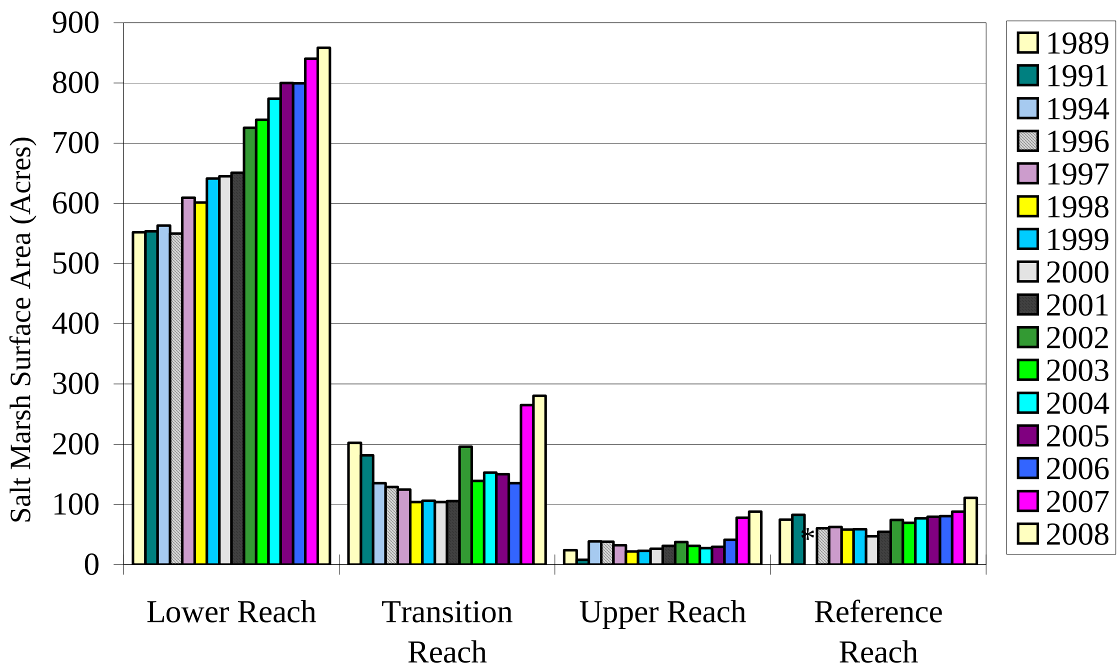
Salt Marsh. Figure 3 presents the total acreage of salt marsh habitat by year and location (Reach). There has been a net gain of 464.3 acres of salt marsh habitat area within the Main Study Area from 1989 to 2008 (Table 4). In 2002 we observed substantial gains in salt marsh habitat from both new marsh formation (which has been occurring steadily since 1997) and conversion of brackish marsh habitat to salt marsh habitat. Some conversion back to brackish marsh occurred in 2003 and this conversion persisted until 2006, after which large-scale shifts to salt marsh occurred.

Lower Reach. Salt marsh area continually increased in the Lower Reach from 1989 through 2008 with the largest single year increase occurring between 2000 and 2001. Much of the increase is due to new marsh formation along the north side of Coyote Creek within Segments 3 and 4.

Transition Reach. Salt marsh area decreased in the Transition Reach from 1989 through 2001; the decrease in salt marsh area was greatest between 1989 and 1994 (Figure 3). There was an increase of 90.1 acres of salt marsh habitat in 2002, then a fluctuation back to near pre-2001 numbers. In the last two years (2007 and 2008) there has been and increase of 145.1 acres of salt marsh (130.0 acres in 2007 and 15.1 acres in 2008) (Figure 3). A small portion of salt marsh gains in 2008 is from new salt marsh habitat on the interior levee slopes and higher marsh plain of the recently restored Island Ponds.

Upper Reach. Salt marsh area in the Upper Reach generally increased since 1989 (with decreases in 1991, 1998 and 1999). In the Upper Reach, salt marsh increased by 36.3 acres between 2006 and 2007 and by an additional 10.4 acres between 2007 and 2008.

Figure 3. Salt Marsh Acreage Comparison between 1989 and 2008, by Reach.



* No data collected in 1994 within Reference Area.

Reference Reach. Variation in the salt marsh acreage of the Reference Reach can be seen in Table 5, as can the net gain of 35.8 acres salt marsh habitat between 1989 and 2008, and the gain of 12.9 acres between 2007 and 2008 (Table 5). The declines in salt marsh in the Reference Reach occurred primarily between 1991 and 2000 (Figure 3). With the exception of 2003, salt marsh habitat remained relatively stable until 2007, when salt marsh area increased by 17.4

acres. The increases in salt marsh between 2004 and 2007 were predominantly from new marsh formation near the mouth of Alviso Slough. The increases in salt marsh in the Reference Reach in 2008 are also due to vegetation shifts from brackish to salt marsh especially in Segments 29 and 30.

Brackish and Freshwater Marsh. Figures 4 and 5 present the total acreage of brackish and freshwater marsh habitats by year and location. Total brackish marsh area increased by a total of 105.5 acres (19% increase) in the Main Study Area between 1989 and 2006 (H. T. Harvey & Associates 2007). However, large areas of brackish marsh converted to salt marsh habitat in 2007 and 2008, resulting in a net loss of 99.0 acres of brackish marsh between 1989 and 2008 (18% decrease). Between 1989 and 2008, alkali bulrush habitat in the Main Study Area decreased by 386.9 acres. Some of this decrease is from the conversion of alkali bulrush habitat to salt marsh habitat in the Main Study Area. However, there were also species shifts within the brackish marsh. While alkali bulrush acreage declined, the acreages of two other brackish marsh species increased. Between 1989 and 2008, peppergrass acreage increased by 123.2 acres (186%). Spearscale was not originally mapping in 1989, but acreage of this species increased by 140% between 2007 and 2008. Spearscale colonized areas where alkali bulrush died back, particularly in the Upper Reach in segments 13 and 17.

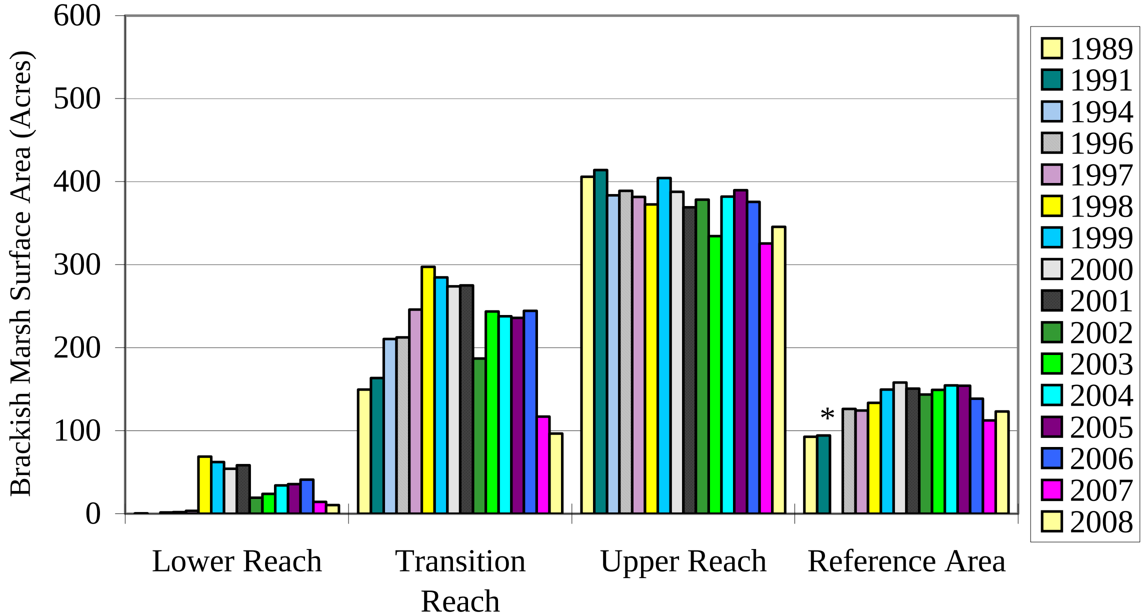
Lower Reach. In the Lower Reach of the Main Study Area, brackish marsh increased dramatically in 1998, but declined since then (Figure 4). Recently, there were declines of 26.6 acres in 2007 and 4.1 acres in 2008.

Transition Reach. The pattern is similar in the Transition Reach with increases in brackish marsh from 1989 through 1998. Since 1998 there has been a steady trend of decreasing brackish marsh, with large decreases in 2002 and 2007. Between 2006 and 2007, brackish marsh acreage in the Transition Reach decreased by 127.6 acres, with an additional decline of 20.1 acres between 2007 and 2008.

Upper Reach. There is an overall trend of decreasing brackish marsh in the Upper Reach of the Main Study Area from 1989 through 2008, but with notable fluctuations. Large decreases of brackish marsh occurred in 2002 and 2007. The decrease in 2007 was primarily related to large scale marsh die-off seen throughout the Main Study Area (H. T. Harvey & Associates 2007). Increases in brackish marsh in 2008 can be attributed to revegetation in areas where marsh die-off occurred in 2006 and 2007. Brackish marsh in the Upper Reach of the Main Study Area increased by 20.0 acres in 2008, rebounding from a decrease of 49.9 acres in 2007 (Figure 4).

Reference Area. Overall, brackish marsh increased by 32.6 acres (35%) in the Reference Area between 1989 and 2008 (Table 5). Most of this increase occurred as marsh conversion (from salt to brackish) between 1989 and 2005. However, large areas of brackish marsh die-off occurred in 2006 and 2007 throughout the Main Study Area and the Reference Area, with alkali bulrush particularly affected by this die-off. In the Reference Area, these areas were replaced with a mixture of saline, brackish, and freshwater species, resulting in brackish marsh decreases of 15.4 acres in 2006 and 26.3 acres in 2007 (Figure 4). Many of the dead areas observed in 2006 and 2007 were dominated in 2008 by brackish or saline species, resulting in an increase of 10.9 acres of brackish marsh in 2008. Most of this increase occurred in Segments 28 and 29 (Figure B-8).

