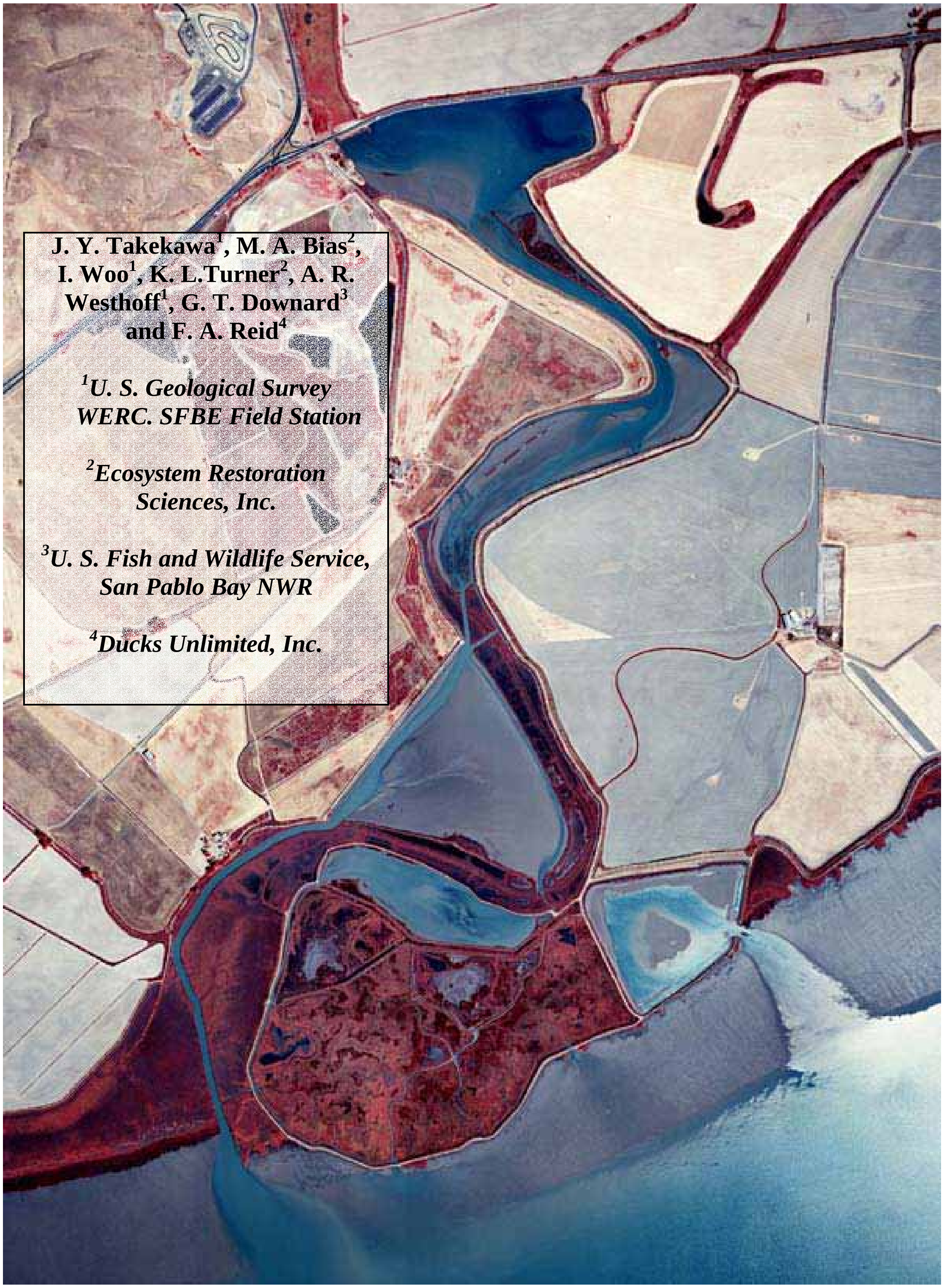
Restoration Research and Monitoring in Bayland Wetlands of San Francisco Bay: The Tolay Creek Restoration Project

2004 Progress Report



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2004 Progress Report

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TABLE OF CONTENTS

TABLES AND FIGURES

TABLES

FIGURES

EXECUTIVE SUMMARY

- Tolay Creek flows into San Pablo Bay on the northwest shore between the Petaluma River and Sonoma Creek. The Tolay Creek Restoration Project, managed by San Pablo Bay National Wildlife Refuge and California Department of Fish and Game, was initiated in 1997 to increase tidal flow to 176 ha of the lower creek (5 km from Highway 37 to San Pablo Bay) and improve habitats for endemic tidal marsh species.

- We developed sampling protocols to monitor changes in physical and biological processes prior to construction in the fall of 1998 (hereafter referred to as pre-breach) and after construction was completed in January 1999 (hereafter referred to as post-breach).

- We distinguished four unique areas in the Tolay Creek Restoration Project: the Mouth, Lower Lagoon, Mid Channel, and Upper Lagoon. The main channel at the Mouth was widened and deepened to increase tidal flow. A channel was created to connect the Lower Lagoon (43 ha) to a mitigation pond constructed in the early 1980s. Flow was also increased in the Mid Channel to reduce mosquito breeding habitat. Finally, a levee separating a diked field (22 ha) from the upper drainage was removed to create the Upper Lagoon (28 ha).

- Water quality measurements indicated that pH values increased from a wide range (3.6-7.9) of acidic conditions in 1998 (pre-breach) to a narrower range (7.1-9.2) of basic conditions from 1999-2004 (post-breach).

- In 2004, the tidal range and period at the Mouth was very similar to predicted values at Sonoma Creek, but there was a 20-minute delay in high tides. Low tides remained slightly muted and were delayed by 45 minutes. Tidal amplitude in the Upper Lagoon increased while tidal lag period decreased to one hour for high tides and higher low tides, and three hours for lower low tides.

- An as-built survey detailed the topography of the site in 2000. Measurement of sediment pins comparing 1999 to 2004 showed an average accumulation of 11.3 cm in the Lower Lagoon and 14.5 cm in parts of the Upper Lagoon. Despite overall accumulation gain during the past 6 years, annual accumulation for both the Upper and Lower Lagoons has stabilized with almost no change in 2004.

- Along the 9 vegetation transects, we detected 42 plant species. Fourteen species were detected during a single pre-breach survey and 35 species were detected over 9 subsequent post-breach surveys. Pickleweed (*Salicornia virginica*) cover increased from 33% (Fall 1998) to 77% (Fall 2004). Pickleweed density increased since the breach. Gum plant (*Grindelia stricta*) was more abundant post-breach, coyote bush (*Baccharis pilularis*) average height increased, while average height of invasive pepperweed (*Lepidium latifolia*) decreased. *Spartina foliosa* has colonized the Lower Lagoon and Mid Channel.

- Cover of exotic plants declined from 38% (Fall 1998) to 0% (Fall 2004) in the quadrat surveys, although invasive exotic species still persisted in low abundance on line transects.

- We have detected 18 species of fish in the restoration project. From 1999 to 2003, the number of species increased from 6 to 11 in the Upper Lagoon and from 6 to 13 in the Lower Lagoon. Fish species sensitive to suspended sedimentation (Pacific herring) were found in the Upper Lagoon with lower apparent suspended sediments concentrations, while species more tolerant to suspended sediment (bay goby) were found in the Lower Lagoon with higher concentrations.

- We observed 97 species of birds: 43 bird species were detected during a single pre-breach survey and 91 bird species were detected during subsequent seasonal post-breach surveys. The Lower Lagoon and Mouth mudflats were dominated by shorebirds. Terns and gulls were observed in the Mid Channel, and diving ducks were most abundant in the Upper Lagoon.

- Bird abundance increased from 1,076 in the fall of 1998 and 798 in the summer of 1999 during pre-breach surveys to seasonal averages of 3,252 birds per survey in 2000, and 4,562 birds per survey in 2001. Bird abundance peaked in 2002 (low tide 6,851; high tide 1,135) and decreased in 2003 (low tide 2,253; high tide 877 birds) and 2004 (low tide 3,570; high tide 746 birds).

- The proportion of shorebirds increased from 58% (pre-breach) to 78% (post-breach). Behavioral observations showed that 75% of shorebirds were foraging, with proportionately less foraging by wading birds, dabbling ducks, and coots. Diving ducks were observed foraging only 17% of the time, suggesting that they used the restoration site primarily for roosting.

- We observed 7 small mammal species: 5 pre-breach and 7 post-breach. The number of small mammals captured fluctuated annually, with highest numbers from 1999-2001 and lowest numbers from 2002-2004. Small mammal captures peaked in the spring of 2001.

- Salt marsh harvest mice (*Reithrodontomys raviventris*) were captured in higher numbers (15 total) during a single pre-breach survey (Fall 1998), especially in the upper reaches of Tolay Creek (14 in transect 8-9). However, salt marsh harvest mice captures are now more evenly distributed amongst sampling grids. Salt marsh harvest mouse abundance may be related to areas with greater pickleweed cover and height.

INTRODUCTION

The northern reach of the San Francisco Bay estuary, which includes San Pablo Bay, comprises the largest remaining expanse of undeveloped baylands in the estuary. A large proportion of this undeveloped land is in diked baylands that have been converted to agricultural use. San Pablo Bay National Wildlife Refuge (NWR) manages more than 5,340 ha of wetlands on San Pablo Bay. The refuge is actively rehabilitating or restoring historic tidal wetlands from previously converted agricultural land. Many endemic species that depend on salt marshes are under state or federal listing (Harvey et al. 1992), such as Mason's lilaeopsis (*Lilaeopsis masonii*), soft bird's beak (*Cordylanthus mollis ssp. mollis*), delta smelt *(Hypomesus transpacificus)*, Sacramento splittail (*Pogonichthys macrolepidotus*), California clapper rail (*Rallus longirostris obsoletus*), California black rail (*Laterallus jamaicensis coturniculus*), San Pablo song sparrow (*Melospiza melodia samuelis*), common yellowthroat (*Geothlypis trichas sinuosa*), salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*), Suisun shrew (*Sorex ornatus sinuosus*), and the salt marsh wandering shrew (*Sorex vagrans halicoetes*) may benefit from the tidal salt marshes restoration projects around the North Bay.

Tidal wetland restoration projects will increase the extent of saline emergent wetlands on the San Pablo Bay NWR and in the estuary, in accordance with the implementation objective of the CALFED Ecosystem Restoration Program (ERP). By understanding how physical attributes influence biological organisms, engineering or control measures will be directed towards increasing favorable habitat for target species and decreasing factors that promote the establishment and spread of non-native and invasive species. However, wetland restoration projects are unpredictable (Race 1985, Zedler 2001) perhaps owing to a lack of comprehensive information of the progression of wetland restoration projects through project completion.

Monitoring biophysical parameters is a critical component for wetland restoration and rehabilitation projects (Zedler 2001). Documentation and quantification of environmental change and the progression of wetland restoration actions is necessary to assess restoration techniques and develop adaptive management strategies. Adaptive management can provide guidelines for fine tuning the design and engineering of projects as needed to achieve an objective. Despite its vital role, monitoring has traditionally received little attention in pre- or post-project planning, field efforts, and funding support. The Tolay Creek Restoration Project includes adaptive monitoring to guide management actions. This report provides a summary of the monitoring results over the past 6 years.

Study Area

Historically, Tolay Creek received freshwater input from Tolay Lake and intermittent streams in the Sonoma Mountains. As it reached lower elevations, Tolay Creek spread out on a tidal flood plain, creating marsh habitat and tidal linkage to Sonoma Creek before connecting with San Pablo Bay (USFWS 1997). Today, Tolay Creek enters San Pablo Bay along a remnant wetland corridor on the northwest shore between the Petaluma River and Sonoma Creek, 16 km west of Vallejo on the south side of Highway 37 (Fig. 1).

Human activities such as levee construction and conversion to agricultural land have dramatically altered the landscape of Tolay Creek, decreasing the size of the tidal flood plain and associated marsh. When Tolay Creek was acquired in 1981, there was no tidal flow to the upper two miles of creek between the north end of the Lower Lagoon and Highway 37 (Fig. 1). Instead, this two-mile stretch consisted of a fallow field, upland plants and large cracks in the substrate that created mosquito habitat. The Tolay Creek Restoration Project, managed by San Pablo Bay NWR and California Department of Fish and Game, was initiated in 1997 to increase tidal flow to 176 ha of the lower creek and improve habitats for endemic tidal marsh species (USFWS 1997). The restoration project included rehabilitation of tidal flow to four areas: the Mouth, Lower Lagoon, Mid Channel, and Upper Lagoon (Fig. 1). In summer 1998 the main channel at the Mouth was widened to increase flow. Additionally, a channel was created to connect the Lower Lagoon (43 ha) to a mitigation pond to the southeast which had been constructed in the early 1980s. In December 1998, the Upper Lagoon (28 ha) was created by removing a levee separating a 22 ha diked agricultural field from the upper drainage (Fig. 1).

The San Pablo Bay NWR restoration project at Tolay Creek provided an opportunity to develop a general framework for wetland monitoring and detailed plans specific to restoration efforts. Monitoring and evaluation to determine the effects of restoration on endangered species was established as a required element of the restoration work for 10 years (1998-2008) following project development (USFWS 1997). Thus, we initiated work in 1998 to develop and undertake biophysical monitoring and evaluation. We developed sampling protocols to monitor biophysical changes from immediately before construction in fall 1998 (pre-breach) to after construction in January 1999 (post-breach).

METHODS

Sampling Framework

Biological monitoring and evaluation of Tolay Creek followed guidelines in the Environmental Assessment (USFWS 1997), based on transects running perpendicular from the creek edge out to the project boundary levee. A series of 9 transects were established at regular intervals (approximately 500 m apart) from the Mouth to the northern boundary of Hwy 37 (Fig.2). A sampling plan was developed for initial surveys (Table 1) (Takekawa et al. 1999a). Water quality and sedimentation rates were sampled throughout the project and water level meters were installed at the Mouth of Tolay Creek and at the Upper Lagoon. Vegetation surveys were conducted at each of the sampling transects. Fish were sampled in the Upper Lagoon, Mid Channel and Lower Lagoon. Birds were enumerated using two methods; area counts for species easily detected by sight and point counts for more secretive species. Small mammals were live-trapped for at least 3 nights in 5x5 or 6x6 trap grids located near the transects. Both benthic and terrestrial invertebrates were sampled along three transects in the marsh plain and Upper and Lower Lagoons. In this report, summary statistics are presented as the mean (± S.E.).

Water Quality

Water quality data was collected with a Horiba or Hydrolab MiniSonde water quality multi-probe along the vegetation transects (Fig. 2) at Tolay Creek between 1998 and 2001. Water quality parameters included: depth (cm), pH (0.1 pH), specific conductivity (0.01 µS/cm), salinity (0.1 ppt; directly converted from specific conductivity), dissolved oxygen (% saturation), and temperature (1°C). In the summer of 2002, the water quality multi-probe was upgraded to include a turbidity meter (10 NTU) and internal memory for deployment in the field for up to 30 days at a time. In September 2002 the Hydrolab water quality multi-probe was deployed for 5 days in the Upper Lagoon. Since the spring of 2004, the multi-probe has been deployed quarterly at both the Upper Lagoon and Mouth (Fig. 2) of Tolay Creek for 48 to 72 hours. The water quality multi-probe unit continuously logs at 15-minute intervals and is kept stationary at 10 cm above the substrate surface to prevent drying of the meter at low tide.

Hydrology

Five data loggers were installed in 1999 to assess water levels throughout the project area. However, initial results suggested that stations at the Mouth and Upper Lagoon (Fig. 2) were sufficient to track tidal changes. We used Global and Telog water loggers initially, but unified sampling with Telog water loggers after 2001. Telog loggers incorporate pressure transducers and convert water pressure to distance from the water surface (water depth). The loggers were programmed to take readings every 15 minutes and were corrected with an adjacent staff gauge referenced to known benchmarks. Tidal readings were downloaded every 60 days, at which time current logger readings were recorded and referenced against a staff gauge and real time.

Geomorphology

Beginning in 2000, digital ground photographs were taken annually of the entire site from 14 photo points located with GPS at strategic locations (Fig. 2). At each photo point, a panorama was taken encompassing the site with the frame including 50% of the sky. In 1998, aerial photographs were taken of Tolay Creek to assess pre- and post- breach differences (Fig. 1). In 2000, and annually since 2002, aerial photos have been taken to track changes at the site (Fig. 1).

A topographical as-built survey was conducted in 2000 by Ducks Unlimited to determine the elevation of the site. A grid was developed from a series of 1:1,200 aerial photographs, ground-truthed to determine elevation, and rectified into a GIS coverage. The California Department of Transportation installed a benchmark at the parking lot in March 2003, and Shoreline Engineering installed and resurveyed existing benchmarks throughout Tolay Creek in May 2003 (Fig. 3).