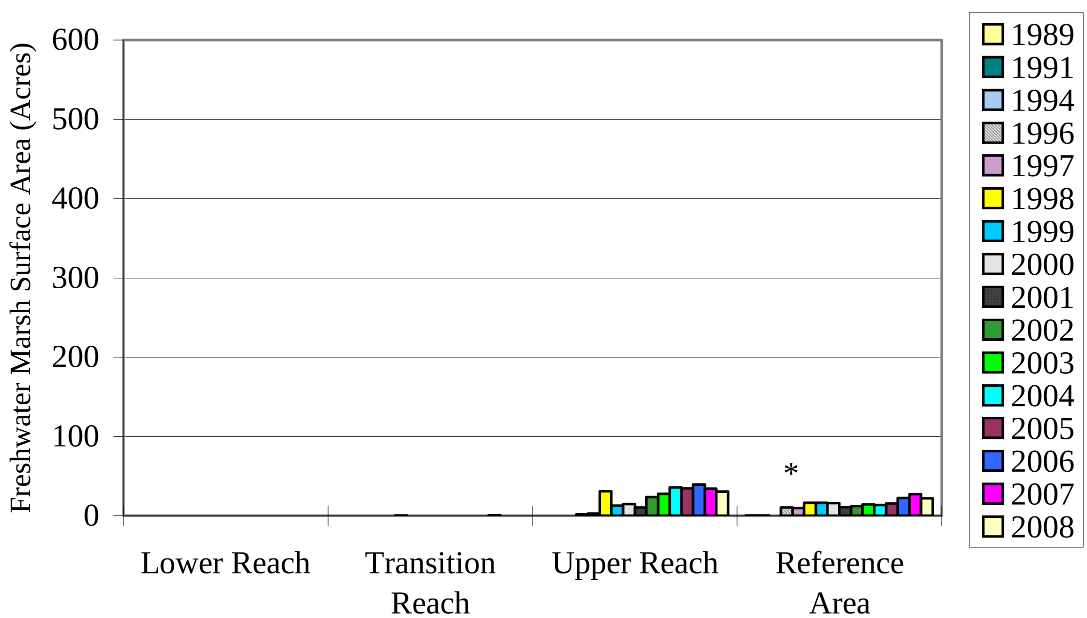
Figure 4. Brackish Marsh Acreage Comparison between 1989 and 2008, by Reach.



* No data collected in 1994 within Reference Area.

The only increases in freshwater marsh habitat since 1989 occurred in the Main Study Area (primarily in the Upper Reach) (Figure 5) and in the Reference Area (Tables 4 and 5). There was a slight decline in freshwater marsh acreage (5.2 acres) in the Upper Reach in 2008.

Figure 5. Freshwater Marsh Acreage Comparison between 1989 and 2008, by Reach.



* No data collected in 1994 within Reference Area.

Habitat Type Conversion

Detailed comparisons by segment were performed by overlaying the 2008 data on the 1989 data in ArcView. Table 6 provides a summary of the segment locations and shifts in acreage by marsh type from 1989 to 2008. This table differs from Tables 4 and 5 in that the changes are defined by Reach. The area calculations in Table 6 were derived from a segment level analysis (by Reach) in ArcView for 1989-2008 (Appendix B).

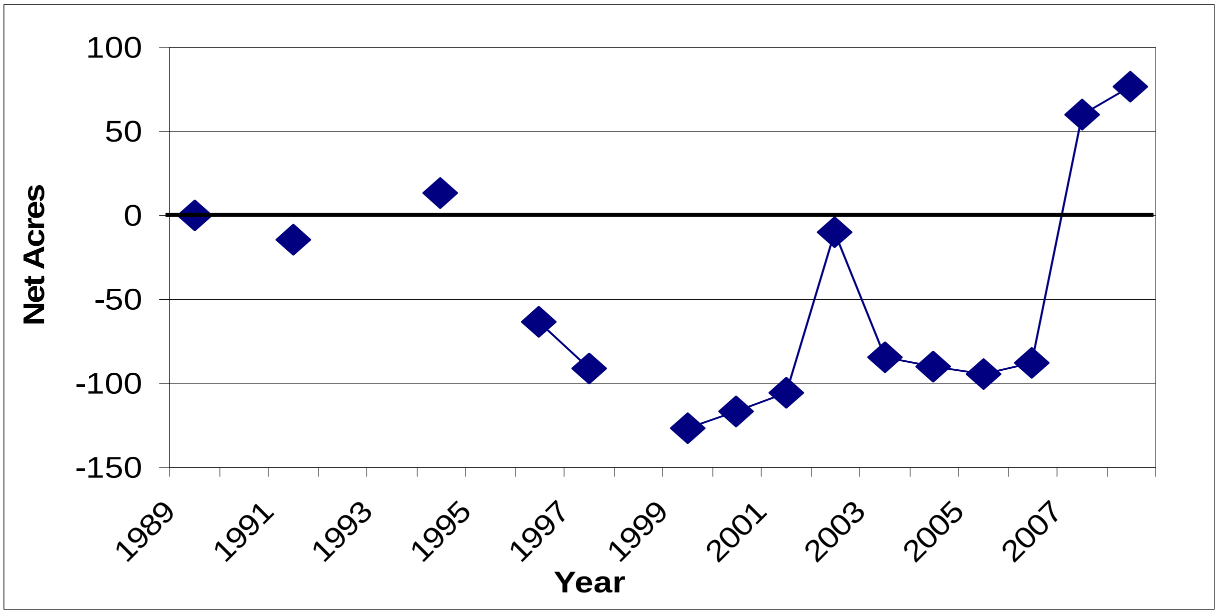
Table 6. Detailed Evaluation of Marsh Type Conversion (in Acres) by Project Reach, 1989 to 2008[1].

Project Reach	Salt to Brackish or Fresh (Acres)	Brackish to Salt (Acres)	Net Conversion of Salt to Brackish (Acres)	Proportion of Salt Marsh Converted	Proportion of Total Marsh Converted
Lower	11.78	0.32	11.46	1.3%	1.3%
Transition	39.40	89.55	-50.15	-17.9%	-12.7%
Upper	12.39	50.32	-37.93	-42.9%	-8.1%
Reference	22.03	7.69	14.34	12.9%	5.6%

[1] Dead vegetation is not included in this analysis.

Table 4 demonstrates that some areas shifted to brackish marsh from 1989 to 2008, but far more shifted towards salt marsh. Specifically, 63.6 acres of salt marsh habitat converted from salt to brackish marsh habitat in the Main Study Area, and 22.0 acres of salt marsh habitat converted to brackish marsh in the Reference Area. The conversion of brackish marsh to freshwater marsh between 1989 to 2008 was 8.3 acres in the Main Study Area and 8.4 acres in the Reference Area. However, during the same time period, 140.2 acres of brackish marsh converted to salt marsh habitat in the Main Study Area as did 7.7 acres in the Reference Area. Much of this conversion from brackish to salt marsh habitat occurred between 2006 and 2008 with large areas of brackish to salt marsh habitat conversion occurring in the Transition Reach of the Main Study Area (Figures B9 - B12). Therefore, within the Main Study Area, 76.5 acres of net conversion from brackish to salt marsh habitat has occurred since 1989. Figure 6 depicts the fluctuation of the habitat types, and the overall net to date. Within the reference area, there were 14.34 acres of net conversion from salt marsh habitat to brackish marsh habitat since 1989.

Figure 6. Net Acres of Salt Marsh Conversion from 1989 Baseline

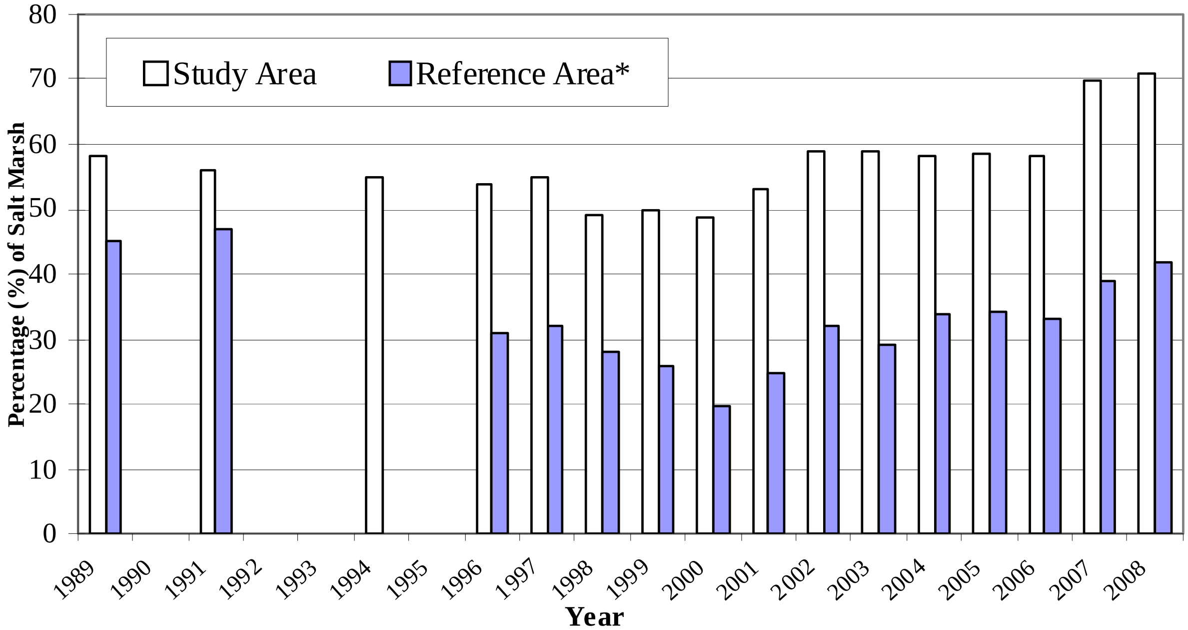


Temporal Changes in Proportional Area of Salt and Brackish Marsh between the Main Study and Reference Areas

The proportion of salt marsh and brackish marsh area relative to total marsh area was compared between the Main Study and Reference Areas from 1989 through 2008 (Figures 7 and 8). This analysis was performed to control for the difference in size between the Main Study and Reference Areas as well as to compare temporal trends in salt marsh conversion between these two areas. The percentage of salt marsh in the Main Study Area remained relatively stable from 1989 through 1997 with a decline between 1998 and 2000 (Figure 7). The percentage of salt marsh in the Main Study Area increased in 2002 and then declined slightly through 2006. In 2007, there was a substantial increase in salt marsh in the Main Study Area with a slight increase again in 2008.

The relative decline in the percentage of salt marsh between 1989 and 2000 was greater in the Reference Area than in the Main Study Area (Figure 7) but it follows a similar temporal pattern. After increases in the percentage of salt marsh in the Reference Area in 2001 and 2002 similar to increases seen in the Main Study Area, a decrease in the relative percentage of salt marsh was observed in 2003, which was not seen in the Main Study Area. The relative percentage of salt marsh in the Reference Area recovered in 2004, and remained stable in 2005, with a slight decline in 2006. However, a similar increase in percentage of salt marsh was seen in both the Reference Area and the Main Study Area in 2007 and 2008.

Figure 7. Temporal Comparison of the Proportion of Salt Marsh Area between the Main Study and Reference Areas.

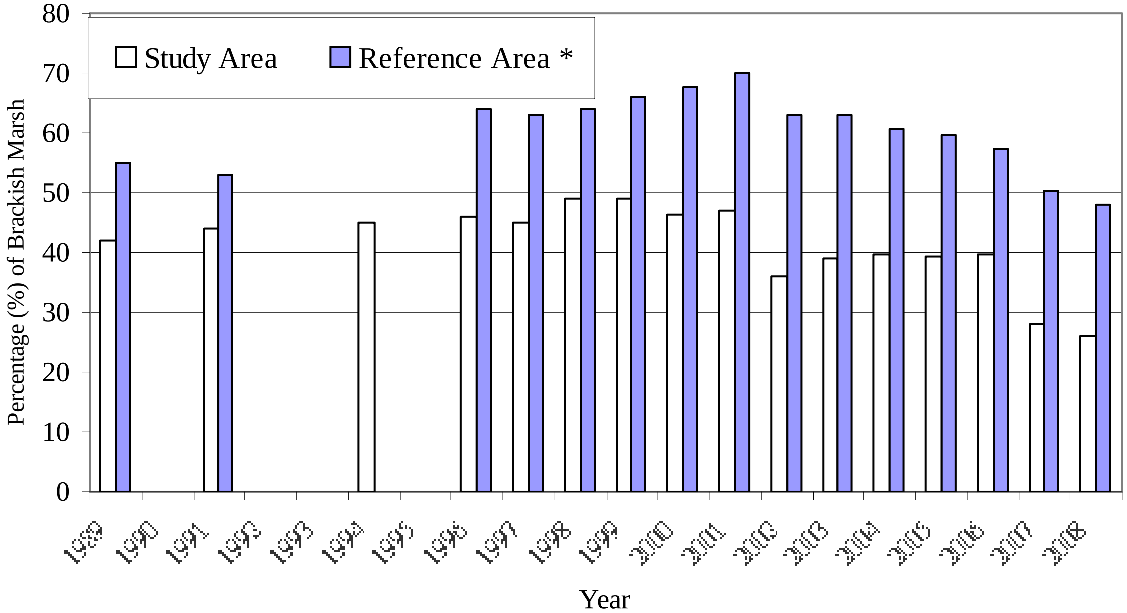


* No data collected in 1994 within Reference Area.

The proportion of the Main Study Area that is brackish marsh remained relatively constant between 40% and 50% until 2002 (Figure 8). The 2002 sampling showed the first significant decrease in the percentage (10%) of brackish marsh since the study began. The percentage of brackish marsh increased in 2003 and remained stable through 2006 (Figure 8). However, the percentage of brackish marsh in the Main Study Area decreased substantially in 2007 and an additional decrease occurred in 2008.

The Reference Area showed a steady increase in brackish marsh until 2001; a larger increase in the percentage of brackish marsh was observed in the Reference Area than in the Main Study Area (Figure 8) between 1989 and 2001. This increase in the proportion of brackish marsh area to total marsh area in the Reference Area occurred primarily between 1991 and 1996 and between 1998 and 2001 (Figure 8) during the same time that the percentage of salt marsh declined (Figure 7). The percentage of brackish marsh in the Reference Area has been declining since 2002, with a substantial decline in 2007, followed by an additional decline in 2008.

Figure 8. Temporal Comparison of the Proportion of Brackish Marsh Area between the Main Study and Reference Areas



* No data collected in 1994 within Reference Area.

DISCUSSION

MARSH CONVERSION

There had previously been a net conversion from salt to brackish marsh since the beginning of the study began in 1989, with decreases in this conversion between 1994 and 1995 and again in 2002. However, beginning in 2007 and continuing in 2008, there was a major shift to salt marsh that overwhelmed previous losses (Figure 6). In this discussion we evaluate this conversion within the historical context of marshes in South San Francisco Bay and offer possible explanations for these large-scale changes.

Historical Context

Historically, tidal marshes were the dominant habitats throughout much of the South San Francisco Bay. The vast area dominated by marshes included the entire Study Area and the Reference Area. Coyote Creek and the adjacent channels, subject to tidal action, had abundant water flow in from, and out to, the Bay. This water flow continually scoured the channels and kept them relatively free of sediment. Prior to the 1940s, these channels were quite broad with extensive salt marshes on either side. Diking for commercial salt production began in the mid-1800s, and by the 1930s over half of the historical salt marshes in the South Bay had been converted into salt ponds (Goals Project 1999). After levees were built to create salt ponds, the dynamics of water flow began to change. The levees sealed off much of the South Bay marshes from tidal action and in turn water flow in the channels decreased, causing them to fill in with sediment.

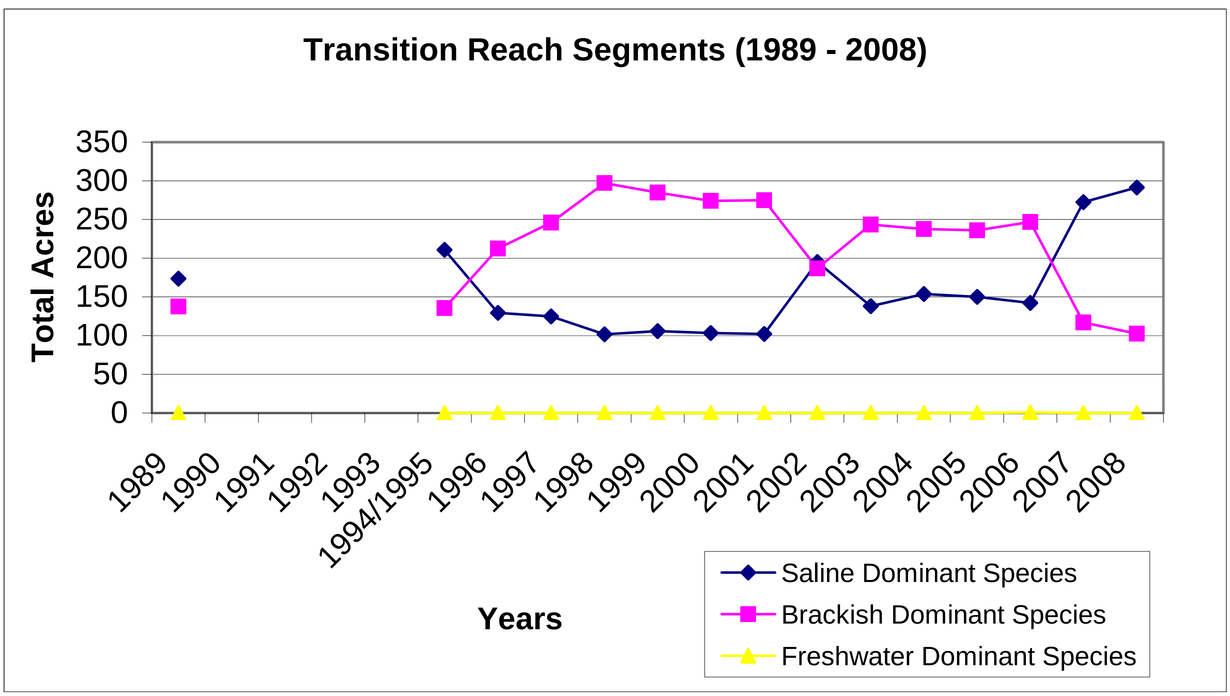
In the 65 or so years since the construction of the levees, Coyote Creek has undergone dynamic changes, both physical and biological. These include diverting Coyote Creek flows via the construction of Anderson Dam and the Coyote Canal in the 1930s, and construction of levees in the late 1800s for flood control (Grossinger and others 2006). After the levees were built, overdrafting of the aquifer from excessive groundwater pumping led to subsidence throughout the region and a corresponding rise in relative sea level. Land around the South Bay subsided from Mountain View to Milpitas, with the town of Alviso sinking up to 10 feet. This sinking apparently caused the levees to sink and some channels to deepen to a point where they could no longer sustain marsh plants. The SCVWD and the salt pond operators repeatedly raised the height of the levees to counteract this trend. Subsidence began to slow starting in 1965 and the channels slowly refilled with sediment, though it took years for marsh plants to re-establish along the edge of the channels.

The dynamic nature of these marshes has been most apparent during the period 2005 - 2008. In 2005, and again in 2006, large patches of dead alkali bulrush were observed in both the Main Study Area and the Reference Area (H. T. Harvey & Associates 2007). These die-offs occurred simultaneously with changes in species distributions observed throughout the Bay. In 2006, alkali bulrush was observed growing in North Bay salt marshes (such as China Camp) at the transition zone between pickleweed and cordgrass where it had not been seen in the preceding years. This sudden appearance of alkali bulrush was short-lived, as most of these observed stands were dead in 2007 and 2008 (pers. comm. Crooks 2007; pers. comm. Callaway 2008). This anecdotal evidence corresponds with the trends observed in the Main Study Area. Early mapping reconnaissance in 2007 indicated that the die-off observed in 2006 throughout the Main Study Area and in the Reference Area persisted, and greatly expanded in some areas in 2007. Detailed vegetation mapping confirmed this die-off and in many of the areas where die-off occurred, the distribution of brackish marsh species shifted to salt marsh dominant species, most notably pickleweed (H. T. Harvey & Associates 2007)(Figures F-1 and F-2). This species shift persisted in 2008, with increased colonization of formerly dead patches by pickleweed in the Transition Reach of the Main Study Area and by spearscale in the Upper Reach of the Main Study Area (Figures A2 and A3).