We initially recorded and processed GIS data in UTM NAD27 to maintain consistency with older USGS maps and available coverages; however, in 2004 we began to reprocess and convert old data to UTM NAD83 to take advantage of the better accuracy of the more recent datum. In 2004, control points were placed throughout the project site for the purpose of georectifying the 2004 aerial photo to UTM NAD83 (Fig 4). The control points were large white "X's" spraypainted on 1.5 m^2 black plastic squares attached to the ground with landscape staples. This was done before the aerial photo was taken so that the X's would be visible on the aerial photograph. The GPS locations were then taken for each of the control points using a Trimble GeoXT Pocket PC using the TerraSync software. Each coordinate was averaged from 50 GPS readings and had a horizontal precision between 0.2-0.6 meters.

Sedimentation

Twenty-five sediment pins (5-cm diameter, schedule 40 PVC, extending from above the water surface to $\geq$ 1 m into the sediment) were installed throughout Tolay Creek in late 1998. In December 2000, 4 more sediment pins were installed in the Lower Lagoon (sediment pin numbers 26-29). One more sediment pin, number 30, was added in the Upper Lagoon in August 2003. Sediment pins were measured three times per year with a graduated rod (sediment pole). A flat disk was attached to the bottom of the sediment pole to minimize the effect of the pole sinking into soft substrates. The average of two readings taken at opposite sides of the sediment pin was reported. A shorter sediment pin indicated sediment accumulation, while a longer sediment pin indicated sediment loss. Sediment pins are checked annually and replaced when they become bent or eroded away.

Vegetation

Vegetation surveys consist of a combination of line transect and 0.25 m^2 quadrat sampling methods. Initial vegetation surveys (1998 to 2000) consisted of nine 15-m-long continuous line transects, spaced 500 meters apart throughout the length of Tolay Creek. The start point of each 15-m transect was at a fixed location and the direction was randomly determined. A 0.25 m^2 quadrat was placed at the beginning (0 m), middle (7 m), and end of each transect (9.5 m) for species identification, ocular estimates of percent cover (total $\geq$ 100%), maximum height (cm), and density (rooted stems/m^2). In 2001, additional transects were added so that the entire area between the levee and the creek were surveyed with a permanent continuous line transect. These permanent, fixed direction transects were placed on top of the start point of the 15-m transects and provided a broader survey area (Fig. 2). We continued to sample the 15 m transects and quadrats; therefore, plant surveys consisted of a total of nine permanent and nine 15 m transects taken in a random direction. Transect sampling provided information on species identification and canopy cover. Canopy cover was calculated as the distance for which a species intersects the line divided by the total length of the line (total = 100%). Because salt marsh vegetation typically grows in monospecific patches, only the uppermost canopy layer was considered for the line transect. Vegetation sampling occurred twice a year (early and late season), until 2004 when vegetation sampling was changed to occur only once a year in the late season.

The September 2004 infrared aerial photograph of Tolay Creek was broken into 15 unsupervised classifications using ERDAS Imagine software to determine area values for tidal marsh vegetation (Fig. 14). Statistical patterns were identified from the pixel data by ERDAS without ground truthing. These 15 classes were then grouped manually in ArcGIS based on similar characteristics (i.e. marsh vegetation, water, mudflat) into seven major classes. Water comprises three of these classes, but was not further grouped in order to display various water depths.

Invertebrates

Invertebrate samples were collected in late fall 2004 (November through December) when shorebird abundances at Tolay Creek are high. Invertebrates were sampled along three permanent vegetation transects (Transect #2, 5 and 9) (Fig. 2) on marsh plain, mudflat, and lagoon habitat types. Three samples were collected in each habitat (N=9) to determine basic invertebrate composition, abundance, and species diversity. In the marsh plain invertebrates were collected within the vegetative canopy using a handheld vacuum (modified garden blower on suction mode) over a $0.25 m^2$ area. We placed a net sleeve inside the vacuum intake to collect all marsh debris and invertebrates (Legg 2001, Takekawa unpublished data) and immobilized them with ethyl acetate. They were then placed in a 70% ethanol with rose bengal solution for temporary storage. We collected benthic invertebrates in the mudflat and deepwater habitat types. We collected sediment cores (10 cm diameter, 10 cm depth) with a clam gun in the mudflat habitat type. For the deep water habitat type in the Upper Lagoon, we used an Eckman dredge to collect benthic samples. Benthic samples were screened on site with a 0.5 mm mesh and preserved in a 70% ethanol/rose bengal solution for temporary storage.

Fish

Open water beach seining was conducted in Tolay Creek in the fall of 1999, spring 2002, summer 2003, fall 2003, summer 2004 and fall 2004. The 1999 fish survey was conducted using a 35-ft beach seine at the Upper (3 hauls) and Lower (5 hauls) Lagoons. Starting 2002, sampling was done in at least 5 locations throughout Tolay Creek in the Upper and Lower Lagoons and Mid Channel areas. In the lagoons, 80 foot beach seines were used for sampling. One end of the line was anchored onshore while the seine was deployed by boat. The seine was deployed perpendicular and parallel to the shore so that the seine formed 3 sides of a rectangle, with the shore forming the 4th side. The two ends of the seine were pulled onshore so that fish species were captured in the net and pulled ashore. All fish, shrimp, and crab species were sorted and counted, with the first 30 specimen of each species measured for total length. Crab species were measured using carapace width. All fish were released back into the creek, except for unknown and voucher specimen, which were preserved in 10% formalin for later identification. Fyke nets were first deployed in 2004 for sampling of channels. The fyke nets were set at high slack on a channel bank with a moderate slope and checked at low tide after the channel had dewatered. Ichthyoplankton nets were towed behind a motor boat for five minutes at every location that seines or fyke nets were used in 2004. The purpose of the plankton tow was to examine the food available for fish in the area.

Birds

Two methods were used to survey birds. Area surveys were used for visual sightings of birds within the Upper Lagoon, Middle Channel, Lower Lagoon and Mouth. The observer visually surveyed an area and tallied all species along with habitat (mudflat, marsh plain, open water, shallow water, levee (inside project), outer levee (outer edge of project), island, marsh pond, outside project (outside levee, still in grid), aerial, channel edge, upland or channel water) and behavior (roosting, foraging, calling, flyover, swimming, preening, alert, courtship display, carrying nest material, carrying food, aggression or unknown). Area counts were initially conducted seasonally regardless of tide.

Observations that bird numbers varied with tide prompted area surveys to be conducted during both high and low tide for each season in 2002. Variable circular plot surveys (point counts) were conducted seasonally and included visual and auditory detection of birds at study transects (DeSante 1981). The observers walked to the center of the plot and waited for 2 minutes to allow birds to settle, followed by an 8-minute survey period. Observers counted all birds seen or heard within a 150-m radius. Point counts were designed to detect passerines and more secretive birds that may not be seen in tall, structurally complex vegetation. Point counts were conducted along vegetation transects (Fig. 2) within 2.5 to 3 hours after sunrise.

Small Mammals

Permanent grids (5x5) of 25 Sherman live traps were set 10 m apart near vegetation transects on Tolay Creek (Fig. 2). A single transect of 10 traps was set out on an island in the upper Mid Channel. One pre-breach small mammal trapping session occurred in the fall of 1998 and subsequent sampling was conducted in winter 1998, summer and winter 1999, summer and winter 2000, spring 2001, spring and fall 2002, summer and fall 2003, and spring 2004. In 2004 we reduced the frequency of small mammal surveys to once a year to minimize effects of walking in the sensitive habitats, and we also expanded grids 1, 2, and 3 to 6x6 trapping grids. Trapping occurred for three consecutive nights led by individuals permitted to handle salt marsh harvest mice. Each captured animal was identified, sexed, weighed, examined for reproductive status, and released at the site of capture. A small area of fur was clipped on the right (first day) or left flank (second day) of each individual to identify recaptures. Additional measurements were taken for harvest mice (*Reithrodontomys* spp.) to distinguish the salt marsh harvest mice from western harvest mice including: body length, ventral pattern, tail length, tail diameter, tail color, ear length, and behavior. Live trapping results were reported as number of captures (excluding recaptures) per 100 trap nights to standardize against trapping efforts.

RESULTS AND DISCUSSION

Water Quality

Pre-beach tidal flow was restricted in sections of the Mid Channel of Tolay Creek, an area that had formerly been farmed and was subsided. Initial conditions were highly acidic in the upper reach of the creek (Fig. 5) and compared closely with our initial pH readings of 3.3 in the subsidized farmlands and oxidized peat soils of the Cullinan Ranch unit (Takekawa et al. 1999b). The pH values throughout Tolay Creek increased from wide ranging acidic conditions of 3.6-7.9 in 1998 (pre-breach) to a narrower range of 6.8 – 7.9 (Fig. 5) seven months after the breach. In 2004, pH averaged 7.84 ± 0.01.

Data showed that the specific conductivity or salinity was largely influenced by spring rain. In March, specific conductivity readings were < 20 µS/cm (roughly 6 ppt), whereas readings were consistently around 40 µS/cm in July and September (25 ppt; Fig. 6). The maximum salinity at Tolay Creek (Upper and Lower Lagoon) was 27 ppt in September 2002 and 26 ppt in September 2004.

Dissolved oxygen (DO) levels followed the rise and fall of water temperature. At the Mouth in July 2004, DO levels reached their lowest value at 0800 h (63.7% saturation) when water temperatures were lowest (18.4 °C) and peaked during midday (142% saturation) when water temperatures were highest (25.6 °C). Supersaturation (> 100% saturation of DO) can occur when already saturated water warms up during the daytime while phytoplankton produce oxygen. The cause of the DO spike (142% saturation) during a few readings on July 17, 2004 is unknown; however, a rapid increase in water temperature, yellowfin goby nesting in the logger (Takekawa et al. 2002), or equipment malfunction may explain the elevated DO level.

Multi-day water quality deployment results indicated larger turbidity fluctuations at the Mouth of Tolay Creek compared with the Upper Lagoon, presumably due to increased tidal currents closer to San Pablo Bay (Fig. 7).

Hydrology

Over 6 years, we have observed increased tidal range and period at the Mouth and Upper Lagoon of Tolay Creek compared with the Sonoma Creek tide station (Figs. 7, 8, 9). After the restoration of tidal influence in December 1998, initial water levels exceeded predicted values. Water level loggers were installed in late January 1999 and verified that corrective channel dredging in the spring of the same year increased tidal flow and stabilized water levels.

In 1999, the tidal range in the Mouth and Upper Lagoon was narrow and elevated with minimum and maximum values fluctuating greatly over the year (Fig. 8), most likely due to the restoration of tidal influence. The daily tidal range (daily max – daily min) at the Mouth has increased from 4.0 $\pm$ 0.0 m in 1999, 4.6 $\pm$ 0.1 m in 2002, and 5.2 $\pm$ 0.1 m in 2004. The daily tidal range has also steadily increased in the Upper Lagoon from 1.3 $\pm$ 0.0 m in 1999 to 2.7 $\pm$ 0.0 m in 2002 to 3.1 $\pm$ 0.0 m in 2004. Water levels at the Upper Lagoon remained slightly muted during lower low tides, though water levels were not elevated (Fig. 7, 8). Mean water levels from May 2004 (Fig. 7) showed that tidal range within the Mouth and Upper Lagoon more closely matched estimated tides at Sonoma Creek than in October 2002. However, the more gradual slope at the bottom of the falling lower low tide at the Mouth showed incomplete drainage, possibly due to the location of the datalogger in a side channel near Tolay Creek (Figs. 2, 7). At the lowest tides, the side channel fully drains and the bottom sediments become exposed, which may cause the water levels at the datalogger to appear muted.

We found an average delay of 20 minutes between high tides at Sonoma Creek to the Mouth of Tolay Creek from 7-13 May 2004. In January 1999, high tides were delayed by roughly 3 hours from Sonoma Creek to the Upper Lagoon, and low tides were delayed by 2 hours. In May 2004, high tides in the Upper Lagoon had an average delay of 73 minutes, a decrease of 2 hours from 1999. The delay between tides at Sonoma Creek and the Upper Lagoon varied between higher low tides and lower low tides. The average delay at the Upper Lagoon for higher low tides was 1 hour; however, the delay was 3 hours for lower low tides, probably because of greater amounts of exposed mudflat causing slow drainage during the lowest tides.

Geomorphology

Aerial photographs of Tolay Creek documented initial changes in the project included widening of the channel below the Lower Lagoon with visible suspended sediment that extended from San Pablo Bay past the Mid Channel (Fig. 1). In 2000, an as-built survey was conducted by Ducks Unlimited to determine site topography (Takekawa et al. 2002). The September 2004 aerial shows increased sedimentation in the Upper Lagoon and Mid Channel and scouring as Tolay Creek enters San Pablo Bay (Fig. 1).

Digital photographs were taken throughout the project to track qualitative changes (Fig. 10). These photos were taken in the fall after the growing season to provide reference points for levee erosion, channel width changes, and changes in vegetation. An increase in pickleweed cover is documented from photopoints taken at the same location in 2000 to 2004 (Fig. 11).

Sedimentation

Sediment pins were distributed throughout the length of Tolay Creek. Cumulative measurements of sediment change indicated that 17 of the 30 sediment pins (hereafter SP) gained sediment since 1999 (Fig. 12). Since 2002, sediment accumulation in the Upper Lagoon has greatly increased. Measurement of sediment pins comparing 1999 to 2002 showed an average loss in the Upper Lagoon of 7.7 $\pm$ 3.6 cm; between 1999 and 2004 this comparison showed an average gain of 14.5 $\pm$ 9.5 cm. From 1999 to 2004, sediment accumulation in the Lower Lagoon was 11.3 $\pm$ 13.2 cm.

The Lower Lagoon had the greatest sediment accumulation and the greatest sediment loss (>50 cm gain at SP 14 and 90 cm loss at SP 4), which would explain the high variability in average sediment accumulation. Eight out of ten pins in the Lower Lagoon accumulated sediment, and the two pins with sediment loss occurred near areas where new channels have formed. Sediment is primarily accumulating in the southwest corner of the Upper Lagoon (Figs. 15, 16), and the Mid Channel has also continued to gain sediment in the northeast corner (Fig. 12).

After the reintroduction of tidal influence to Tolay Creek, we expected a large initial accumulation of sediment that would decrease over time as the site stabilized. This transition has occurred in both the Upper and Lower Lagoons (Fig. 13); there were large initial gains and losses that have declined to almost no annual rate of change in 2004. In the Lower Lagoon, sediment accumulation rates have gradually declined since 2001 and may indicate that the sediment bed is stabilizing. In the Upper Lagoon, however, pulse events may have a greater influence on sedimentation. Four sediment pins (8, 17, 20, 26) showed dramatic spikes in sediment accumulation followed by periods of little accumulation or loss (Fig. 13).

Vegetation

Forty-two plants have been detected along Tolay Creek transects (Table 2). Fourteen species were detected during a single pre-breach survey and 35 species have been detected in the nine post-breach surveys. Common vegetation at Tolay Creek consisted of mosaics of *Salicornia virginica*, *Frankenia salina*, *Baccharis pilularis*, *Jaumea carnosa*, *Grindelia stricta*, *Cuscuta salina, Raphanus sativus, Brassica rapa, Atriplex triangularis*, *Spartina foliosa*, *Spergularia rubra*, *Lepidium latifolia,* and *Scrophularia californica*. In comparison, Siegel (1998) reported seven salt marsh plant species for the Petaluma River Marsh restoration surveys including *Salicornia virginica, Distichlis spicata*, *Scirpus* spp., *Grindelia humilis, Frankenia grandifolia*, *Spartina foliosa*, and *Rumex crispus*. While Tolay Creek contains similar dominant species as Petaluma River Marsh, the greater species diversity found at Tolay may reflect differences in the sampling design, the hydrogeomorphologies in the two wetlands, the histories, and restoration efforts of the sites.

Following the breach of Tolay Creek, *Atriplex triangularis* sharply decreased, primarily because it was located in transects which are now submerged (Fig. 1). The sampling during spring 2001 was conducted early in the season (February) and perhaps underestimated species occurrence of those plants that emerge later in the spring. Subsequent plant surveys were conducted twice a year in April or May and also in August until 2004 when vegetation surveys were reduced to annual surveys in late summer. Although species diversity is not necessarily correlated with marsh age, young salt marshes tend to be characterized by low-diversity vegetation dominated by *Salicornia*, while some older marsh remnants may comprise complex and annual variable mosaics of *S. virginica*, *Distichlis*, *Cuscuta*, *Jaumea*, *Frankenia* and *Atriplex*. However, age and species diversity generalizations cannot be made for all wetlands: old wetlands at China Camp were found to support a low diversity of vegetation dominated by *Salicornia virginica* (Goals Project 2000).

Increasing pickleweed cover is a desired outcome of restoration because it functions as a cover and food plant for tidal marsh species. Cover of the 7 most common species groups showed an increasing proportion of pickleweed since 1998 (Fig. 16). Pickleweed increased from 33% prior to restoration to 72% in less than one year and represented 77% of the total in 2004 (Figs. 16, 17). Since the breach in 1998, percent cover of pickleweed has increased along transects 1, 5, and 7 and decreased along transects 2, 3, 4, 6 and 8. The decrease in pickleweed cover along transects 2, 3 and 4 may be due to channel widening and hydrological changes from restoration. The decrease in transects 6 and 8 is due to inundation following the breach (Figs. 1, 2).

Following restoration activities, pickleweed density increased while average height decreased (Fig. 18). Quadrat samples from transect #3 showed that pickleweed density ranged from 4.0 $\pm$ 4.0 plants/m^2 (pre-breach), to 12.8 $\pm$ 1.2 plants/m^2 (post-breach) (Fig. 18). Post-breach pickleweed height ranged from 47.1 $\pm$ 2.5 cm to 57.8 $\pm$ 2.9 cm at transects 1 and 3, respectively. There was no correlation between cover and height (p = 0.329), cover and density (p = 0.934), nor density and height (p = 0.065). The average height of *Frankenia salina* (Pre-breach 23.6 $\pm$ 6.7 cm; post-breach 38.7 $\pm$ 3.0 cm) increased while invasive pepperweed (*Lepidium latifolium*) heights decreased (103.4 $\pm$ 10.7 cm; post-breach 71.3 $\pm$ 7.7 cm; Fig. 19).

Percent cover of exotics decreased in quadrats from 38% (Fall 1998) to 8% (Summer 1999) to 2% (Spring 2002) to 0% (Summer 2003 and 2004) (Fig. 20). Exotic plants were further categorized as non-invasive or invasive based on the California Exotic Pest Plant Council (CalEPPC 2005). The decrease in exotic cover mostly consists of the decrease of non-invasive exotic species in the first year after wetland restoration. Invasive exotic cover in vegetation quadrats has slightly decreased from 10% (Fall 1998) to 6.3% (Summer 1999) to 1% (Summer 2000) to 2% (Spring 2002) to 0% (Summer 2003 and 2004). However, exotic species were still detected in the <3% of transects in the summer of 2003 and 2004. Despite volunteer efforts to remove the invasive pepperweed, it persists along with five other invasive species (Table 2): Australian saltbush, Italian rye grass (*Lolium multiflorum*), ripgut brome (*Bromus diandrus*), purple starthistle (*Centaurea calcitrapa*), yellow starthistle (*Centaurea solstitialis*).

Baccharis was the tallest plant at 110 cm, followed by *Grindelia* at 78 cm, pepperweed at 71 cm, and *Salicornia* at 53 cm (Fig. 19). Because plants are distributed along multiple environmental gradients, such as tolerance to salinity, drought, and submergence, further study is needed to assess whether taller foliage may give pepperweed a competitive advantage over *Salicornia* and other native salt marsh species. Pepperweed is an invasive exotic plant of concern. It is perennial and produces dense monospecific stands. Stems can reach up to 1.5 m in height, almost 1 m taller than pickleweed canopies (Renz 2000). Dense pepperweed threatens native salt marsh habitat by altering soil salt ions (Blank and Young 1997), displacing native plant species and threatened species such as the salt marsh harvest mouse (Trumbo 1994), which depends on the native pickleweed. Besides decreasing plant diversity, pepperweed is also believed to reduce nesting frequency of waterfowl in and near wetlands that it invades (Trumbo 1994).

The use of aerial photography to classify land cover types was used to provide rough estimates of tidal marsh development. Though this preliminary method (unsupervised classification; ERDAS Imagine software) proved to be valuable, we detected a few problems and limitations. Unsupervised classification is computer-automated, the computer uses basic parameters outlined by the user as guidelines to find statistical patterns in raster data; the user may not indicate which pixels are associated with a particular habitat. As a result, what a user may know to be *Baccharis* may get classified as *Salicornia*, or water may be classified as bare ground if it is reflecting light (Fig. 14). Similarly, the time at which the photograph is taken also will have an effect on the classification process. In September, when *Salicornia* is beginning to senesce, it may have a different spectral signature than in the spring when it is still growing. Despite these limitations, we were able to group the raster data into general land cover categories: tidal marsh, upland, bare ground, mudflat, and open water.

In 2004, tidal marsh vegetation comprised 375 ha (33%) of 1,144 ha analyzed through unsupervised classification of the Tolay Creek Restoration Project and surrounding areas including Tubbs Setback and Tubbs Island (Fig. 14). Upland vegetation, concentrated on and around levees and roads made up 38 hectares (3%). Bare ground, including roads and farmland comprised 159 ha (14%) and mudflat made up 110 ha (10%) of the site. Open water represents the largest habitat type at 462 ha (40%).

The challenges of land cover classifications may be mitigated in the future with supervised classification (ERDAS Imagine software), which allows the user to define pixels based on patterns they recognize through ground truthing and other sources. The drawback to this method is that it requires extensive field and lab time. In addition, aerial photographs could be taken during active growth (summer) to reduce error based on plant condition.

Invertebrates

Invertebrate collection was completed in 2004. All samples were sieved and samples are being processed for species composition and abundance by habitat type (open water, mudflat, and marsh plain).

Fish

Fish abundance and distribution can vary with season, salinity, and tide. Fyke nets were deployed during slack high tides and retrieved during slack low tide; while beach seines were deployed throughout the day without standardization of tide. We detected 18 fish species during surveys (Table 3) in 1999, 2002 and 2003. Data from 2004 is still being processed and verified. Six species were detected in the Upper and Lower Lagoon of Tolay Creek in 1999. In 2002, we detected 13 aquatic species in the Upper Lagoon and 9 in the Lower Lagoon, and we detected 11 species in the Upper Lagoon and 13 in the Lower Lagoon in 2003. No special status fish species were captured in these surveys, but incidental observations of carcasses on banks included a few adult sturgeon and salmon.

Species composition and abundance varied by season. In June 2003, 16 species were observed throughout Tolay Creek: 15 species in the Upper Lagoon and 13 species in the Lower Lagoon. The 5 most abundant species were topsmelt (*Atherinops afinins*), yellowfin goby (*Acanthogobius flavimanus*), arrow goby (*Clevelandia ios*), hemigrapsus crab (*Hemigrapsus sp.*) and striped bass (*Morone saxatilus*). In November 2003, 12 species were observed throughout Tolay Creek: 9 species were captured in the Upper Lagoon and 7 in the Lower Lagoon (Figs. 21, 22). The 5 most abundant species were topsmelt, Crangon shrimp (*Crangon spp.*), American shad (*Alosa sapidissima*), rainwater killifish (*Lucania parvu*), and Pacific staghorn sculpin (*Leptocottus armatus*). Yellowfin gobies were found in very high numbers in May 2002 (512 fish caught, 59.3% of total catch) and June 2003 surveys (371 fish caught, 32.2%), yet very low numbers in the November 2002 (5 fish caught, 0.9%) and November 2003 surveys (2 fish caught, 0.3%; Fig. 21).

The common aquatic species found in the Upper Lagoon includes shrimp species, yellowfin goby, Pacific staghorn sculpin, topsmelt, and Pacific herring. *Crangon* shrimp species were the most abundant specimen collected in the Upper Lagoon and are prey for many estuarine fish. Common species found in the Lower Lagoon included arrow goby, shrimp species, Pacific staghorn sculpin, topsmelt and yellowfin goby. Several species found in the Lower Lagoon are bottom dwellers that can tolerate sediment loads such as goby species (Moyle 2002). Fish found in the Upper Lagoon included species such as the Pacific herring that are sensitive to high sediment loads.

Incidental observations in 2004 detected colonization of Asian clam *Potamocorbula amurensis* throughout Tolay Creek. Though clams are not measured or enumerated during fish surveys, we collected benthic invertebrate cores in the deep water and shallow water habitat types in the Upper and Lower Lagoons, respectively for future analysis (see Invertebrate section).

Birds

Tolay Creek lies along the Pacific Flyway and provides habitat for migratory waterbirds and shorebirds. We detected 97 species of birds in the project: 43 bird species were detected during a single pre-breach survey and 91 bird species were detected during subsequent seasonal post-breach surveys (Table 4). The average number of birds per survey increased from single pre-breach numbers in fall 1998 (1,076 birds) and summer 1999 (798 birds) to seasonal average in 2000 (3,252 ± 1,099 birds per survey), and 2001 (4,562 ± 2,952). Since 2002, bird surveys were conducted at both high and low tides per season. During low tide, mudflats in the Lower Lagoon are exposed, attracting numerous migratory shorebirds. Bird abundances for low tide surveys peaked in 2002 (6,851 ± 3,026 birds per survey) and decreased in 2003 (2,253 ± 1,222) and 2004 (3,570 ± 969). The average bird count per survey during high tide has stayed rather consistent 2002 (1,135 ± 319), 2003 (877 ± 199), and 2004 (746 ± 132).

Area surveys documented a change in total bird numbers according to tide: more birds were observed during low tide than at high tide, largely due to the high influx of shorebirds during low tide (Fig. 24). Birds that use open water habitat such as diving ducks did not show any pattern associated with tide. Percent of dabbling ducks, diving ducks and passerines have declined in area surveys, while percent of shorebirds have increased from pre-breach 58% to post-breach 77% of the total bird count (Fig. 23). Shorebird counts in the Lower Lagoon have increased since 1998 (Fig. 24), presumably because of increased sedimentation, creating favorable foraging habitat. Post-breach, shorebirds made up the majority (77%) of the birds observed, followed in decreasing composition by diving ducks, terns or gulls, dabbling ducks, coots, passerines, wading birds, cormorants, raptors, grebes, geese, pelicans and upland birds (Fig. 23).

The Lower Lagoon and Mouth channel mudflats were dominated by shorebirds whereas diving ducks were primarily found in the Upper Lagoon (Fig. 25). As of 2002, the Middle Channel was dominated by terns and gulls (32%); however, in 2004 shorebirds consisted of 48% of the total count while terns and gulls comprise 35%. These changes may be due to increased sedimentation in the Middle Lagoon (Figs. 12, 15). The majority of birds were observed using mudflat (51%), open water (16%) and shallow water (15%) habitats.

Observation of bird behavior was also conducted during surveys and included foraging occurrence (Fig. 26). Foraging was the primary behavior for shorebirds (75%), with a lower percentage foraging for dabbling ducks (42%), wading birds (42%), and grebes

(35%). In contrast, only 17% of diving ducks counted were foraging, indicating that this guild used the restoration site for resting.

The state threatened California black rail (*Laterallus jamaicensis coturniculus*) and the federally and state endangered California clapper rail (*Rallus longirostris obsoletus*) were detected during point counts at Tolay Creek (Table 5). The California black rail has been detected near the Lower Lagoon and Mouth of Tolay since 1999; while the California clapper rail was first detected near the Mouth of Tolay in spring 2002. Abundance indices of three tidal marsh passerines were calculated from point count bird surveys (Fig. 27). The San Pablo song sparrow (*Melospiza melodia samuelis*, a state species of concern) was the most common species observed in point count surveys, followed by the marsh wren (*Cistothorus palustris*) and the common yellowthroat (*Geothlypis trichas sinuosa,* a state species of concern). Though song sparrow occurrences varied seasonally, their numbers were relatively low in 2001 (25 per survey), 2002 (16), and 2003 (16) and increased in 2004 (33).   In 2004, there was a large increase of song sparrow detection, with a total count of 130 individuals compared to only 65 in 2003.

Small Mammals

We detected 7 small mammal species: 5 during pre-breach surveys and 7 during post-breach surveys (Table 6). New small mammal captures per 100 trap nights ranged from 47 in the spring 2001 to 14 in the spring 2004 for grids that have been sampled repeatedly (Fig. 28). Total numbers of new captures were lower from 2002-2004 compared to 1998-2001. The large numbers captured in 2001 may reflect a spike in small mammal populations, and more individuals captured in the spring and summer than in the fall and winter.

The greatest abundance of salt marsh harvest mice were detected in the upper reach during pre-breach surveys (transects 8 and 9) (Figs. 2, 29). However, salt marsh harvest mice are now captured in higher numbers in the lower reach, partly because of inundation in the upper reach (transects 2 and 3). There were no salt marsh harvest mouse captures on grid 2 before the breach, but there have been 62 animals captured in the 9 surveys conducted since the breach. Salt marsh harvest mice are dependent on thick, perennial cover such as pickleweed (Bias 1994), and their numbers may be related to areas of greater pickleweed density and height (Takekawa et al. 2002). They may also be found in adjacent upland habitats (Botti et al. 1986, Bias 1994).

Conflicting results exist regarding interactions of salt marsh harvest mice with other species. Geissel et al. (1988) suggested seasonal displacement of salt marsh harvest mice from optimal habitat by California voles; however, Bias (1994) demonstrated that this pattern is not substantiated with greater number of trap nights. At Tolay Creek, voles have been the dominant small mammal captured. Shrews (*Sorex* spp.) comprise a small percentage of small mammal captures. Shrew habitat preference appears to be more strongly associated with vegetation structure rather than species composition. Shrews are found in areas with dense vegetation cover, abundant food source (invertebrates) and fairly continuous ground moisture, while salt marsh harvest mouse habitat consists of thick perennial cover (Goals Project 2000).

ASSESSMENT OF RESTORATION GOALS

The overall goal of the Tolay Creek Restoration Project is to restore and enhance tidal salt marsh habitat in Tolay Creek to benefit endangered and threatened species (USFWS 1997). Specific objectives were to: 1) restore tidal flows to Tolay Creek from San Pablo Bay to Highway 37, 2) restore two former farm fields to tidal marsh habitat, 3) enhance existing tidal marsh habitat in the Tolay Creek flood plain south of Highway 37, 4) restore the property in a manner that will require minimal maintenance, 5) create habitat that minimizes mosquito production and 6) monitor and evaluate the results for its effects on endangered species (USFWS 1997).

Our monitoring and evaluation results suggest that the Tolay Creek Restoration Project has been highly successful in reaching its goals, despite early difficulties with muted tides in the Upper Lagoon. Restoration activities transformed what was a choked, narrow drainage with limited tidal flow into a developing tidal marsh with increased diversity. A primary lesson of this restoration has been that dealing with small remnant wetland fragments is complex and engineering solutions can often be difficult to predict. This is especially true when restoration projects extend across decades (nearly 30 years have elapsed since the

Tolay Creek acquisition in 1974) with several groups involved. A restored, "maintenance-free" habitat fragment is not the norm, and is not a realistic management goal.

Adaptive management approaches could provide solutions to problems that arise. Monitoring protocols should also be adaptive to be more inclusive and adapt to developing habitat types. For example, the observation that birds used areas of Tolay Creek at different times prompted area bird surveys to be done during both high and low tide. We have learned that restoration monitoring must include not only the ultimate target species and characteristics of the ecosystem, but the relevant physical parameters for management actions including geomorphology, elevation, levee erosion, sedimentation, water levels, and water quality.

(1) Restore tidal flows to Tolay Creek from San Pablo Bay to Highway 37.-- Flows have been restored at Tolay Creek from San Pablo Bay to Highway 37. Dredging channels and creating new areas at the upper reach of the project have been beneficial. Tidal delay between Sonoma Creek and the Upper Lagoon has decreased since 1999 while sediment accumulation has increased. However, as the marsh plain develops, channels between the Lower and Upper Lagoons may become constricted and require dredging or connection to historic channels or nearby tidal marshes to improve tidal flushing.

(2) Restore tidal marsh habitat to two former farm fields (now the Upper Lagoon and Mid Channel). -- There has been a noticeable increase in sediment accumulation along the southwestern edge of the Upper Lagoon in just the past two years along with colonization of *Spartina foliosa* (Fig. 13). Similarly, *S. foliosa* has colonized the Mid Channel and sediment is accumulating rapidly along the northeastern corner (Fig. 14).

Circular clumps of *S. foliosa* have colonized in the Lower Lagoon; however, annual sediment accumulation data indicates that the rate of accumulation for most sediment pins in the Lower Lagoon has decreased since 2002 (Fig. 13). A similar pattern has been observed in the Upper Lagoon with lower accumulation rates in 2004 (Fig. 13). This trend observed in both lagoons may indicate that sediment levels are stabilizing in Tolay Creek, especially in the Lower Lagoon. Future monitoring is necessary to determine if this trend will continue and if gradual sediment accumulation will still facilitate vegetation colonization.