Marsh Conversion in 2008

The conversion of brackish marsh to salt marsh observed in 2007 continued into 2008, and is particularly evident in the Transition Reach of the Main Study Area. As shown graphically in Figure 9, brackish marsh acreage in the Transition Reach increased between 1989 and 1998. Since 1998, the amount of brackish and salt marsh in the Transition Area has remained relatively stable, with a noticeable shift in 2002 (which may be related to a corresponding decrease in mean sea level, which is discussed further below, also see Figure 15). However in 2007, a substantial decline in brackish marsh species back to 1989 levels was concomitant with an increase in saline marsh species (Figure 9). This shift persisted into 2008 with increases is saline dominant species and simultaneous decreases in brackish marsh species.

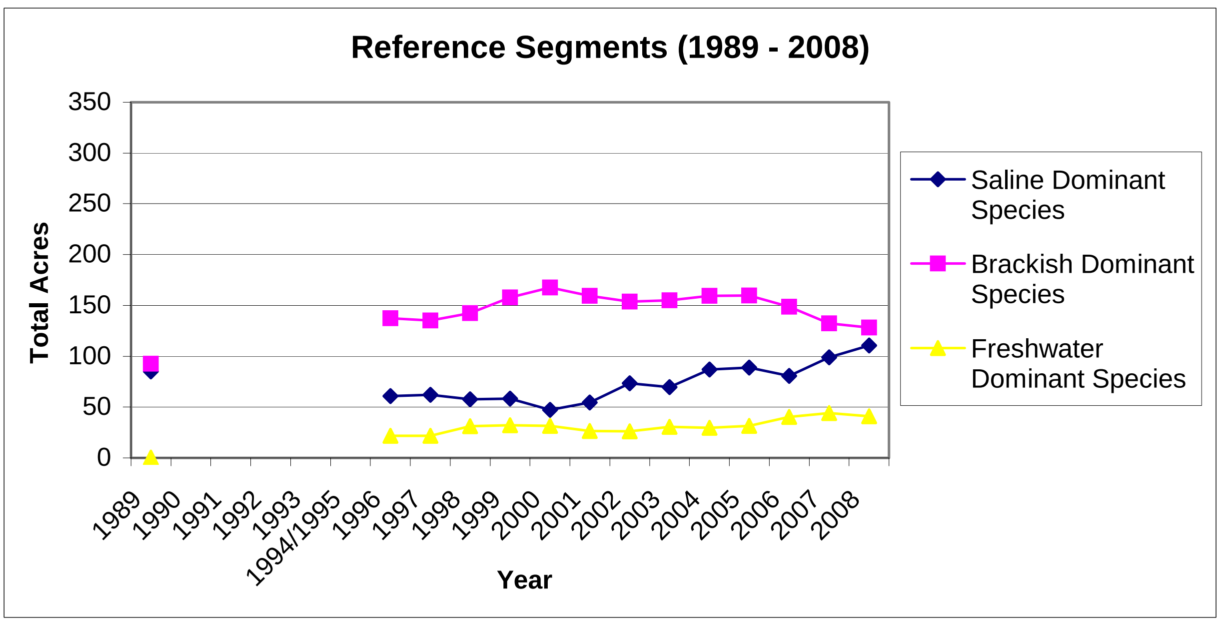
Figure 9. Transition Reach Dominant Species Acreages by Marsh Habitat Types (1989 – 2008).



Changes in the Main Study Area between 2006 and 2008 have not been limited solely to changes in marsh type; shifts in species composition within the remaining brackish marsh component occurred in 2007 and continued in 2008. Spearscale and peppergrass actively colonized areas of alkali bulrush die-off. Between 2007 and 2008, there was an increase of 56.0 acres of spearscale (Figure F-7), and an increase of 14.6 acres of peppergrass in the Main Study Area. In addition, the marsh species composition along the upper segments of Artesian Slough within the Main Study Area is comprised primarily of freshwater species such as cattail and California bulrush (Figure F-4). During mapping in 2008, large areas of stressed California bulrush were observed along the channel edges of Artesian Slough (Figure F-9).

The conversion from brackish to salt marsh in the Reference Area in 2007, which also continued into 2008, shows a similar pattern to the conversion mapped in the Transition Reach segments of the Main Study Area (Figure 10). In the Reference Area, there was a net conversion of salt to brackish marsh between 1989 and 2008 of 14.34 acres (5.6%). Shifts in species composition within the brackish marsh component also occurred in the Reference Area. Shifts in species composition within the brackish marsh component also occurred in the Reference Area. These shifts demonstrate the dynamic nature of these marshes from year to year. For example, in 2008 the acreage of peppergrass increased by 6.5 acres, compared with a decrease in 2007 of 6.4 acres (Tables 5 and 6, Figure F-8).

Figure 10. Reference Reach Dominant Species Acreages by Marsh Habitat Types (1989 – 2008).



New Marsh Formation

There has been a net increase of 396.1 acres (30%) of overall marsh area (new marsh formation less marsh loss) since 1989 in the Main Study Area. Much of the new marsh formation within the Main Study Area occurred on accreting mudflats along Coyote Creek near Calaveras Point. These mudflats reached an elevation that would support wetland plant species in 1996/1997 and continue to rapidly colonize. The large mudflat in Coyote Creek just upstream of the confluence with Alviso Slough reached an elevation that could support marsh plants around 2000/2001 and this area continues to be colonized by saline species such as cordgrass and pickleweed.

The majority of this increase is due to sediment accretion along slough and river channels and subsequent vegetation colonization to form new marsh. The majority of new marsh formation is located in the Main Study Area in the Lower Reach (Segments 2, 3 and 4 near the mouth of Coyote Creek, Segment 8 near the mouth of Mowry Slough, as well as Segments 22 and 23 near the mouth of Alviso Slough) (Figures B-5 and B-6). New marsh is also located along Coyote Creek in Segments 9 and 10. The majority of new marsh formation in the Reference Area is located in Segment 30 near the mouth (Figure B-8).

Despite the increase in tidal prism resulting from the breaching of the Island Ponds in Spring 2006, the anticipated scour of the existing mudflats has not been detected. However, scour and undercutting along the banks was observed along the tidal edge of Segments 11, 12, 14, and 21 while mapping vegetation from the boat in 2007 (H. T. Harvey & Associates 2007). Some scour was observed in 2008 along Segment 16 in the Upper Reach of the Main Study Area (Figure F-6). This type of bank undercutting represents the first stage of marsh edge erosion, and is typically followed by marsh slumping and loss. In subsequent years we will continue to evaluate the potential affect of levee breaching on new marsh formation in the South Bay (see below for further discussion on the Island Pond breaches).

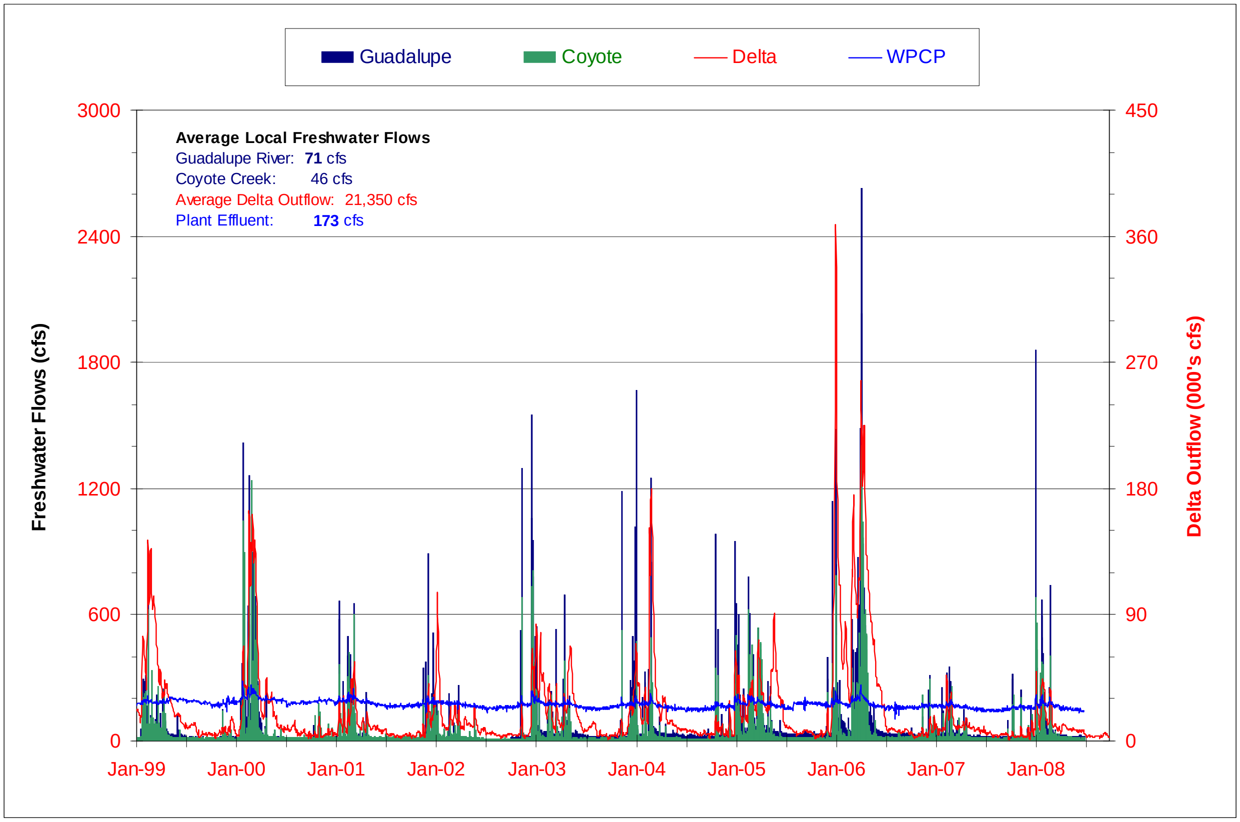
Evaluation of Marsh Conversion

As described in the Introduction Section of this report, research has shown that a number of variables control the distribution of plant species in coastal marshes. Depth and duration of flooding over the marsh surface can influence marsh species composition (Webb and Mendelssohn 1996, Webb et al. 1995, Pennings and Callaway 1992, Mendelssohn and McKee 1988, Mall 1969) and surface water and soil salinity have been shown to correlate significantly with vegetation distributions (Reardon 1996, Callaway and Sabraw 1994, Allison 1992, Callaway et al. 1989, Zedler 1983, Zedler and Beare 1986). Espinar et al. (2005) found that the salinity and flooding regime of a site can influence the germination process of alkali bulrush, showing that an increase in salinity and prolonged inundation during germination results in decreased germination.

Natural variability in abiotic factors such as precipitation, tidal fluctuation, and evapotranspiration, as well as anthropogenic changes to those factors such as freshwater discharges, non-point source pollution (nutrients and sediments), and regional/global climate changes (drought, temperature, sea level) can also influence plant species distribution. The sections below evaluate and discuss the potential contributions of each of these inputs and their influence on vegetation distribution in the South Bay marshes.

WPCP Discharges and Freshwater Flows. Figure 11 shows the relative contribution of the freshwater inputs to the Bay from the WPCP Discharge, the Guadalupe River (Alviso Slough), Coyote Creek and the Sacramento/San Joaquin Delta (courtesy of the City of San Jose). The average local freshwater flows in the South Bay and from the Delta have fluctuated between years. However, the WPCP discharges have been relatively constant since 1989 (~180 cfs ±30%). While the WPCP effluent dominates the dry season flows, freshwater input from the local drainages (Coyote Creek and Guadalupe River) during the winter are much larger, and all are dwarfed by the overall influence of the inputs from the Delta. These larger overall inputs contribute to variations in bay-wide salinities.

Figure 11. South San Francisco Bay Average Freshwater Flows (Courtesy of the City of San Jose).



Rainfall. In addition to WPCP effluent flow and regional freshwater inputs, vegetation distribution is also driven by the distribution and amount of rainfall. Total rainfall and timing at critical times of the year can affect salinity, thereby influencing vegetation distribution. For example, prolonged inundation as described by Espinar (2005) can significantly alter germination success of alkali bulrush. The variability of rainfall between years in California's Mediterranean climate contributes to variation in the germination conditions of upper intertidal marshes. Based on work by Noe and Zedler (2001), rainfall events have a strong influence on soil salinity and this influence may be stronger than the influence of estuarine water salinity on marsh species germination. Figure 11 shows that since 1998, the amount of brackish marsh vegetation mapped in the summer may be directly influenced by the rainfall in the previous months (note: 2008 data were not available from the National Weather Service at the time of report preparation). Below-average late season rains occurred in Spring 2007 and Spring 2008 (Figure 12), resulting in decreased freshwater input from local drainages and from the Delta and contributed to higher than normal ambient Bay salinities (Figure 13).

Decreased freshwater input can influence surface water salinities in the local drainages. The lowest surface water salinities in the South Bay typically occur in the period from January through April. However, surface water salinities in January 2007 at Calaveras Point were the highest recorded salinities in a decade (City of San Jose, Figure 13). Surface water salinities for 2008 were similar to those observed in 2007, with higher than average salinities again recorded during the germination period of the marsh vegetation.

Figure 12. Total Winter/Spring Rains (January to May) for San Jose, California from 1989-2008 (National Weather Service station at San Jose).

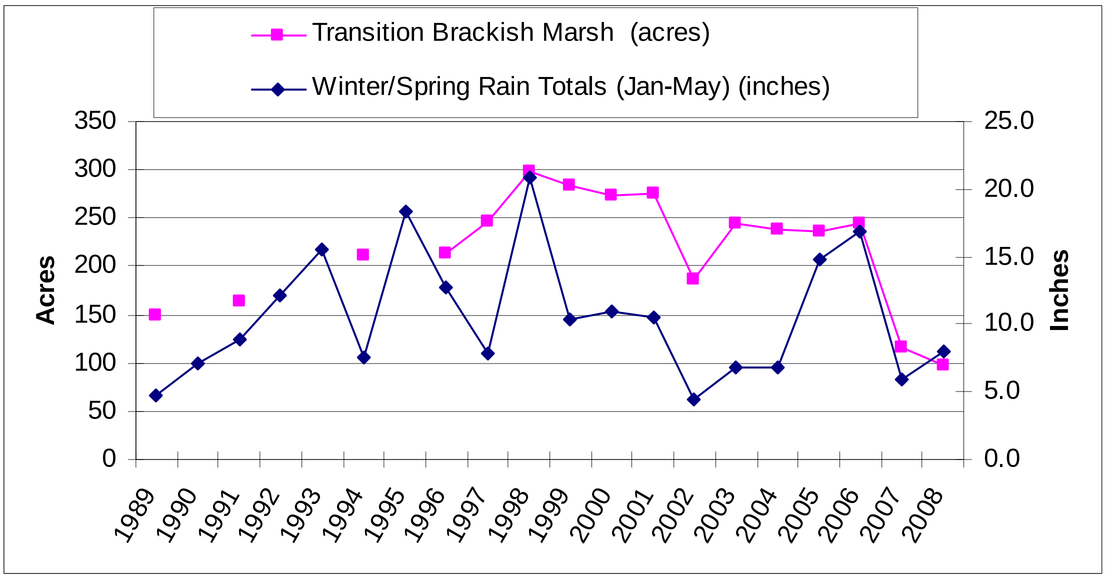
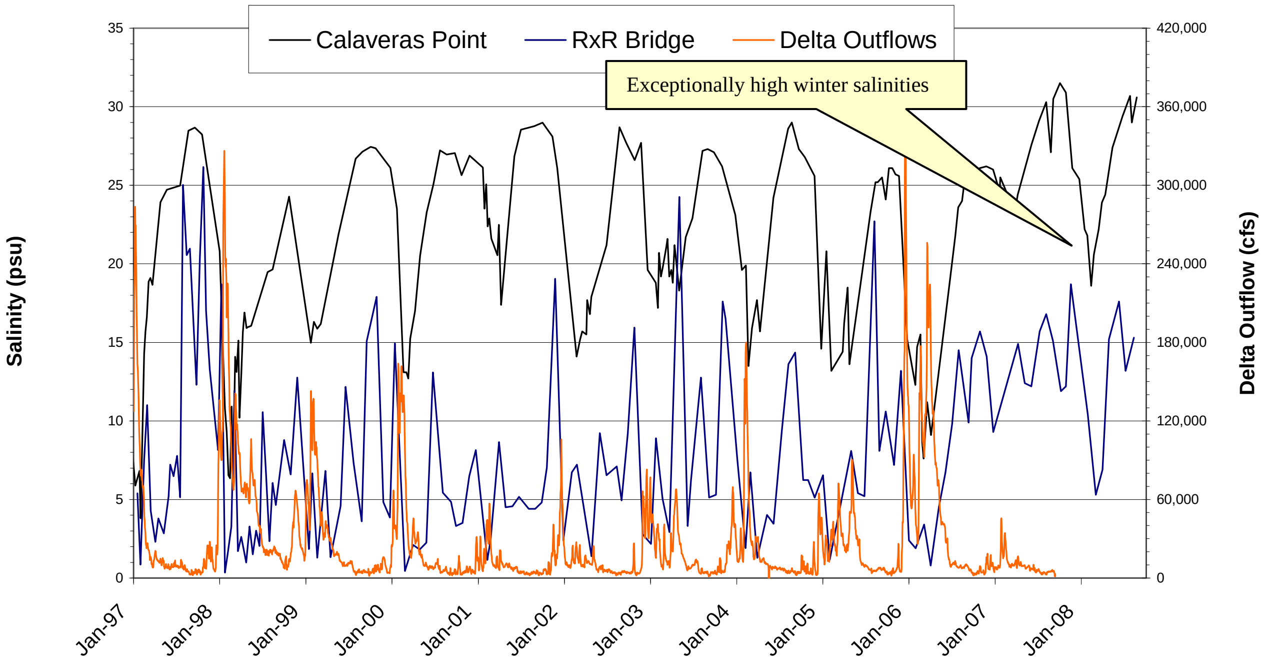


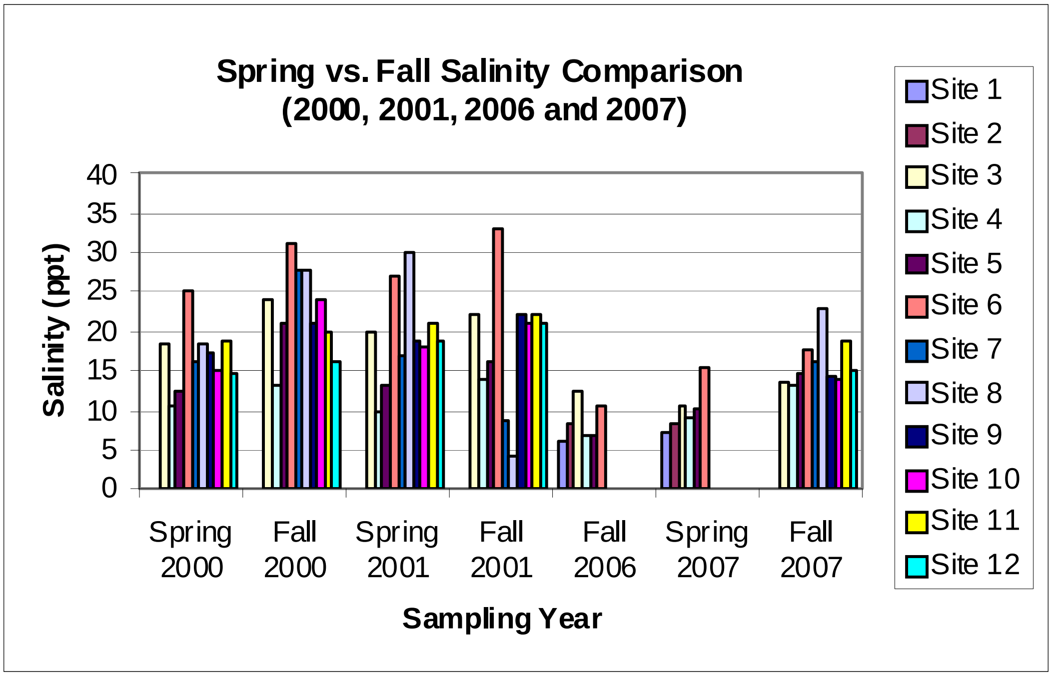
Figure 13. South San Francisco Bay Surface Water Salinities and Delta Outflows.