(3) Enhance existing tidal marsh habitat in the Tolay Creek flood plain south of Highway 37. -- We found improvements in the existing tidal marsh habitat with increased pickleweed cover and density. Average height of pickleweed has slightly decreased from 55 to 53cm post-breach, but other native species such as *Baccharis pilularis* and *Frankenia salina* have increased in average height. Many of the exotic invasive species were removed through inundation, and their numbers have steadily declined since restoration in 1998. However, a few invasives such as perennial pepperweed remain. We found an increase in relative percent cover of pickleweed in the marsh plain near the Mouth, Lower Lagoon and in the channels below the Mid Channel and Upper Lagoon. Near the Lower Lagoon, improved drainage has resulted in less inundated areas of dead pickleweed. *S. foliosa* has colonized the Upper and Lower Lagoons and gentle-sloped banks along the Mid Channel.

4) Restore the property in a manner that will require minimal maintenance.-- Significant maintenance was initially required to strengthen the levees surrounding Tolay Creek. However, as the tidal marsh plain has risen and channels developed, less maintenance has been required. Along the Upper Lagoon, a deeper area of water along the fetch (Fig. 14, southwest of the parking lot) may result in higher energy waves and still poses a threat of continued erosion. Levee repairs were recently conducted at this location on the Upper Lagoon. Although marsh development may be very slow, the Upper Lagoon is likely critical in maintaining the tidal prism in the project.

(5) Create habitat that minimizes mosquito production.-- The cracked sediments in the Upper Lagoon and Mid Channel were eliminated with disking and inundation in 1998. Areas surrounding the Lower Lagoon have improved in tidal flow, which has reduced breeding habitat for mosquitoes, decreasing control efforts.

(6) Monitor and evaluate the results for its effects on endangered species.-- Our monitoring showed immediate increases in salt marsh harvest mice post-breach in 1999,

but wide seasonal variation. In post-breach seasonal surveys, salt marsh harvest mice populations generally increased, although they showed wide annual variation with higher numbers from 1999-2001 and lower numbers from 2002-2004. Similarly, San Pablo song sparrow numbers also showed annual variation, with increased numbers in 1999-2001, decreases in 2002, and increased numbers in 2003 and 2004. We have had consistent detections of the California black rail since 1999 (post-breach) and the first detection of a California clapper rail in 2002, suggesting that habitats in the Mouth have improved for these species. Population trends of endangered species will be more easily determined with more years of data, but the limited trend data highlights the importance of conducting surveys well-before projects are completed, to develop a baseline for comparison. We continue to monitor trends in state and federally listed species (and others) in relation to habitat so that we can better understand their requirements.

MANAGEMENT RECOMMENDATIONS

The Tolay Creek restoration project remains a valuable model to learn about processes in restoration management. There are few restoration projects in this area that include a continuous dataset started before construction was completed. Thus, it would be valuable to continue comprehensive monitoring to study long-term ecological processes. Our management recommendations for monitoring include continuing water level, sedimentation rate, and levee erosion physical measurements to determine if corrective actions would improve marsh development, and to relate these findings to results from biological surveys to determine how biota are responding to the restoration project.

Our monitoring and evaluation detected constrictions, such as tidal delay and potential sediment stabilization, to the tidal prism of the Upper Lagoon. However, due to the linear shape of the Tolay Creek parcel, tidal delay is expected in the Upper Lagoon and further monitoring is necessary to determine if sediment levels are stabilizing. If this proves to be the case, future action may be necessary to prevent the lower reaches of Tolay Creek from restricting tidal flow and suspended sediments to the Upper Lagoon. We suggest an assessment to maintain and increase the tidal prism in the Upper Lagoon, including modeling the effects of connecting Tolay Creek to Sonoma Creek north of Highway 37.

Another option may be to collaborate with the Sonoma Land Trust, who are planning to restore tidal marsh to 405 ha (North Point and Dickson) south of the old Southern Pacific and Northwestern Pacific railroad as part of the Sears Point Restoration Project (acquired in January 2005). Restoration on this land, which is west of the Tolay Creek Restoration Project, is scheduled to begin in approximately 5 years. Opening Tolay Creek to tidal flushing on both ends may improve tidal flushing and sedimentation dynamics as well as increase habitat types for a variety of wildlife. Additionally, to decrease erosion and promote sediment accretion and marsh plain development in the Upper Lagoon we suggest installing wave buffers along the east levee.

Sixty restoration projects are ongoing or proposed for the North Bay, and Tolay Creek may provide a monitoring model for other restoration projects in the region (Siegel 1998). Monitoring funding should be continued for this effort and built into future projects as an integral component of the design (Block et al. 2001).

FUTURE RESEARCH

Our USGS study plan (USGS 2002) includes continued monitoring through the next 2 years. We are improving measurements of tidal levels and sedimentation rates to reference them with elevation benchmarks. We continue to evaluate additional monitoring parameters such as soil composition, organic matter, and salinity and channel length and cross-sections (Zedler 2001).

In the July 2003, a culvert was replaced that connected the southeast corner of the Lower Lagoon and Tubbs Island. We will develop monitoring protocols to evaluate how this connection is affecting both the Tolay Creek restoration project and Tubbs Island. A water level datalogger has already been installed (Fall 2003) in the large marsh pond running west to east on the northern portion of the island. We will also examine benefits of tidal marsh restoration results at the Tolay Creek Restoration Project in light of regional habitat goals, including proposed conversion of salt evaporation ponds in the estuary.

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Table 1. Biophysical monitoring completed from 2002-2004.

Survey	Number samples	Frequency required	2002	2003	2004
Vegetation	9 transects Mapping (based off Fall aerial photos)	Annual Biennial	Spring, Summer	Spring, Summer	Summer December
Birds	Area survey (High and Low Tide) 9 point counts	Quarterly Bi-annual	Quarterly Quarterly	Quarterly Quarterly	Spring, Summer, Oct., Nov., Dec. Quarterly
Fish	Variable	Annual	Spring, Fall	Summer, Fall	Summer, Fall
Small Mammals	8 grids	Annual	Summer, Fall	Summer, Fall	Spring
Invertebrates	12 samples	Every 4 years			Fall
Water Levels	2 loggers	Continuous	Continuous	Continuous	Continuous
Sediment Pins	12 pins	Bi-annual	Quarterly (29 pins)	Quarterly (30 pins)	Quarterly (30 pins)
Water Quality	2 locations (based off loggers)	Not required	Fall		Spring, Summer, Fall
Photographs	14 locations	Not required	Winter, Summer	Spring, Summer, Fall	Fall

Table 2. List of plant species, species code, native and invasive status for pre-breach (September 1998) and post-breach (1999-2004) surveys.

Common Name	**Scientific Name**	**Code**	**Native**	**Invasive** *	**Pre-breach**	**Post-breach**
Alkali heath	*Frankenia salina*	FRSA	Y	N	X	X
American bulrush	*Scirpus americanus*	SCAM	Y	N		X
Australian saltbush	*Atriplex semibaccata*	ATSE	N	Y		X
Beeplant	*Scrophularia californica*	SCCA2	Y	N		X
Bentgrass	*Agrostis avenacea*	AGAV	N	N	X	
Birdfoot trefoil	*Lotus corniculatus*	LOCO	N	N		X
Brass buttons	*Cotula coronipifolia*	COCO	N	N		X
California bulrush	*Scirpus californicus*	SCCA1	Y	N		X
Coast fiddlehead	*Amsinckia menziesii*	AMME	Y	N		X
Common pickleweed	*Salicornia virginica*	SAVI	Y	N	X	X
Common sowthistle	*Sonchos oleraceus*	SOOL	Y	N		X
Common wild radish	*Raphanus sativus*	RASA	N	N		X
Common yarrow	*Achillea millefolium*	ACMI	Y	N		X
Cordgrass	*Spartina foliosa*	SPFO	Y	N		X
Coyotebush	*Baccharis pilularis*	BAPI	Y	N	X	X
Cudweed	*Gnaphalium stramineum*	GNST	Y	N		X
Curly dock	*Rumex crispus*	RUCR	N	N	X	
Ditch grass	*Ruppia maritima*	RUMA	Y	N		X
Dodder	*Cuscuta salina*	CUSA	Y	N		X
European pickleweed	*Salicornia europa*	SAEU	Y	N		X
Fat hen	*Atriplex triangularis*	ATTR	Y	N	X	X
Fleshy jaumea	*Jaumea carnosa*	JACA	Y	N	X	X
Gum plant	*Grindelia stricta*	GRST	Y	N	X	X
Italian rye grass	*Lolium multiflorum*	LOMU	N	Y		X
Mediterranean barley	*Hordeum marinum*	HOMA	N	N		X
Milk Thistle	*Silybum marianum*	SIMA	N	N		X
New Zealand Spinach	*Tetragonia tetragonioides*	TETE	N	N		X
Perennial pepperweed	*Lepidium latifolium*	LELA	N	Y	X	X
Perennial rye grass	*Lolium perenne*	LOPE	N	N	X	
Prickly lettuce	*Lactuca serriola*	LASE	N	N	X	
Prostrate knotweed	*Polygonum arenastrum*	POAR	N	N	X	
Purple star-thistle	*Centaurea calcitrapa*	CECA	N	Y		X
Rabbitfoot beardgrass	*Polypogon monspeliensis*	POMO	N	N	X	
Ripgut brome	*Bromus diandrus*	BRDI	N	Y		X
Salt grass	*Distichlis spicata*	DISP	Y	N		X
Saltmarsh bulrush	*Scirpus maritimus*	SCMA	Y	N		X
Sand spurry	*Spergularia rubra*	SPRU	Y	N		X
Sea lavender	*Limonium californicum*	LICA	Y	N		X
Sea milkwort	*Glaux maritima*	GLMA	Y	N		X
Soft chess	*Bromus hordeaceous*	BRHO	N	N		X

Common Name	**Scientific Name**	**Code**	**Native**	**Invasive** *	**Pre-breach**	**Post-breach**
Wild oats	*Avena fatua*	AVFA	N	N		X
Wild turnip	*Brassica rapa*	BRRA	N	N		X
Yellow Starthistle	*Centaurea solstitialis*	CESO	N	Y	X	
Areas without plants	*Bare*	BARE				
Dead plants	*Litter*	LITR				
Inundated with water	*Open Water*	OPWA				

* Invasive status follows the guidelines of the California Exotic Pest Plant Council

Table 3. List of fish species and location for the surveys conducted annually from 1999-2003 (* indicates non-native species).

		1999		2002		2003	
Common Name	**Scientific Name**	**Upper Lagoon N=3**	**Lower Lagoon N=5**	**Upper Lagoon N=4**	**Lower Lagoon N=4**	**Upper Lagoon N=4**	**Lower Lagoon N=4**
American shad*	*Alosa sapidissima*					X	X
Arrow goby	*Clevelandia ios*				X	X	X
Bay goby	*Lepidogobius lepidus*			X	X		
Bay pipefish	*Syngnathus leptorhynchus*			X		X	X
Chinese mitten crab*	*Eriocheir sinensis*					X	
Crangon spp.	*Crangon spp.*			X	X	X	X
Green crab	*Carcinus maenas*					X	
Hemigrapsus sp.	*Hemigrapsus sp.*			X	X	X	X
Inland silverside*	*Menidia beryllina*	X	X				
Mosquito fish*	*Gambusia afinis*	X	X				
Pacific herring	*Clupea pallasi*			X			
Pacific staghorn sculpin	*Leptocottus armatus*	X	X	X	X		X
Palaemon sp.	*Palaemon sp.*			X	X	X	X
Prickly sculpin	*Cottus asper*					X	X
Rainwater killifish*	*Lucania parvu*			X		X	X
Shimofuri goby*	*Tridentiger bifasciatus*					X	
Speckled sanddab	*Citharichthys stigmaeus*			X			
Starry flounder	*Platichthys stellatus*						X
Striped bass*	*Morone saxatilus*	X	X	X		X	X
Threespine stickleback	*Gasterosteus aculeatus*	X	X	X		X	X
Topsmelt	*Atherinops afinis*			X	X	X	X
Wakasagi Goby*	*Hypomesus nipponensis*					X	
Yellowfin goby*	*Acanthogobius flavimanus*	X	X	X	X	X	X

Table 4. List of bird species observed in pre-breach (1998) and post-breach (1999-2004) surveys from area and point count survey methods.

				Survey Method	
Common Name	**Scientific Name**	**Pre-breach**	**Post-breach**	**Area Count**	**Point Count**
American avocet	*Recurvirostra americana*	X	X	X	X
American bittern	*Botaurus lentiginosus*		X		X
American coot	*Fulica americana*	X	X	X	X
American crow	*Corvus brachyrhynchos*		X		X
American goldfinch	*Carduelis tristis*		X	X	X
American kestrel	*Falco sparverius*	X	X	X	
American white pelican	*Pelecanus occidentalis*	X	X	X	
American widgeon	*Anas americana*	X		X	
Barn swallow	*Hirundo rustica*		X	X	X
Black phoebe	*Sayornis nigricans*	X		X	X
Black tern	*Chlidonias nigra*		X	X	
Black-bellied plover	*Pluvialis squatarola*		X	X	
Black-crowned night heron	*Nycticorax nycticorax*	X	X	X	
Black-necked Stilt	*Himantopus mexicanus*	X	X	X	X
Bonaparte's gull	*Larus philadelphia*		X	X	
Brewer's blackbird	*Euphagus cyanocephalus*	X	X		X
Brown-headed cowbird	*Molothrus ater*	X		X	
Bufflehead	*Bucephala albeola*		X	X	X
California black rail	*Laterallus jamaicensis coturniculus*		X	X	X
California clapper rail	*Rallus longirostris obsoletus*		X		X
California gull	*Larus californicus*	X	X	X	X
Canada goose	*Branta canadensis*		X	X	X
Canvasback	*Aythya valisineria*		X	X	X
Caspian tern	*Sterna caspia*		X	X	X
Cinnamon teal	*Anas cyanoptera*		X	X	X
Clark's grebe	*Aechmophorus clarkii*	X	X	X	X
Cliff swallow	*Petrochelidon pyrrhonota*		X	X	X
Common goldeneye	*Bucephala clangula*		X	X	X
Common raven	*Corvus cryptoleucus*	X		X	X
Common snipe	*Gallinago gallinago*	X	X	X	X
Common yellowthroat	*Geothlypis trichas*	X	X	X	X
Cooper's Hawk	*Accipiter cooperii*		X	X	
Double-crested cormorant	*Phalacrocorax auritus*	X	X	X	X
Dowitcher	*Limnodromus spp.*		X	X	
Dunlin	*Calidris alpina*		X	X	X

Table 4. Continued.

Common Name	Scientific Name	Pre-breach	Post-breach	Survey Method: Area Count	Survey Method: Point Count
Eared grebe	*Podiceps nigricollis*		X	X	
European starling	*Sturnus vulgaris*		X		X
Forster's tern	*Sterna forsteri*		X	X	X
Gadwall	*Anas strepera*		X	X	X
Golden-crowned sparrow	*Zonotrichia albicollis*		X		X
Great blue heron	*Ardea herodias*		X	X	X
Great egret	*Ardea alba*	X	X	X	X
Greater scaup	*Aythya marila*		X	X	
Greater yellowlegs	*Tringa melanoleuca*		X	X	X
Green-winged teal	*Anas crecca*		X	X	X
Heermann's gull	*Larus heermanni*		X	X	
Herring gull	*Larus argentatus*		X	X	
Horned grebe	*Podiceps auritus*	X	X	X	
Horned lark	*Eremophila alpestris*		X	X	
House finch	*Carpodacus mexicanus*		X	X	X
Killdeer	*Charadrius vociferus*	X	X	X	X
Least sandpiper	*Calidris minutilla*		X	X	X
Least tern	*Sterna antillarum*		X	X	
Lesser golden-plover	*Pluvialis dominica*		X		X
Lesser scaup	*Aythya affinis*		X	X	
Lesser yellowlegs	*Tringa flavipes*		X	X	
Long-billed curlew	*Numenius americanus*	X	X	X	X
Long-billed dowitcher	*Limnodromus scolopaceus*		X	X	X
Mallard	*Anas platyrhynchos*	X	X	X	X
Marbled godwit	*Limosa fedoa*		X	X	X
Marsh wren	*Cistothorus palustris*	X	X	X	X
Mourning dove	*Zenaida macroura*	X	X	X	X
Northern flicker	*Colaptes auratus*	X		X	
Northern harrier	*Circus cyaneus*	X	X	X	X
Northern pintail	*Anas acuta*	X	X	X	X
Northern rough-winged swallow	*Stelgidopteryx serripennis*		X		X
Northern shoveler	*Anas clypeata*		X	X	X
Peregrine falcon	*Falco peregrinus*	X	X		X
Pied-billed grebe	*Podilymbus podiceps*	X	X	X	X
Red knot	*Calidris canutus*		X	X	
Redhead	*Aythya americana*		X	X	
Red-necked phalarope	*Phalaropus lobatus*	X	X	X	X

Table 4. Continued.