Interstitial Salinities

Edaphic (or soil) properties are important in understanding the physical parameters that can determine the spatial distribution of plant communities. In 2006 and 2007, limited edaphic sampling was done in the Main Study Area and in the Reference Area in response to observed vegetation die-off and vegetation shifts in those years. Core samples collected during these studies evaluated interstitial salinity and conductivity, bulk density, and soil pH. The 2006/2007 data compared to sites previously sampled during edaphic studies performed in 1999, 2000, and 2001 (Figure G-1) (H. T. Harvey & Associates 2000b and 2002b). Salinity studies performed in 2006 and 2007 found that salinity in the areas of dead alkali bulrush was lower than in the areas of live alkali bulrush indicating that low salinity (concomitant with prolonged inundation) was likely a factor in the observed die-off and vegetation shifts to saline species with wider salinity tolerances during 2006 and 2007 (Figure 14) (H. T. Harvey & Associates 2007).

Figure 14. Soil Salinity Comparison by Year in the Main Study Area (H. T. Harvey & Associates 2007).

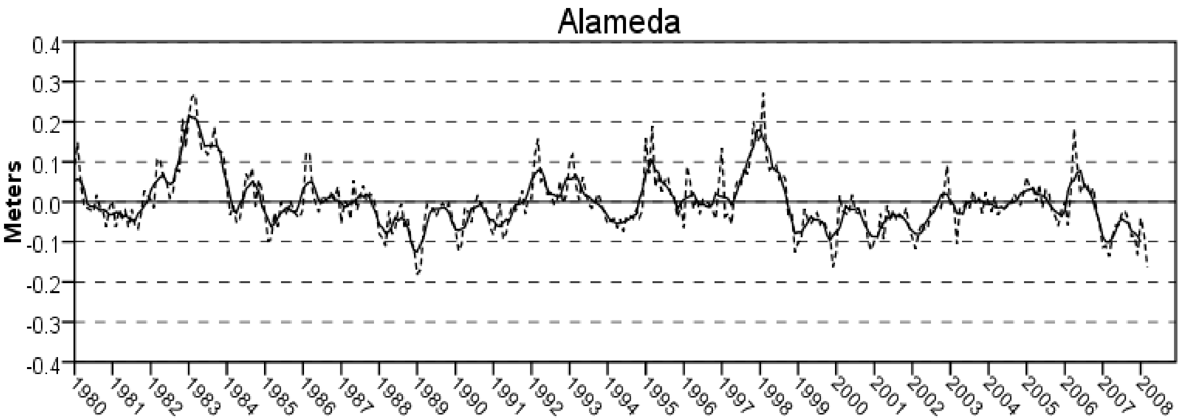


Initially, the decreased soil salinities may have been a significant contributing factor causing depressed germination of alkali bulrush in brackish marshes in these years. However, those reduced salinities may have provided the opportunity for pickleweed (which has a wider salinity tolerance) to dominate marshes in the Main Study Area in 2007 and again in 2008.

Mean Sea Level. The shift between alkali bulrush and pickleweed distribution does not appear to be solely related to interstitial salinities, surface water salinities, and inundation stress. In combination with these factors, shifts in vegetation are likely also related to additional environmental stress factors including interspecific competition and changes in average mean sea level. There was a steady increase in the mean sea level from 1999 to 2006, with higher than average mean sea level in both 2005 and 2006 (Figure 15). This increase in average mean sea level contributed to flooding over the marsh surface and inundation stress in brackish marsh communities in 2005 and 2006. However, mean sea level dramatically decreased between 2006 and 2008 (Figure 15).

Decreased marsh inundation related to lower mean sea levels in 2007 and 2008 may have contributed to increased soil salinities and less available porewater, causing plant stress and suppression of alkali bulrush populations. A change of around 0.2 meters is roughly equivalent to 7.8 inches. This vertical difference translates into a relatively large horizontal difference within the relatively flat marsh plain and may affect the moisture content of the soil as observed in the field during sediment coring. The deeper typical rooting depth of pickleweed (~18 in) versus the more shallow typical rooting depth of alkali bulrush (~8 in) may have increased the competitive advantage of pickleweed during 2007 and facilitated the colonization of dead areas by pickleweed as a result of the ability of pickleweed to tap into available porewater at increased depths during this period of lower mean sea level (Kantrud 1996).

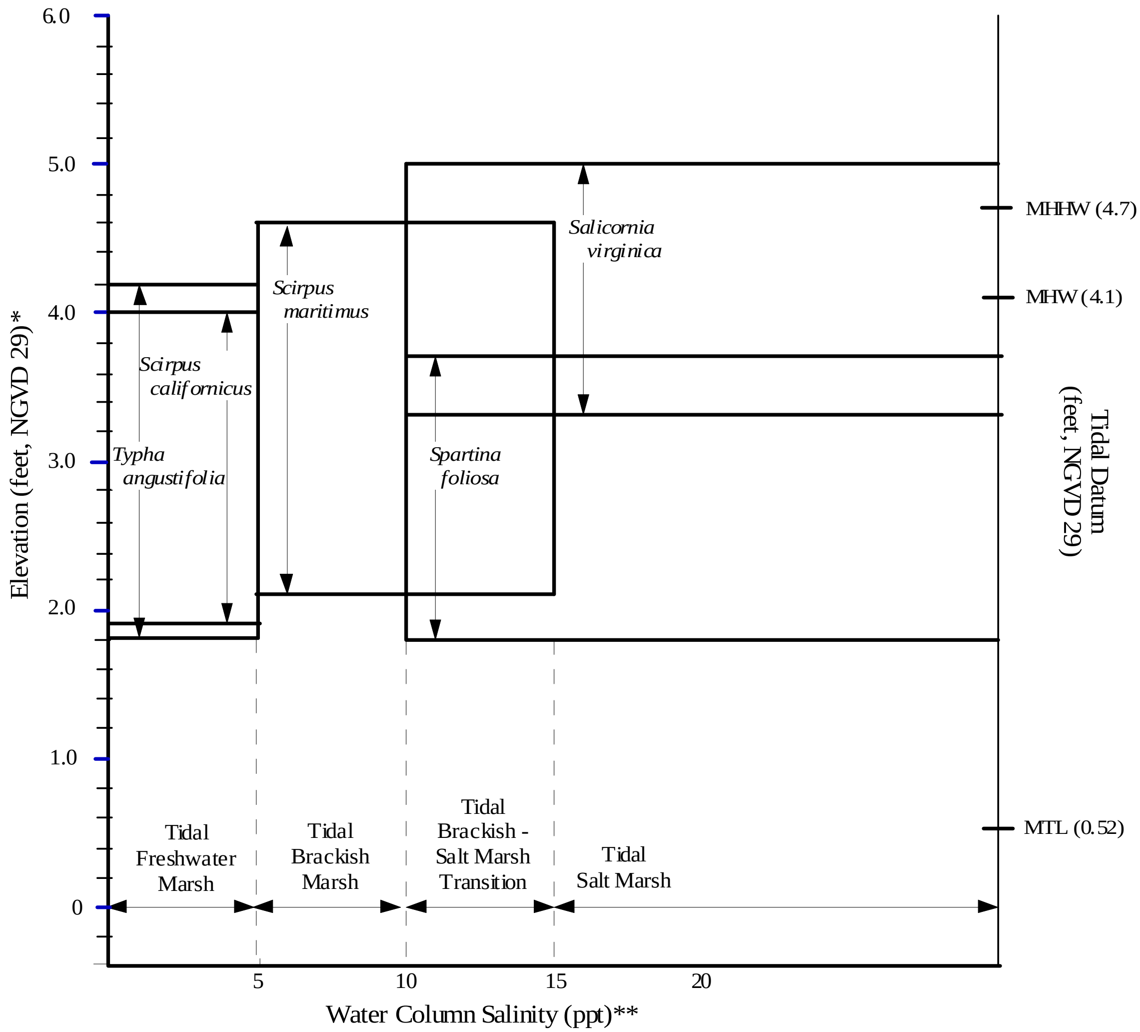
Figure 15. Interannual Variation of Mean Sea Level for Alameda, California 1980-2008 (http://tidesandcurrents.noaa.gov/sltrends).



Note: The plot shows the monthly mean sea level with the average seasonal cycle and the linear trend removed (dashed curve) and the 5-month average (solid curve). The data are taken at Alameda and the graph is indicative of the trends in San Francisco Bay. However, it should be noted that the tidal amplitude in the South Bay is greater than the values reported above for Alameda.

The range of elevations for marsh plant species with the corresponding predictions of water column salinity controls on tidal marsh species were projected for the Transition Reach as part of the Island Ponds restoration planning (H. T. Harvey & Associates 2005b). The mean elevation ranges of the dominant marsh plant species are sensitive to distinct variations in both salinity and position in the tidal profile. As shown in Figure 16, tidal salt marsh is projected to occur between 1.8 and 5.0 feet NGVD29 where water column salinity is greater than 15 ppt, while tidal brackish marsh is projected to occur from 2.1 and 4.6 feet NGVD29, where water column salinities are 5-10 ppt. (Figure 15). Based on these projections, tidal marsh habitats develop along salinity and elevation gradients with specific lower and upper mean elevations. Based on these overlapping salinity and elevation zones, changes in mean sea level such as those shown in Figure 15, could contribute to shifts in species composition.