Common Name	Scientific Name	Pre-breach	Post-breach	Survey Method Area Count	 Point Count
Red-tailed hawk	*Buteo jamaicensis*	X	X	X	X
Red-winged blackbird	*Agelaius phoeniceus*	X	X	X	X
Ring-billed gull	*Larus delawarensis*	X	X	X	X
Ring-necked pheasant	*Phasianus colchicus*		X	X	
Rough-legged hawk	*Buteo lagopus*		X	X	
Ruddy duck	*Oxyura jamaicensis*	X	X	X	X
San Pablo song sparrow	*Melospiza melodia samuelis*	X	X	X	X
Sanderling	*Calidris alba*		X	X	
Savannah sparrow	*Passerculus sandwichensis*	X	X	X	X
Say's Phoebe	*Sayornis saya*		X	X	
Semipalmated plover	*Charadrius semipalmatus*		X	X	
Short-billed dowitcher	*Limnodromus griseus*		X	X	
Short-eared owl	*Asio flammeus*		X	X	
Snowy egret	*Egretta thula*	X	X	X	X
Sora	*Porzana carolina*	X			X
Turkey vulture	*Cathartes aura*	X	X	X	X
Violet-green swallow	*Tachycineta thalassina*	X	X	X	X
Western grebe	*Aechmophorus occidentalis*		X	X	X
Western gull	*Larus occidentalis*		X	X	X
Western meadowlark	*Sturnella neglecta*	X	X	X	X
Western sandpiper	*Calidris mauri*		X	X	X
Whimbrel	*Numenius phaeopus*		X	X	X
White-crowned sparrow	*Zonotrichia leucophrys*	X	X	X	X
White-tailed kite	*Elanus leucurus*	X	X	X	X
Willet	*Catoptrophorus semipalmatus*	X	X	X	X

Table 5. List of occurrences of rail species detected during point count surveys at Tolay Creek.

Common Name	Scientific Name	Month Year	Point	Number
California black rail	*Laterallus jamaicensis coturniculus*	June-99	1	1
California black rail	*Laterallus jamaicensis coturniculus*	June-99	2	1
California black rail	*Laterallus jamaicensis coturniculus*	June-99	4	1
California black rail	*Laterallus jamaicensis coturniculus*	March-00	1	1
California black rail	*Laterallus jamaicensis coturniculus*	March-00	2	1
California black rail	*Laterallus jamaicensis coturniculus*	March-00	4	2
California black rail	*Laterallus jamaicensis coturniculus*	October-01	3	1
California black rail	*Laterallus jamaicensis coturniculus*	February-02	3	1
California clapper rail	*Rallus longirostris obsoletus*	April-02	1	1
California black rail	*Laterallus jamaicensis coturniculus*	July-02	1	1
California black rail	*Laterallus jamaicensis coturniculus*	July-02	2	1
California black rail	*Laterallus jamaicensis coturniculus*	October-03	3	1
California black rail	*Laterallus jamaicensis coturniculus*	March-04	2	1
California black rail	*Laterallus jamaicensis coturniculus*	May-04	2	1
California black rail	*Laterallus jamaicensis coturniculus*	July-04	1	1
California black rail	*Laterallus jamaicensis coturniculus*	October-04	1	1

Table 6. List of small mammal species found at Tolay Creek during pre- and post-breach surveys.

Common name	**Scientific name**	**Pre-breach**	**Post-breach**
Salt marsh harvest mouse	*Reithrodontomys raviventris*	X	X
Western harvest mouse	*Reithrodontomys megalotis*	X	X
Deer mouse	*Peromyscus maniculatus*	X	X
California vole	*Microtus californicus*	X	X
Shrew [1]	*Sorex* spp.		X
House mouse	*Mus musculus*	X	X
Norway rat	*Rattus norvegicus*		X

[1] *Sorex ornatus* or *Sorex vagrans*

Figure 1. Comparison of Tolay Creek hydrogeomorphology, September 1998 pre-breach (A), December 1998 post-breach (B) and September 2004 (C) color infrared aerial photographs. Four study areas within the Tolay Creek Restoration Project are indicated in the 2004 aerial (C) and include: the Mouth, Lower Lagoon, Mid Channel and Upper Lagoon. Note the widening of the lower channel and inundation in the upper section shown in the December 1998 aerial. The September 2004 aerial shows increased sedimentation in the Upper Lagoon and Mid Channel and scouring as Tolay Creek enters San Pablo Bay.

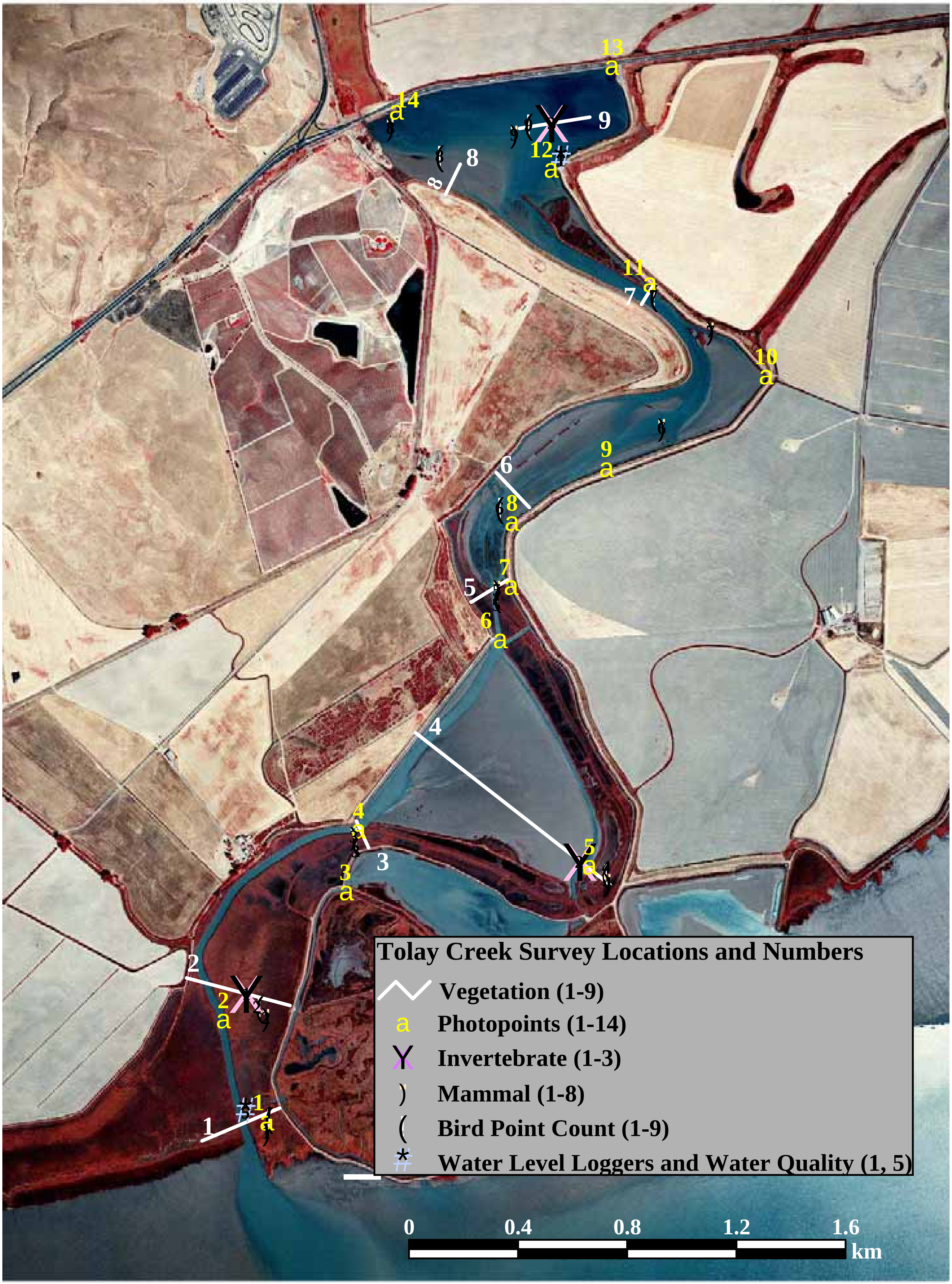


Figure 2. Location and number of vegetation sampling transects, photo points, invertebrate samples, mammal trapping grids, bird point counts, water level loggers and water quality locations at the Tolay Creek Restoration Project.

Figure 3. Location of benchmarks at Tolay Creek. Benchmarks were resurveyed in May 2003 by Shoreline Engineering. All GPS coordinates are recorded in NAD27 Zone 10 North. Several more benchmarks will be added and surveyed in 2005.

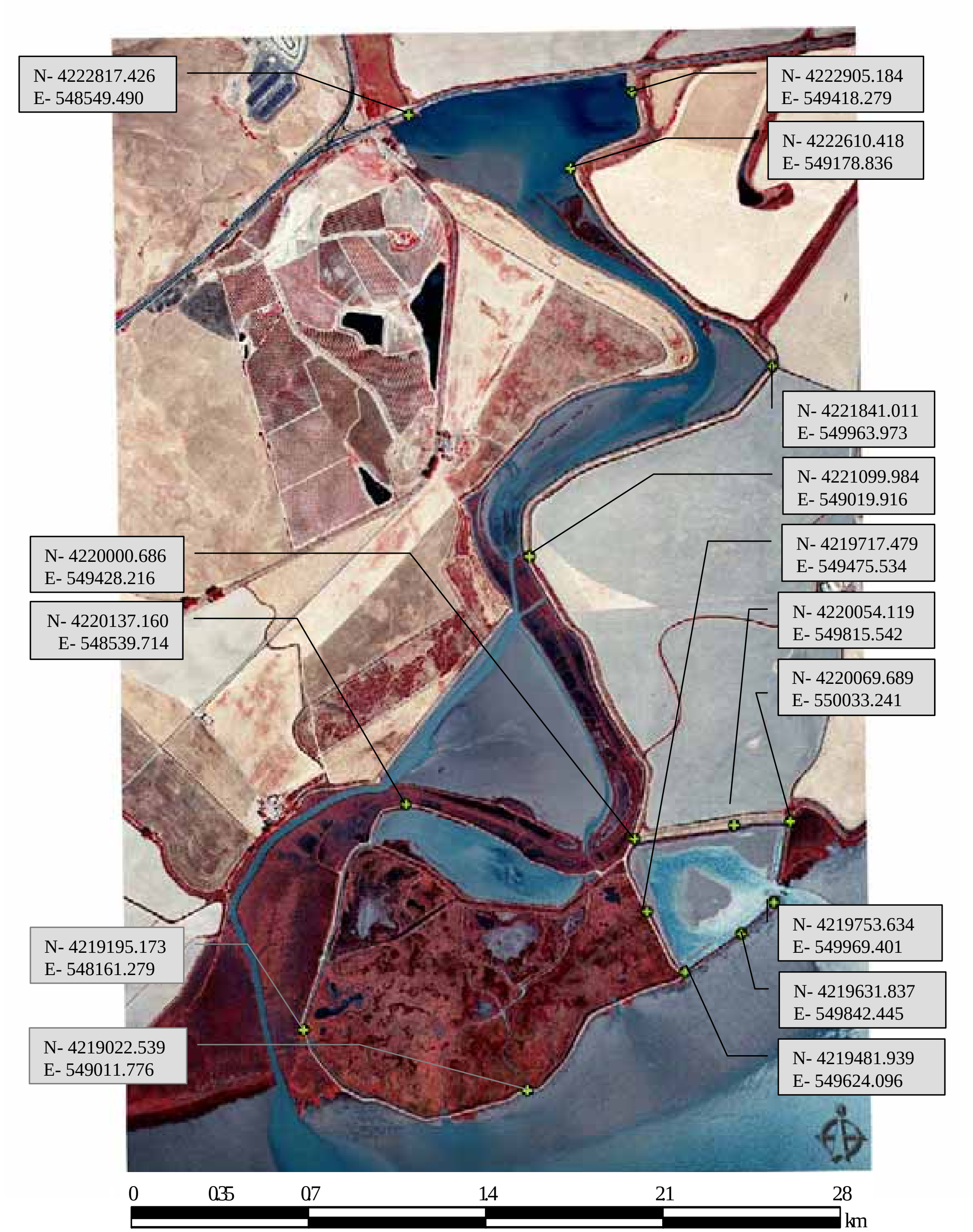
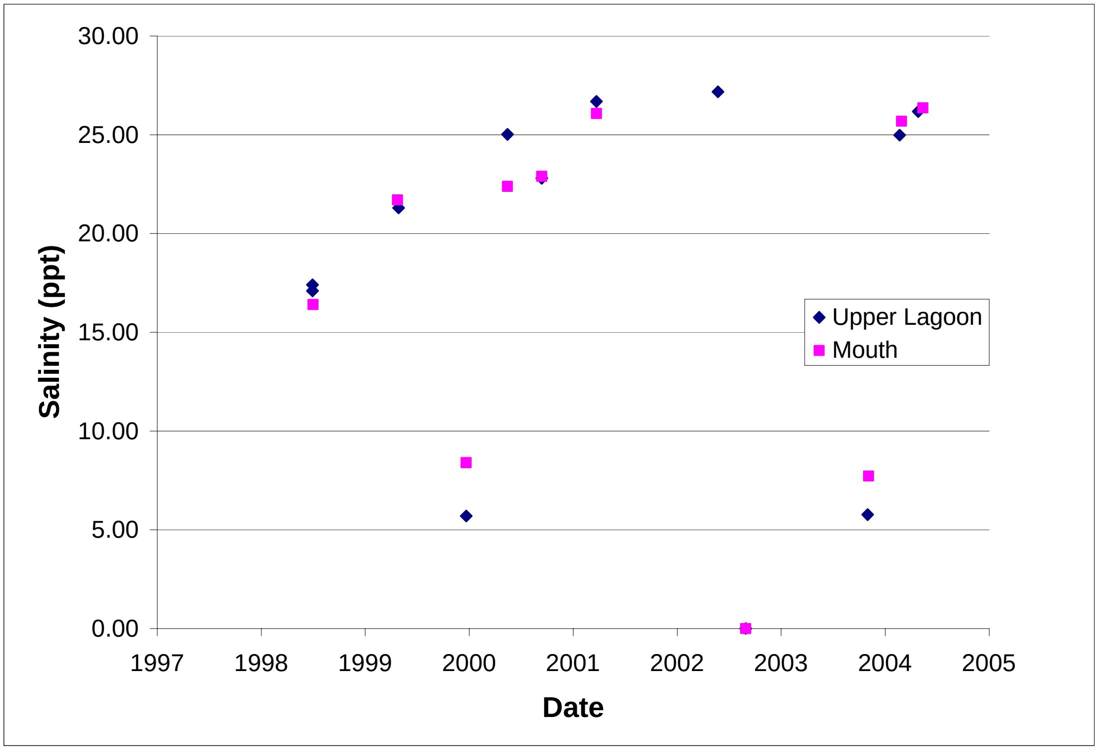


Figure 4. Location of control points at Tolay Creek. Control points were used to georectify the September 2004 aerial photo in ArcGIS. All GPS coordinates are recorded in NAD83 Zone 10 North.

a.



b.

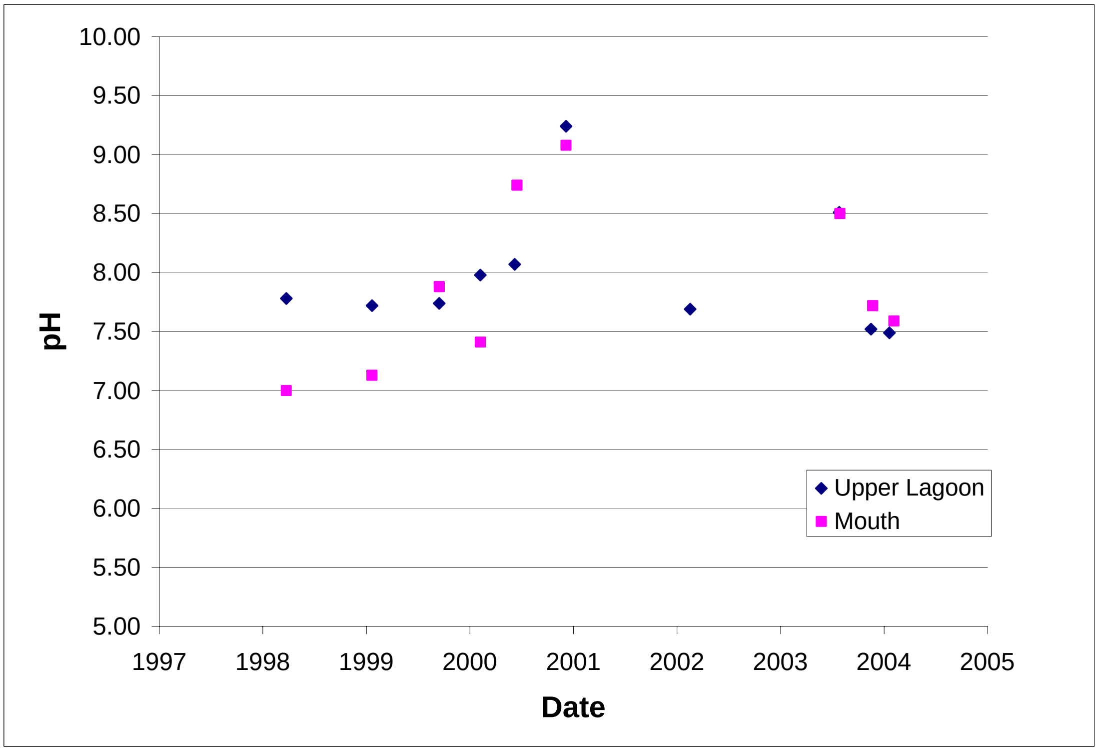
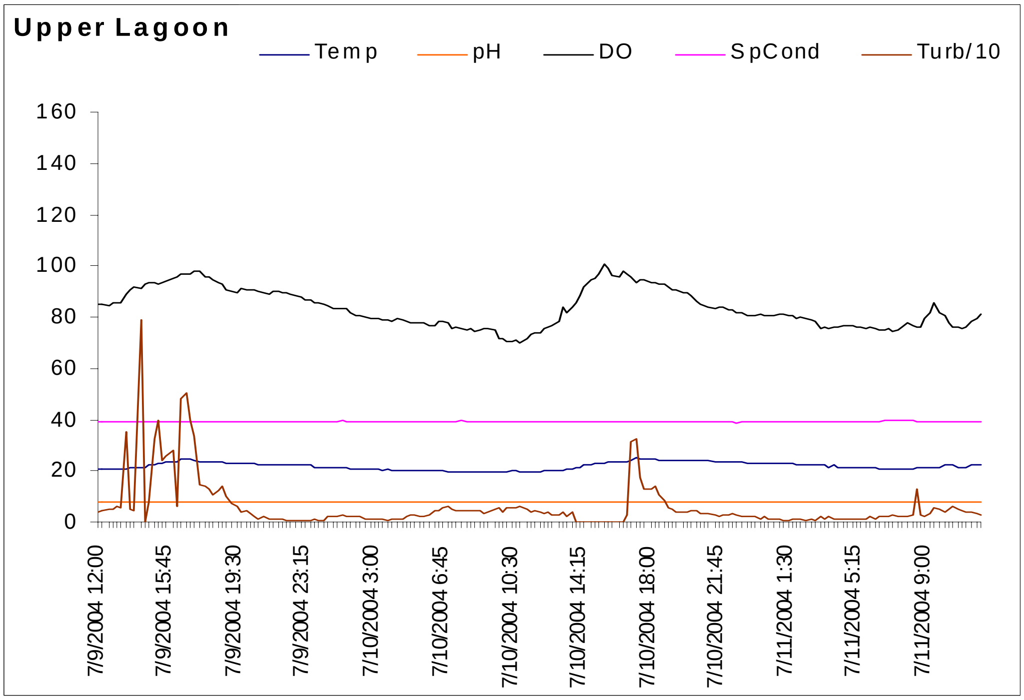


Figure 5. Salinity (a) and pH (b) measurements of the Upper Lagoon and Mouth of Tolay Creek. Prior to 2002, readings were taken as spot measurements on each respective date. From 2002 on, measurements represent the mean value from a 2-5 day continuous collection period. Water quality was not measured in 2003. Note that salinity is much lower in March of 2000 and 2004, likely influenced by rainfall.

a.



b.

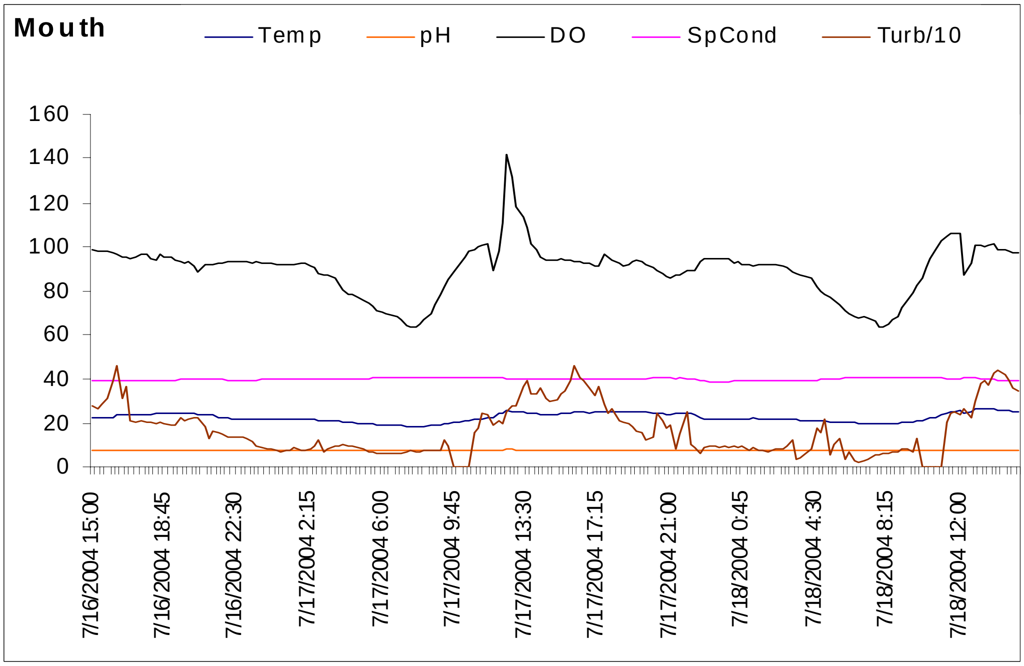
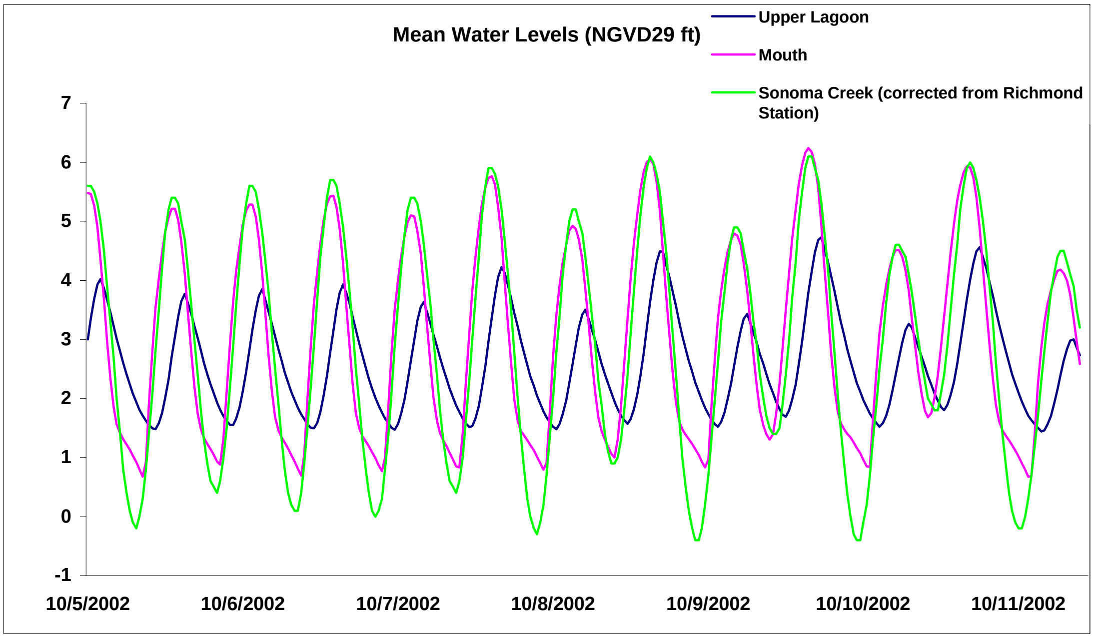


Figure 6. Water quality graphs from the Upper Lagoon (a) and Mouth (b) at Tolay Creek in July 2004. Water temperature (1°C), specific conductivity (0.01µS/cm), and pH (0.1 pH) remained relatively constant, while DO (% Saturation) and turbidity (10 NTU) varied by tide. Turbidity data was divided by 10 for comparison with other parameters.

a. Oct. 2002



b. May 2004

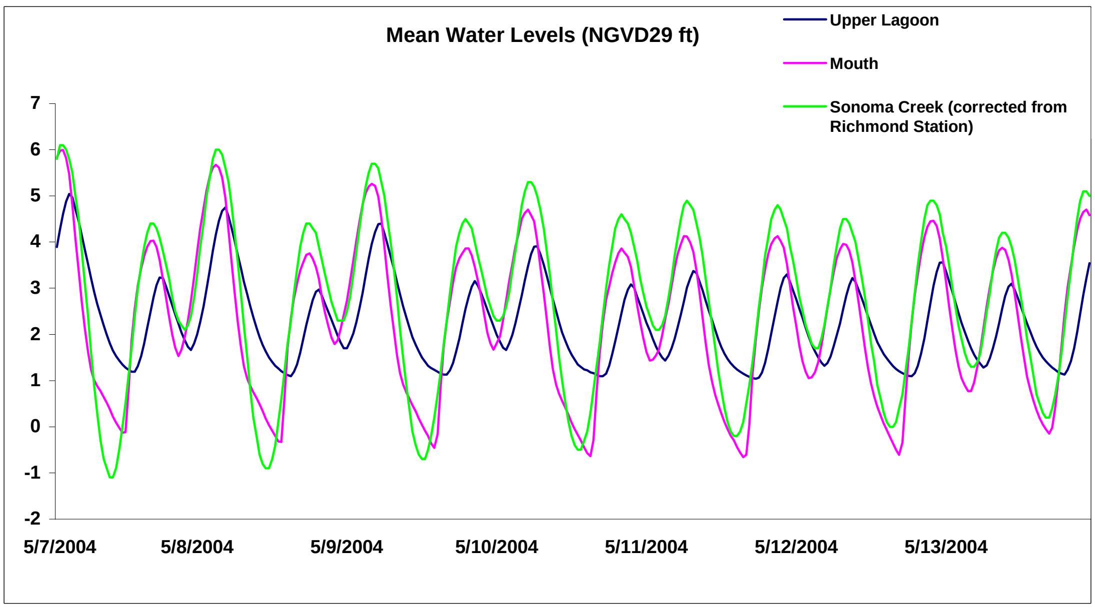
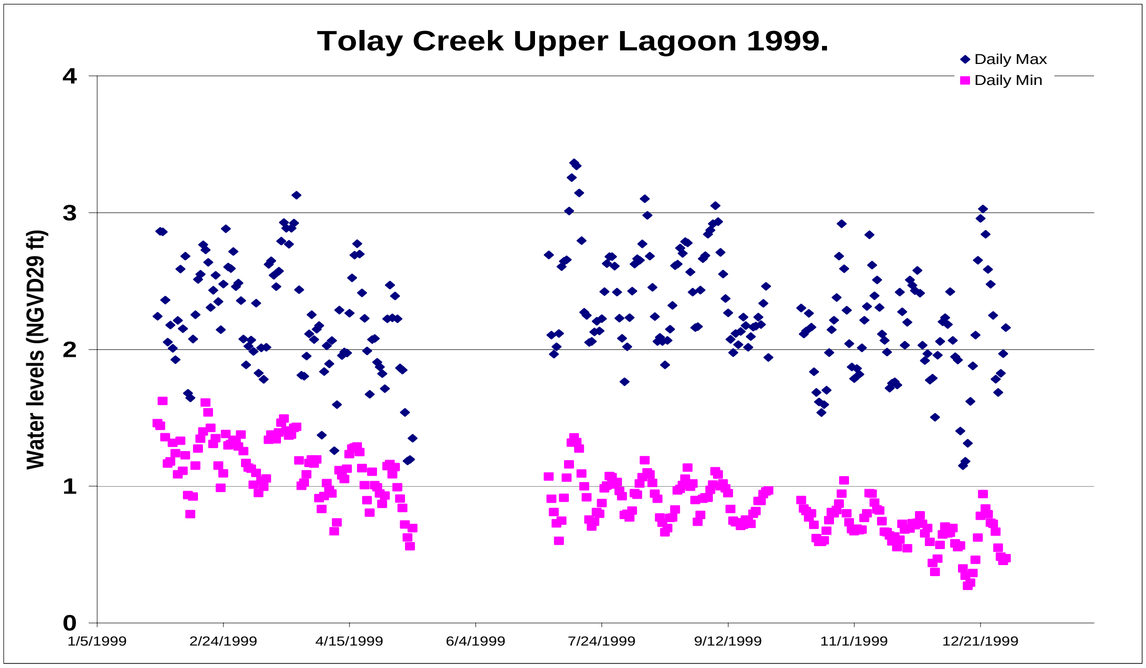


Figure 7. Mean water levels from October 2002 (a) and May 2004 (b). Due to its proximity to San Pablo Bay, water levels at the Mouth of Tolay Creek are more subject to tidal fluctuations than the Upper Lagoon. In 2002 and 2004 for both high and low tides there was an average 20-28 min tidal delay from Sonoma Creek to the Mouth. Average tidal delay between Sonoma Creek and the Upper Lagoon for high tides was roughly one hour for both years observed. However, the low tide delay between Sonoma Creek and the Upper Lagoon varied significantly between higher low and lower low tides in both years. In October 2002, delay for higher low tides averaged 1 hour and 50 minutes; in May 2004 this delay dropped to 1 hour. For both years tidal delay during lower low tides averaged 3 hours. This difference may be due to exposed mudflat slowing water drainage during lower low tides.

a. Daily minimum and maximum water levels at the Upper Lagoon of Tolay Creek in 1999.



b. Daily minimum and maximum water levels at the Mouth of Tolay Creek in 1999.

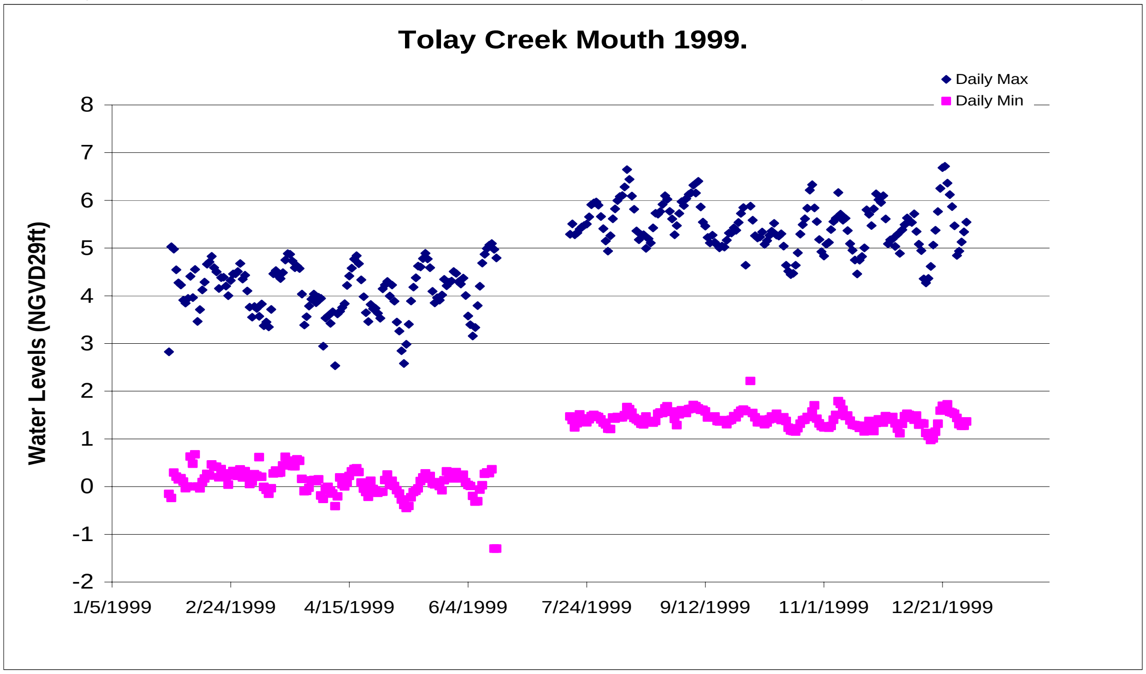
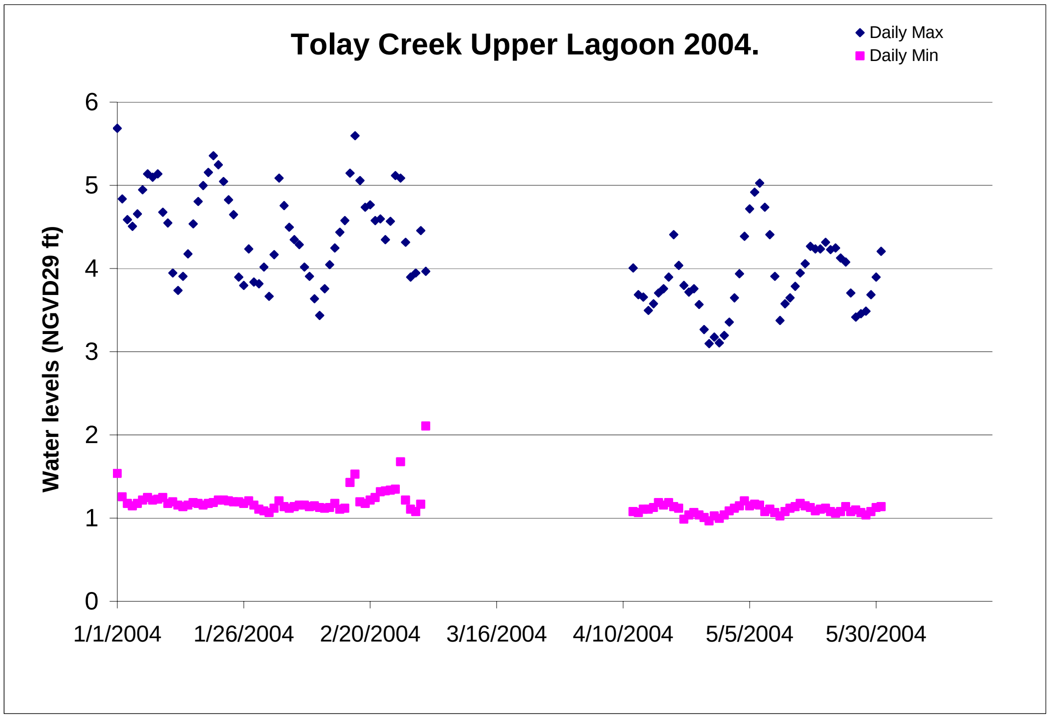