Figure 16. Approximate Elevation and Water Column Salinity Range of Dominant Plant Species in Tidal Marsh Habitats Along Coyote Creek and Mud Slough (South Bay).



* Shows means of elevation limits. Island Pond Report (2456-01) Appendix B contains complete data.
** Salinity data modeled (Gross, 2003). Elevation and habitat data is empirical.

Sea Level Rise

There is considerable uncertainty surrounding the projected rate of global sea-level rise depending on the model used. IPCC (2007) used a variety of atmosphere-ocean general circulation models to predict a full range global average sea-level rise between 1990 and 2100 of 0.6 to1.9 feet. The use of a linear empirical relationship (not models) by Rahmstorf (2007) projected higher rates of global sea-level rise of 1.6 to 4.6 feet during the 21st century. South San Francisco Bay has historically been a sediment-laden depositional environment (EDAW and others 2007). If sea level rise sea level rise predictions and sediment availability to the South Bay remain the same, vegetated tidal marshes are likely to keep pace with changing sea level conditions. However, higher than predicted sea-level rise rates could result in marsh loss or additional species shifts within the Main Study Area and the Reference Area.

Tidal Prism

During the period of land subsidence in the South Bay (which ceased in the 1960s), the relative tidal height was increasing, which may have been a factor contributing to the more saline marshes observed prior to that time. The subsidence presumably helped to counterbalance the sedimentation in channels like Alviso Slough. When subsidence was controlled by increased water imports, regulated pumping, and artificial recharge, high sedimentation rates began to reduce the tidal prism, eventually leading to the expansion of vegetated marshes we are still documenting today.

The recent sedimentation in the South Bay has resulted in the expansion of mudflats as well as narrower channels with steeper channel banks, which provides additional area for the expansion of marsh vegetation. Habitat conversion within the Main Study Area (especially in the Upper and Transition Reaches) is related to this ongoing resizing of channels and resulting decrease in tidal prism in the South Bay.

The combination of the recent restoration in the South Bay at the Island Ponds and the proposed SBSP Phase 1 restoration actions will increase the tidal prism in the Main Study Area and the Reference Area in the future.

Temperature

In January 2007, a prolonged period of below-freezing air temperatures in the San Francisco Bay region resulted in heavy frost in the area (CIMIS 2007). In the 2007 report, we considered the possibility that low minimum air temperatures and heavy frost impacting the shallow rooting zone of alkali bulrush may have contributed to the lack of germination success of this species in 2007 (H. T. Harvey & Associates 2007). However, no similar such period of below-freezing air temperatures were observed in 2008, and yet the species shifts persisted. Consequently, it is unlikely that temperature has been a factor in the dominant species shifts observed in 2007 and 2008.

Invasive Cordgrass

The salt marsh habitat in the South Bay consists primarily of pickleweed, and two species of cordgrass including California cordgrass, and smooth cordgrass (*S. alterniflora*), and its hybrids (*Spartina alterniflora* [hybrids]), a non-native species from the east coast. Control and management of *Spartina alterniflora* [hybrids] falls primarily within the scope of the Invasive *Spartina* Project (ISP) and their agency partners U.S. Fish and Wildlife Service and Santa Clara Valley Water Control District (California State Coastal Conservancy and U.S. Fish and Wildlife Service 2003).

Increases in cordgrass acreage were observed in Segments 1, 2, and 23 in past years, and this trend continues in 2008. Increased colonization by cordgrass species was also observed along the edges of Coyote Creek in 2008. It is difficult to tell how much of the increases in acreage are related to colonization by invasive *Spartina* versus native *Spartina*, as it is often difficult to distinguish between the native and the hybrid species in the absence of genetic testing. Because of the difficulty in distinguishing this difference, these species were mapped collectively as cordgrass. However, based on morphological observations made in the field, we assume that the native species as well as the hybrids are both present in the study area.

Treatment in 2008 was focused in areas along Segment 22 and 23, and along Coyote Creek (pers. comm. Grijalva 2008). Future decreases in acreage of salt marsh species may occur in these areas, as well as with increased efforts in other segments to control invasive *Spartina* by the ISP and its partner agencies.

Alkali Bulrush Ecology

In northern California, alkali bulrush is dormant in the winter months, with shoot growth from corms occurring in March and April and flowers appearing in May. The peak growth of alkali bulrush occurs in June or July with peak shoot mass in August or September (Kantrud 1996) Alkali bulrush typically reproduces by means of asexual reproduction with the expansion of clones by a network of creeping rhizomes and corms concentrated at the outside edges of the clones. Corm sprouting and growth are inhibited by increased water salinity, with the upper salinity limit for sprouting of corms of approximately 21-30 g/L (Kantrud 1996). Corms may remain dormant under conditions of low water levels and high salinity for at least 2 years. Under normal rainfall conditions in San Francisco Bay, we anticipate a possible resurgence in alkali bulrush populations in areas that have been displaced by pickleweed in the past 2 years.

South Bay Salt Pond (SBSP) Restoration Project. As part of the Initial Stewardship Plan for the SBSP Restoration Project, three former salt ponds (Island Ponds A19, A20, and A21) adjacent to Segments 14, 15, and 21 in the Main Study Area were breached in the Spring of 2006 (Figure 1). Based on a study by Gross (2003) prior to breaching of the Island Ponds, restoration of these ponds contributes approximately 1200 acre feet of additional tidal prism at Mean Higher High Water. Given the central location of the Island Ponds within the Main Study Area, an increase in tidal prism of this magnitude may contribute to vegetation shifts unrelated to the WPCP discharges.

The shifts to more saline marsh species within the Transition Area suggest that there may be effects on species composition as a result of this restoration. These examples include increases in saline marsh species mapped in the vicinity of the Island Pond and the increases in saline marsh habitat mapped on the interior slopes of the Island Ponds levees in 2008 (Figure F-3). While it is unclear at this time (because of the confounding factor of the simultaneous low rainfall years) whether an increased tidal prism is contributing to the vegetation shifts observed in the Transition Reach of the Main Study Area over the past two years, habitat shifts resulting from the breaches were anticipated.

Current research indicates that saline waters discharged from recently breached Pond A21 are retained along the northern portions of Coyote Creek near the Island Ponds, particularly on the ebb tide. This horizontal salinity stratification along this portion of Coyote Creek likely confines the flows from the WPCP freshwater outfall along the southern bank (pers. comm. Stacey 2007). A discernable difference between species distributions along the northern and southern shores in this stretch of Coyote Creek would likely indicate an effect related to the Island Ponds breaching.

No difference was observed in 2007 or 2008, as conversion from brackish to saline marsh occurred in habitats bordering both the northern and southern shores of Coyote Creek.

In the Reference Area, sedimentation has resulted in upstream portions of the channels filling with estuarine sediment and sediment accumulation occurring along channel banks and fringing marshplain areas. Changing species composition and newly forming freshwater marsh upstream of the old Alviso marina, suggests a gradual reduction in tidal prism in the Reference Area (PWA 2007) which may also be contributing to species shifts.

Main Study Area. Long-term breach scenario modeling for the Island Pond restoration projected increased tidal flows in Coyote Creek and predicted that water column salinities for restored conditions in Coyote Creek adjacent to the Island Ponds would increase by 3-8 ppt after breaching (Gross 2003). Minimum salinities at low tide were projected to range from 8 to 14 ppt for the dry or "high salinity" month of July (H. T. Harvey & Associates 2005).

Large-scale vegetation shifts in the Transition Reach of the Main Study Area, combined with increased water column salinities in Coyote Creek at Calaveras Point and the railroad bridge (Figure 12) suggest that the Island Ponds (Figure 1, Ponds 19, 20, and 21) restoration may be increasing the tidal prism and salinities along Coyote Creek. The increase in tidal prism resulting from the opening of these three former salt ponds to tidal action is anticipated to result in some scour of the existing mudflats and possibly some fringing marshes. Monitoring for the Island Ponds has recorded fringing marsh loss related to scour along the north and south edges of Coyote Creek (Santa Clara Valley Water District (SCVWD) 2008). Marsh edge scour was observed from the boat along the marsh edges of a number of segments along Coyote Creek during mapping in 2007 and again in 2008 (H. T. Harvey & Associates 2007) (Figure F-6), suggesting that the Island Ponds restoration is having some effect on the fringing marshes in the vicinity of the breaches. With a return of a normal rainfall year, continued monitoring in future years will help to determine the relative effects of rainfall, freshwater inputs, and the increase in tidal prism on the vegetation shifts observed over the past two years.

Reference Area. Brackish to salt marsh conversion occurred in the Reference Area, but was mapped primarily in Segments 29 and 30 (Figure B-4), and this conversion was not as extensive as the marsh conversion observed in the Main Study Area. In fact, a large area of former brackish marsh converted to freshwater marsh in Segment 28 in both 2007 and 2008.

OVERALL CONCLUSION

Large-scale conversion of brackish marsh to salt marsh has occurred across the entire Main Study Area between 1989 and 2008, with most of this conversion occurring between 2006 and 2008 (Figures B1 – B3). This conversion comprises the largest such shift seen since the study began in 1989 and emphasizes the dynamic nature of these marshes.

Salt marsh conversion has historically been driven by large-scale influences (both environmental and anthropogenic) affecting the entire system. These include local and regional freshwater inputs, historic landscape-scale changes such as salt pond construction (SFEI 1999) and subsequent changes in channel morphology. Interannual differences in rainfall and mean sea level, as well as changes in relative tidal height and generally lowering salinities in the Coyote Creek system since the late 1960s due to the reduced tidal prism, have also contributed to marsh conversion in the South Bay. Although the average local freshwater flows in the South Bay and from the Delta have fluctuated between years, the WPCP flows have remained relatively constant (~180 cfs ±30%) since the inception of this study in 1989.

Vegetation shifts from alkali bulrush to pickleweed observed throughout the Main Study Area and in the Reference Area in 2007 and 2008 appear to be related to a combination of factors. The lack of late season rainfall in 2007, combined with increased surface water salinities, lower mean sea level and the localized effect of SBSP restoration of the Island Ponds have all influenced marsh vegetation distribution between 2006 and 2008.

The only other period (since data collection began in 1989) where saline marsh species were more dominant than brackish marsh species in the Transition Reach of the Main Study Area was in 1989 and 1994 (Figure 9). In 1994, similar to 2007 and 2008, there was a combination of low mean sea level (Figure 15) and comparable elevated salinities at Calaveras Point, with monthly mean salinities in the 20-30 ppt range for the first 4 months of each year. This combination of lower mean sea level and higher ambient salinities are likely the key contributors to the saline species dominance in these past two years.

While pickleweed growth in 2008 is healthy and vigorous, the recent changes in rainfall patterns, freshwater inputs, and ambient Bay salinities suggest that these marshes could shift back to alkali bulrush dominated habitats if rainfall patterns return to average (or greater) amounts. Monitoring vegetation distribution during a typical or above average rainfall year will also assist in discerning the relative contribution of the Island Pond restoration on the recent brackish to salt marsh conversion.

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PERSONAL COMMUNICATIONS

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Crooks, S. 2007. Personal communication between Steve Crooks (PWA) and John Bourgeois (H. T. Harvey & Associates) regarding alkali bulrush die-offs around San Francisco Bay

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APPENDIX A.
2008 VEGETATION MAPS

APPENDIX B.
1989/2008 SPATIAL ANALYSIS MAPS

APPENDIX C.
VEGETATION MATRICES

APPENDIX D.
PLANT LIST

Appendix D. Plants Observed in the South Bay Marsh Project Site		
FAMILY NAME	**SCIENTIFIC NAME**	**COMMON NAME**
Aceraceae	*Acer negundo* ssp. *californica*	California box elder
Aizoceae	*Carpobrotus edulis*	iceplant
	Mesembryanthemum nodiflorum	slender-leaved iceplant
	Tetragonia tetragonioides	New Zealand spinach
Alismataceae	*Alisma plantago-aquatica*	water plantain
Apiaceae	*Conium maculatum*	poison hemlock
	Foeniculum vulgare	sweet fennel
Asteraceae	*Baccharis pilularis*	coyote brush
	Carduus pycnocephalus	Italian thistle
	Centaurea solstitialis	yellow star-thistle
	Conyza canadensis	horsetail
	Cotula coronopifolia	brass-buttons
	Euthamia occidentalis	grass-leaved goldenrod
	Grindelia angustifolia	gumplant
	Picris echioides	bristly ox-tongue
	Pluchea odorata	salt-marsh fleabane
Boraginaceae	*Heliotropium curassavicum* var. *oculatum*	heliotrope
Brassicaceae	*Brassica nigra*	black mustard
	Hirschfeldia incana	small-pod mustard
	Lepidium latifolium	perennial peppergrass
	Rorippa nasturtium-aquaticum	water cress
Caryophyllaceae	*Spergularia marina*	sand-spurrey
Chenopodiaceae	*Atriplex semibaccata*	Australian saltbush
	Atriplex prostrata (*Atriplex triangularis*)	Spearscale, fat hen
	Bassia hyssopifolia	five-hook bassia
	Chenopodium sp.	goosefoot
	Salicornia europeae	annual pickleweed
	Salsola soda	Russian thistle
	Salsola tragus	Russian thistle
	Sarcocornia pacifica (*Salicornia virginica*)	common pickleweed
Convolvulaceae	*Cressa truxillensis*	alkali weed
Cuscutaceae	*Cuscuta salina* var. *major*	salt marsh dodder
Cyperaceae	*Bolboschoenus maritimus* (*Scirpus maritimus*)	alkali bulrush
	Eleocharis macrostachya	common spikerush
	Schoenoplectus acutus (*Scirpus acutus*)	tule
	Schoenoplectus americanus (*Scirpus americanus*)	Olney’s bulrush
	Schoenoplectus californicus (*Scirpus californicus*)	California bulrush
	Schoenoplectus robustus (*Scirpus robustus*)	common bulrush
Dipsacaceae	*Dipsacus fullonum*	wild teasel
Equisetaceae	*Equisetum arvense*	common horsetail
Frankeniaceae	*Frankenia salina*	alkali heath
Juglandaceae	*Juglans californica*	California black walnut
Juncaceae	*Juncus balticus*	Baltic rush
	Juncus bufonius	toad rush
	Juncus effusus var. *brunneus*	bog rush
Juncaginaceae	*Triglochin maritima*	seaside arrow-grass

Appendix D. Plants Observed in the South Bay Marsh Project Site		
FAMILY NAME	**SCIENTIFIC NAME**	**COMMON NAME**
Lamiaceae	*Mentha spicata*	spearmint
Malvaceae	*Lavatera assurgentiflora*	malva rosa
Myoporaceae	*Myoporum laetum*	lollypop tree
Plantaginaceae	*Plantago subnuda*	plantain
Plumbaginaceae	*Limonium californicum*	western marsh-rosemary
Poaceae	*Agrostis sp.*	bentgrass
	Arundo donax	giant reed
	Avena fatua	wild oats
	Bromus diandrus	ripgut grass
	Bromus hordeaceus	soft chess
	Cortaderia jubata	pampas grass
	Distichlis spicata	saltgrass
	Hordeum sp.	barley
	Lolium multiflorum	Italian ryegrass
	Parapholis incurva	curved sicklegrass
	Paspalum distichum	knotgrass
	Phragmites australis	common reed
	Puccinellia nutkaensis	Nootka alkaligrass
	Spartina foliosa and *S. alterniflora* and hybrids	cordgrass
Polygonaceae	*Polygonum coccineum* var. *emersum*	water smartweed
	Polygonum punctatum	knotweed
	Rumex crispus	curly dock
Potamogetonaceae	*Potamogeton foliosus*	leafy pondweed
	Ruppia maritima	ditch-grass
Ranunculaceae	*Ranunculus aquatilus*	whitewater crowfoot
Salicaceae	*Populus fremontii*	Fremont's cottonwood
	Salix sp.	willow
	Salix babylonica	weeping willow
Scrophulariaceae	*Kickxia elatine*	fluellin
	Veronica americana	American brooklime
Solanaceae	*Nicotiana glauca*	tree-tobacco
	Solanum americanum	deadly nightshade
Typhaceae	*Typha angustifolia*	narrow-leafed cattail
	Typha latifolia	broad-leaved cattail
The species are arranged alphabetically by family name for all vascular plants encountered during the plant survey. Plants are also listed alphabetically within each family. In some cases it was not possible to accurately identify a particular plant to the species level due to the absence of specific anatomic structures required for identification.		

APPENDIX E.
DOMINANT SPECIES CATEGORIES, MARSH TYPE AND VEGETATION ASSOCIATIONS FOR 1989 AND 2008

DOMINANT SPECIES CATEGORY	HABITAT TYPE	VEGETATION ASSOCIATIONS	
		1989	**2008**
Cordgrass	Salt	Cordgrass	Cordgrass Cordgrass/Wrack Cordgrass/Pickleweed
Pickleweed	Salt	Pickleweed Pickleweed, Alkali Heath, Spearscale (Fat Hen)	Pickleweed Pickleweed/Alkali Bulrush Pickleweed/Alkali Heath Pickleweed/Cordgrass Pickleweed/Gumplant Pickleweed/Jaumea Pickleweed/Peppergrass Pickleweed/Peripheral Halophytes Pickleweed/Spearscale Picleweed/Wrack
Pickleweed-Cordgrass Mix	Salt	•	Pickleweed-Cordgrass Mix
Alkali Heath	Salt	•	Alkali Heath Alkali Heath/Alkali Bulrush Alkali Heath/Peppergrass Alkali Heath/Pickleweed Alkali Heath/Spearscale
Gumplant	Salt	•	Gumplant Gumplant/Pickleweed
Jaumea	Salt	•	Jaumea
Peripheral Halophytes	Salt	Spearscale (Fat Hen), Alkali Heath	Peripheral Halophytes Peripheral Halophytes/Alkali Bulrush Peripheral Halophytes/Peppergrass Peripheral Halophytes/Spearscale
Russian thistle	Salt	•	Russian Thistle Russian Thistle/Alkali Bulrush Russian Thistle/Spearscale
Saltgrass	Salt		Saltgrass Saltgrass/pickleweed
Dead Vegetation	Salt/Brackish	Dead Vegetation	Dead Vegetation Dead Vegetation/Alkali Bulrush Dead Vegetation/Peppergrass Dead Vegetation/Pickleweed Dead Vegetation/Spearscale
Alkali Bulrush	Brackish	Alkali Bulrush	Alkali Bulrush Alkali Bulrush/California Bulrush Alkali Bulrush/Cattail Alkali Bulrush/Cordgrass Alkali Bulrush/Grass-leaved Goldenrod Alkali Bulrush/Peppergrass

DOMINANT SPECIES CATEGORY	HABITAT TYPE	VEGETATION ASSOCIATIONS	
		1989	**2008**
			Alkali Bulrush/Peripheral Halophytes Alkali Bulrush/Pickleweed Alkali Bulrush/Spearscale Alkali Bulrush/Wrack
Peppergrass	Brackish	Peppergrass	Peppergrass Peppergrass/Alkali Bulrush Peppergrass/Peripheral Halophytes Peppergrass/Pickleweed Peppergrass/Spearscale Peppergrass/Upland Species Peppergrass/Wrack
Spearscale	Brackish	•	Spearscale Spearscale/Alkali Bulrush Spearscale/California Bulrush Spearscale/Peppergrass Spearscale/Peripheral Halophytes Spearscale/Pickleweed Spearscale/Wrack
California Bulrush	Fresh	•	California Bulrush California Bulrush/Alkali Bulrush California Bulrush/Cattail California Bulrush/Wrack
Cattail	Fresh	•	Cattail Cattail/Alkali Bulrush Cattail/California Bulrush Cattail/Wrack
Smartweed	Fresh	•	Smartweed
Arundo	Fresh		Arundo
Grass-Leaved Goldenrod	Fresh		Grass-Leaved Goldenrod
Water Primrose	Fresh	•	Water Primrose

• Not a Dominant Species Category in Analysis Year

APPENDIX F.
2008 PHOTOGRAPHS OF VEGETATION IN REFERENCE AND MAIN STUDY AREA

APPENDIX G.
2007 EDAPHIC CHARACTERISTICS STUDIES