Fig 8. Daily minimum and maximum water levels (NGVD 29, feet) at the Upper Lagoon (a) and Mouth (b) of Tolay Creek in 1999. Daily minimum and maximum levels in the Mouth and Upper Lagoon fluctuated dramatically, possibly due to restoration of tidal activity. The Global datalogger at the Mouth was replaced by a Telog logger in July 1999; this explains the overall rise in water levels from June to July.

a. Daily minimum and maximum water levels at the Upper Lagoon of Tolay Creek from January to May of 2004.



b. Daily minimum and maximum water levels at the Mouth of Tolay Creek from January to May of 2004.

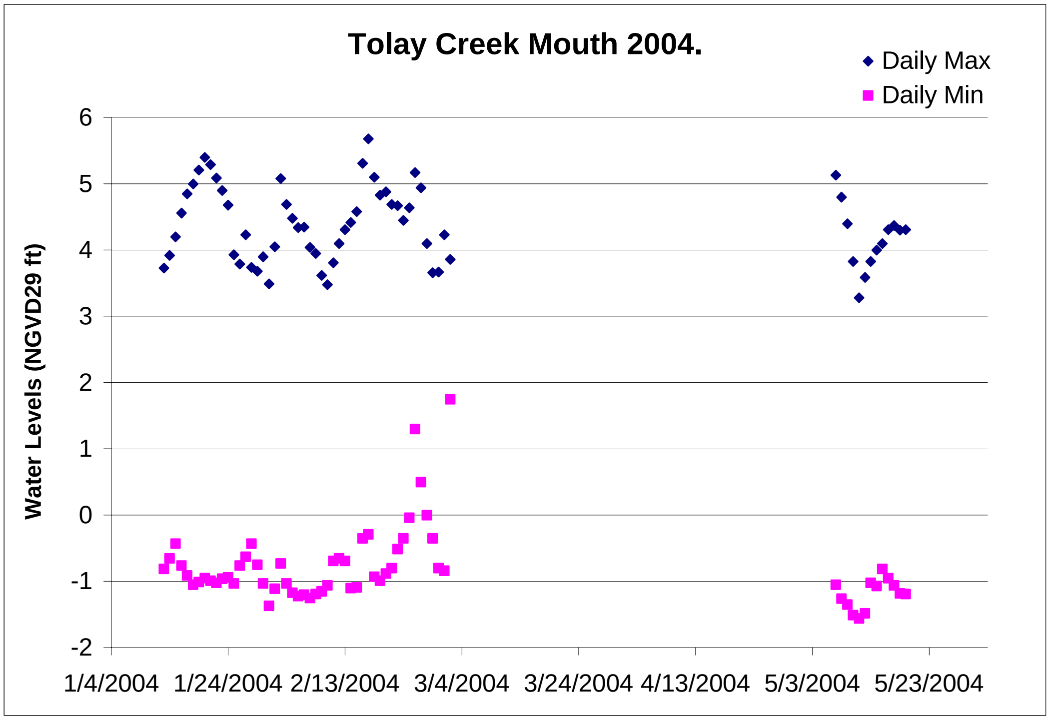


Fig 9. Daily minimum and maximum water levels (NGVD 29, feet) at the Upper Lagoon (a) and Mouth (b) of Tolay Creek from January to May of 2004. Fluctuations in water levels reflect tidal patterns.

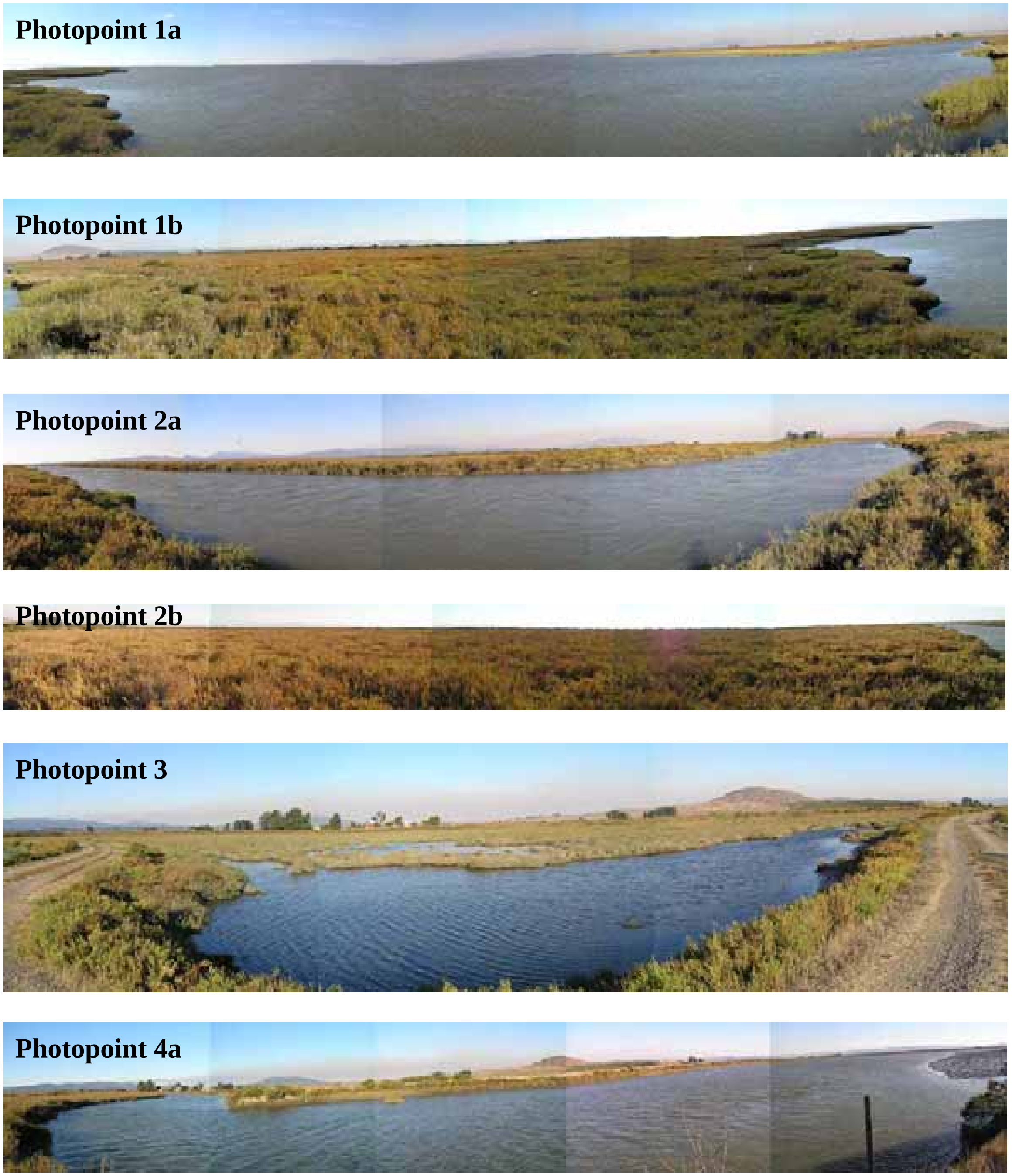


Figure 10. Panoramic views at photo points throughout the Tolay Creek project, October/November 2004.

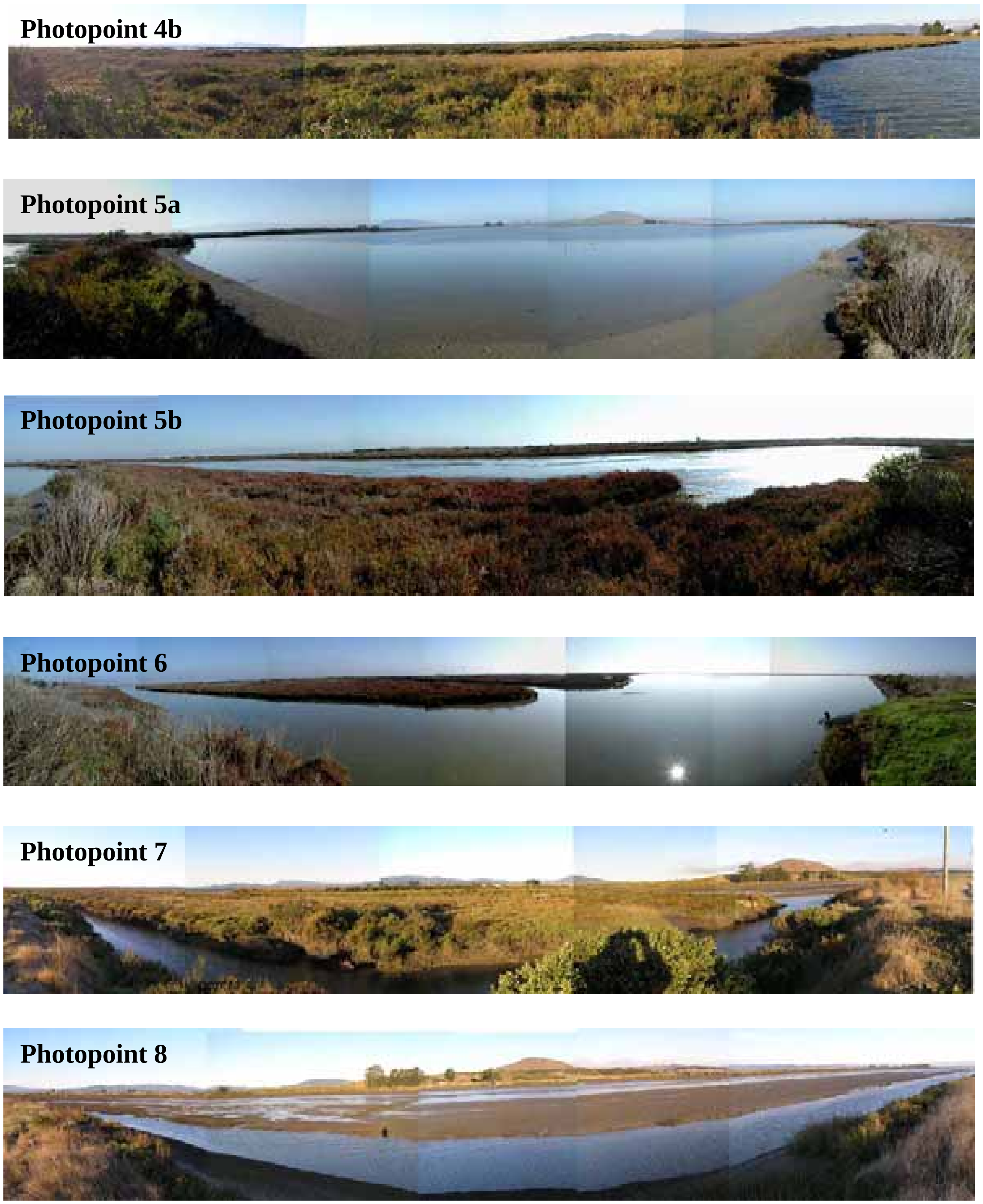
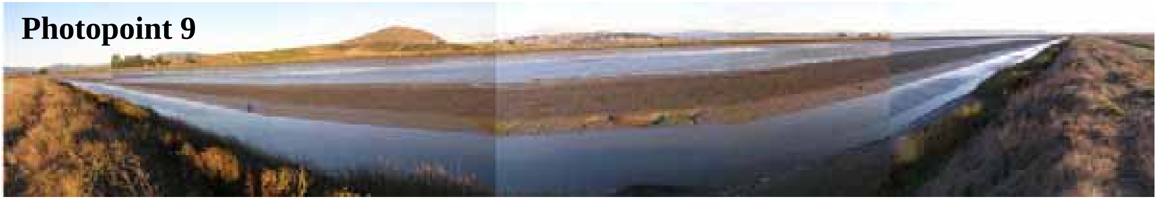
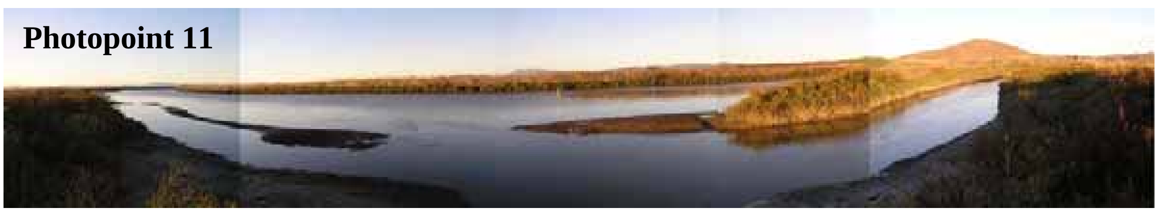


Figure 10. Continued.





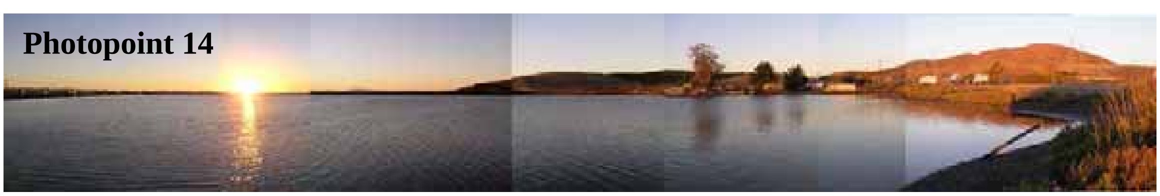


Figure 10. Continued.

a. 2000

b. 2002

c.2003

d. 2004

Figure 11. Comparison of panoramic views from photo point #5B in 2000 (a), 2002 (b), 2003 (c) and 2004 (b) (a photo was not taken in 2001) providing evidence of qualitative change. Here we document increased pickleweed cover from 2000 to 2004.

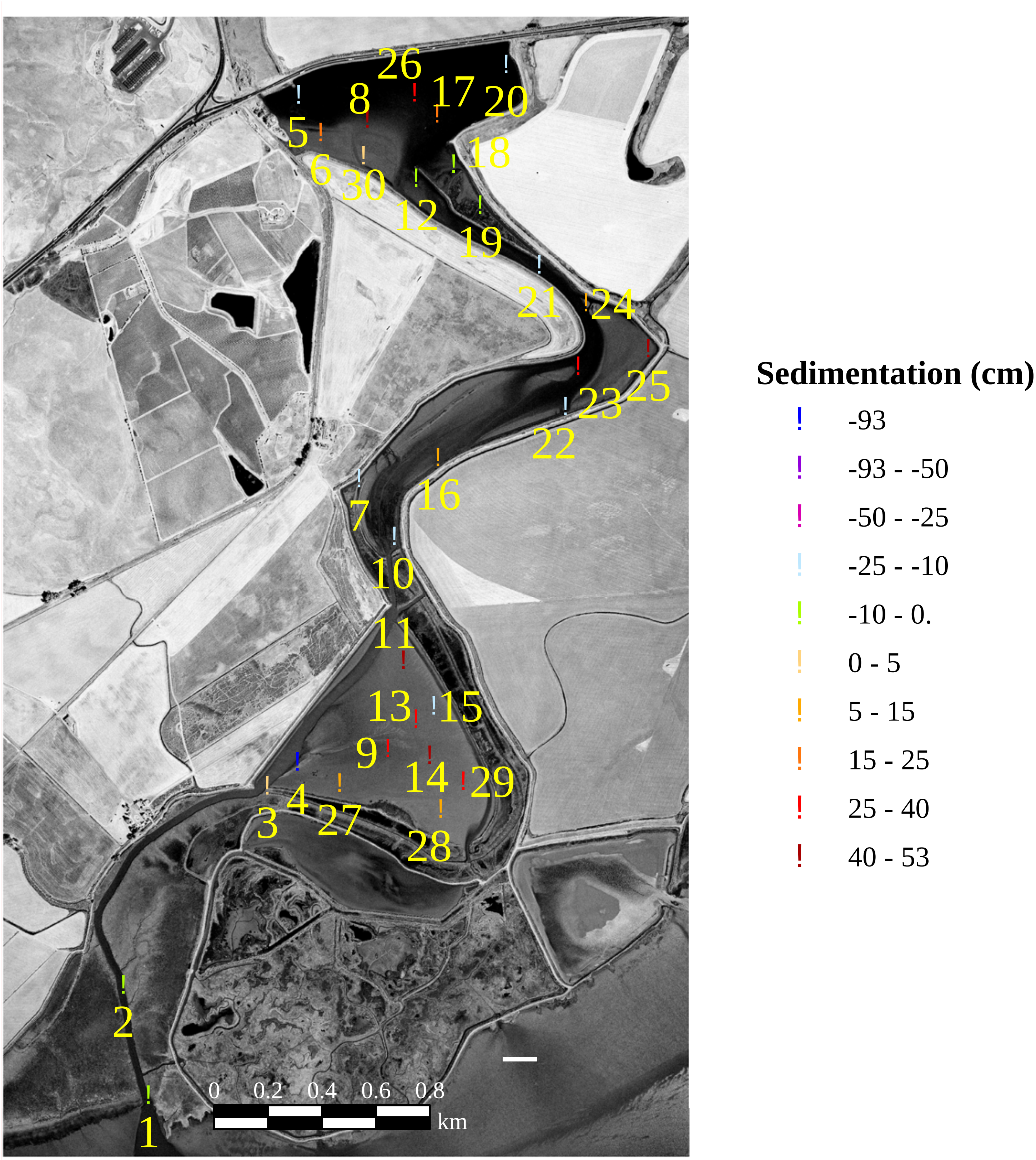
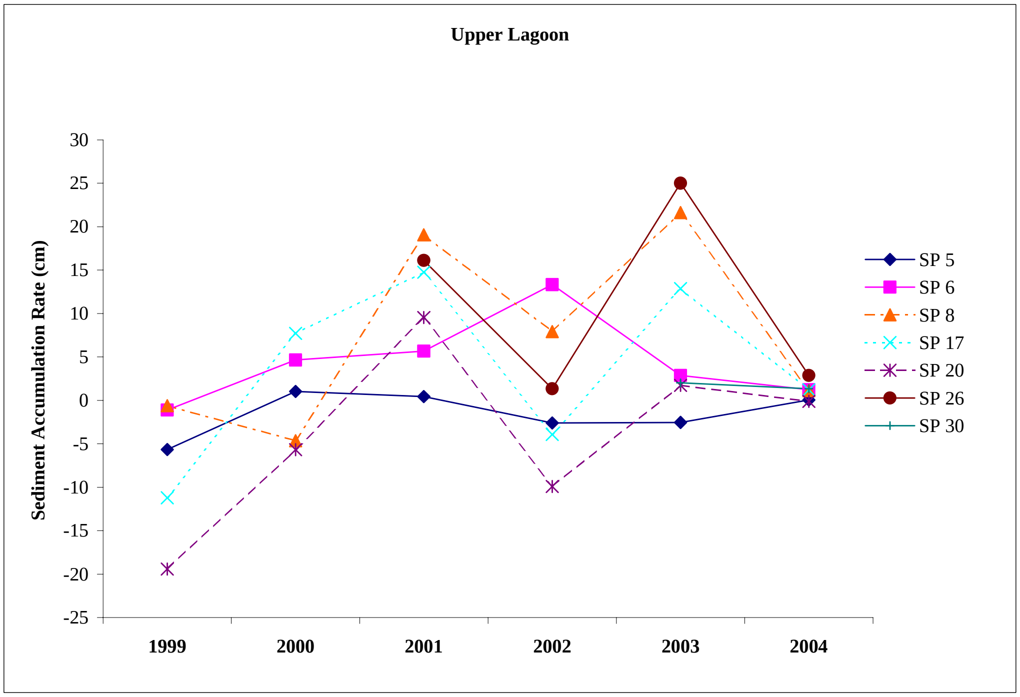


Figure 12. Overall sediment accumulation or loss (cm) throughout Tolay Creek from 1999 to 2004.

a. Upper Lagoon



b. Lower Lagoon

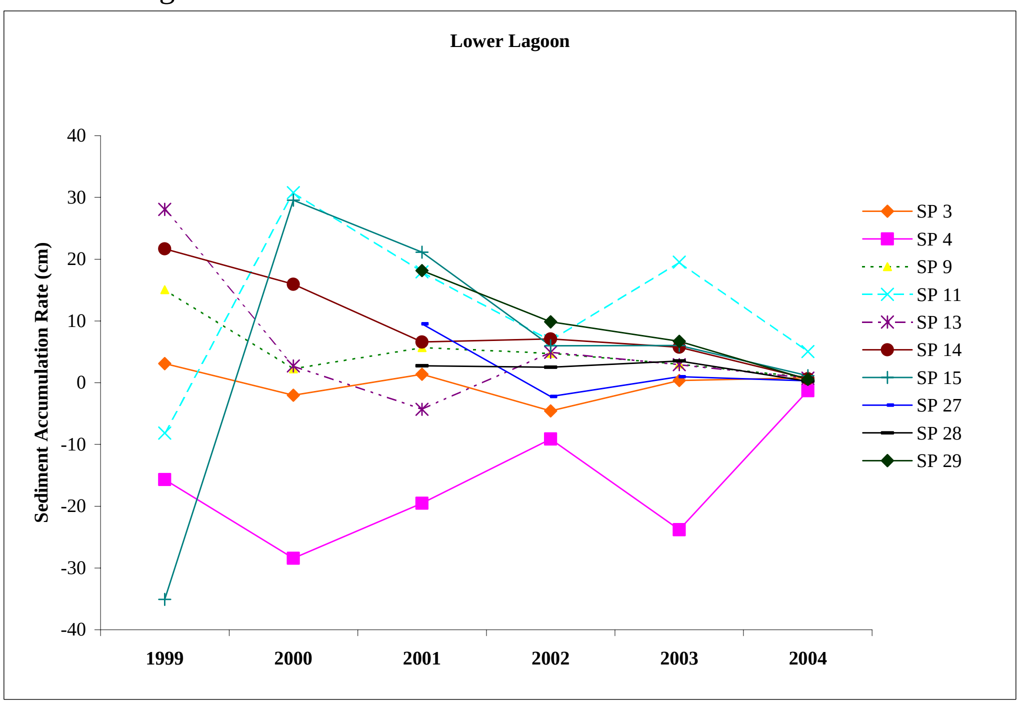


Figure 13. Annual sediment accumulation rate (mean daily accumulation (cm) x 365 days) for sediment pins in the Upper (a) and Lower (b) Lagoons. In the Upper Lagoon, four of the six sediment pins (8, 17, 20, 26) show similar annual variation of accumulation and loss between 2001to 2004, with all seven sediment pins recording almost no change in 2004. Initial sediment accumulation and loss in the Lower Lagoon was dramatic in 1999 and 2000, but has consistently evened out to almost no change in 2004. This trend observed in both lagoons may indicate that sediment levels are stabilizing in Tolay Creek.

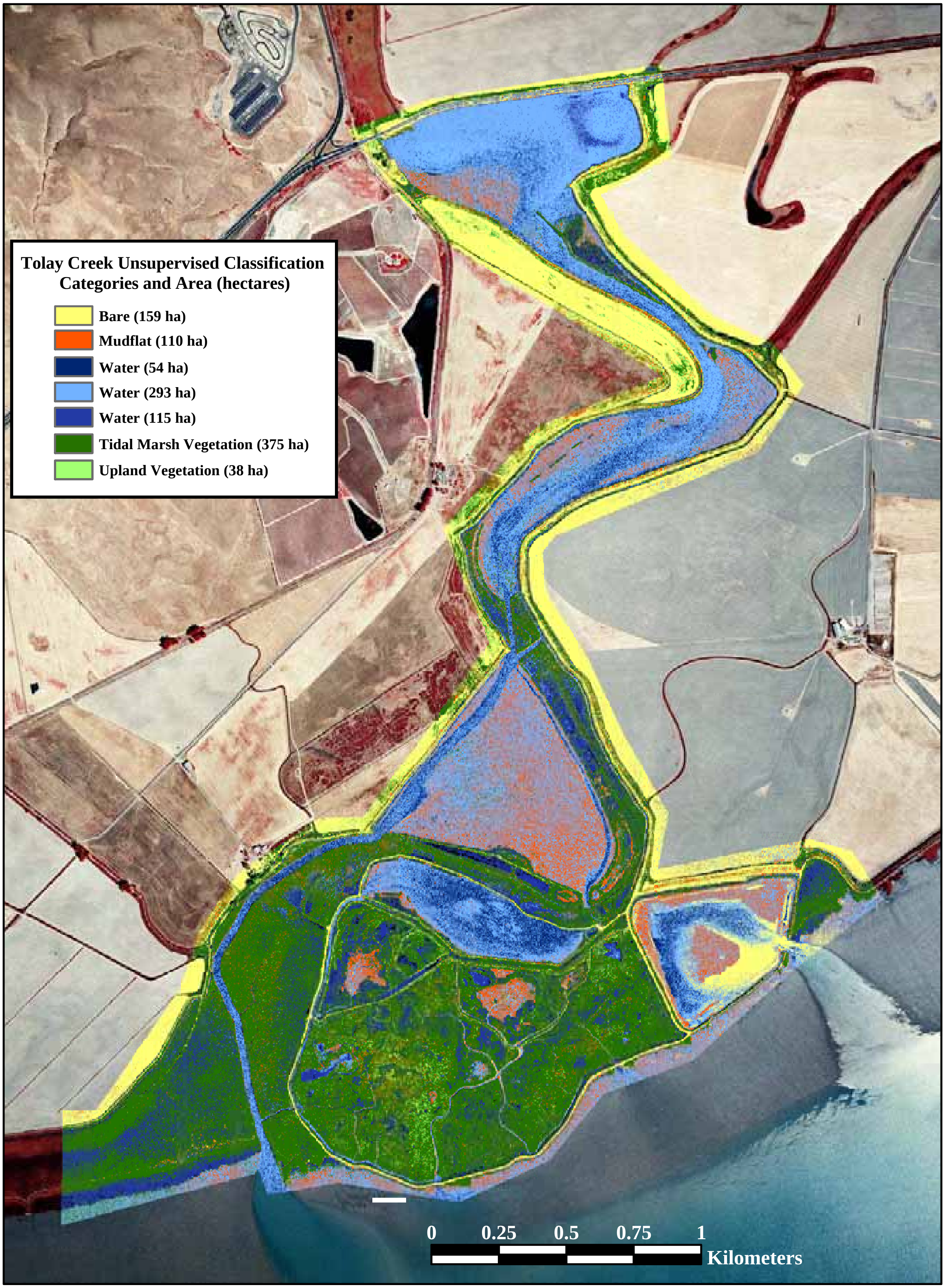
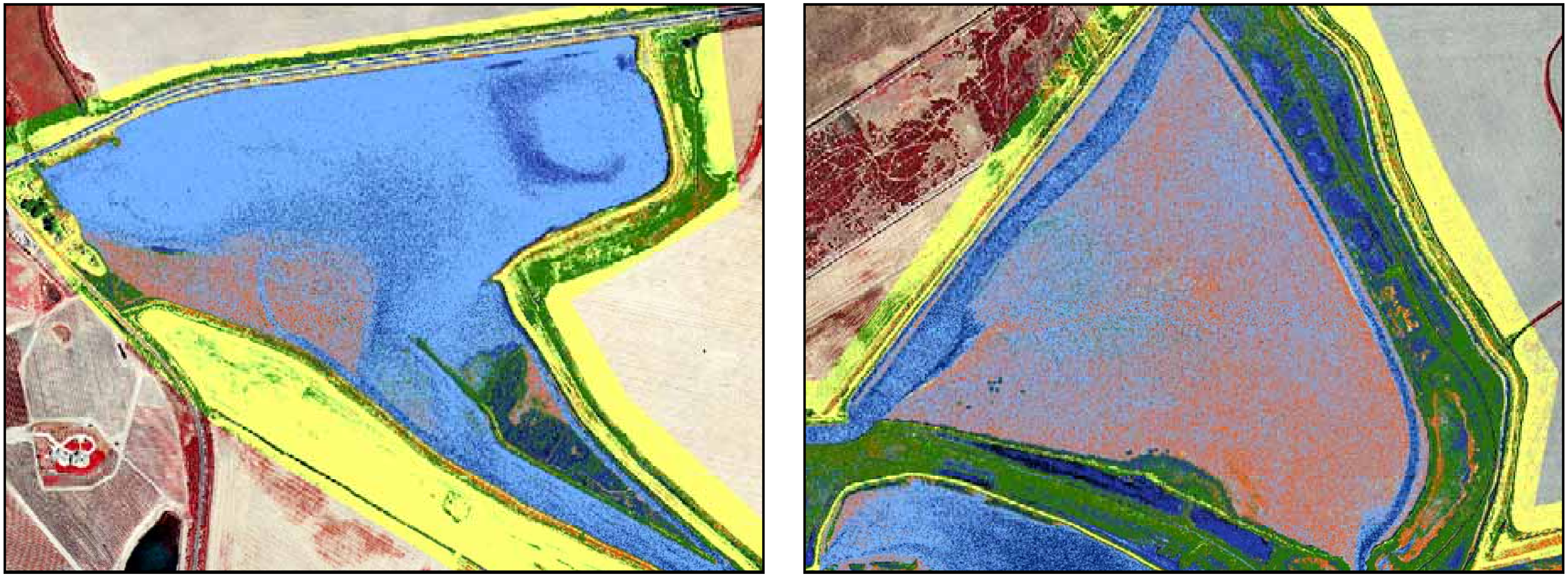


Figure 14. September 2004 infrared aerial photo was broken into 15 unsupervised classifications using ERDAS Imagine software. Classes were then grouped based on similar characteristics (i.e. marsh vegetation, water, mudflat) into seven major classes. Water comprises three of these classes, but was not further grouped in order to display various depths. Total water area is 462 hectares. Sediment deposition is noticable in the Upper Lagoon, Mid Channel and Lower Lagoon. Statistical patterns were identified from the pixel data by ERDAS withouth ground truthing, and are therefore rough classifications. For example, some water is classified as bare ground because of heavy glare.

Upper Lagoon **Lower Lagoon**



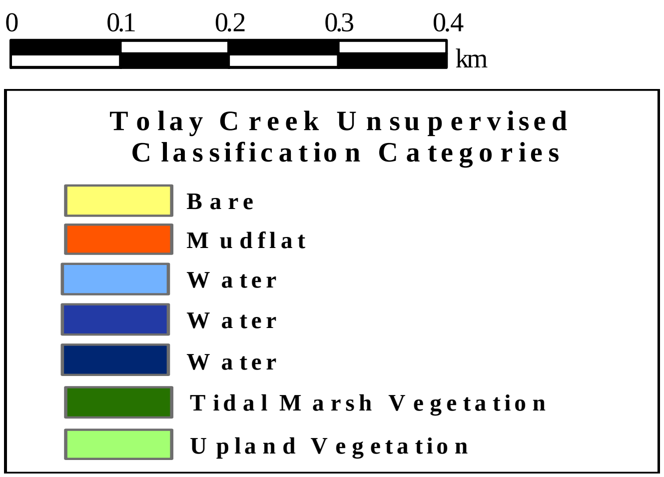


Figure 15. September 2004 unsupervised classification of Tolay Creek Upper and Lower Lagoons. Refer to Fig.15 for classification methods. Development of mudflat is evident in both lagoons, especially the lower. *Spartina foliosa* is colonizing the southwestern corner of the Lower Lagoon and vegetation is present on the island south of the Upper Lagoon.

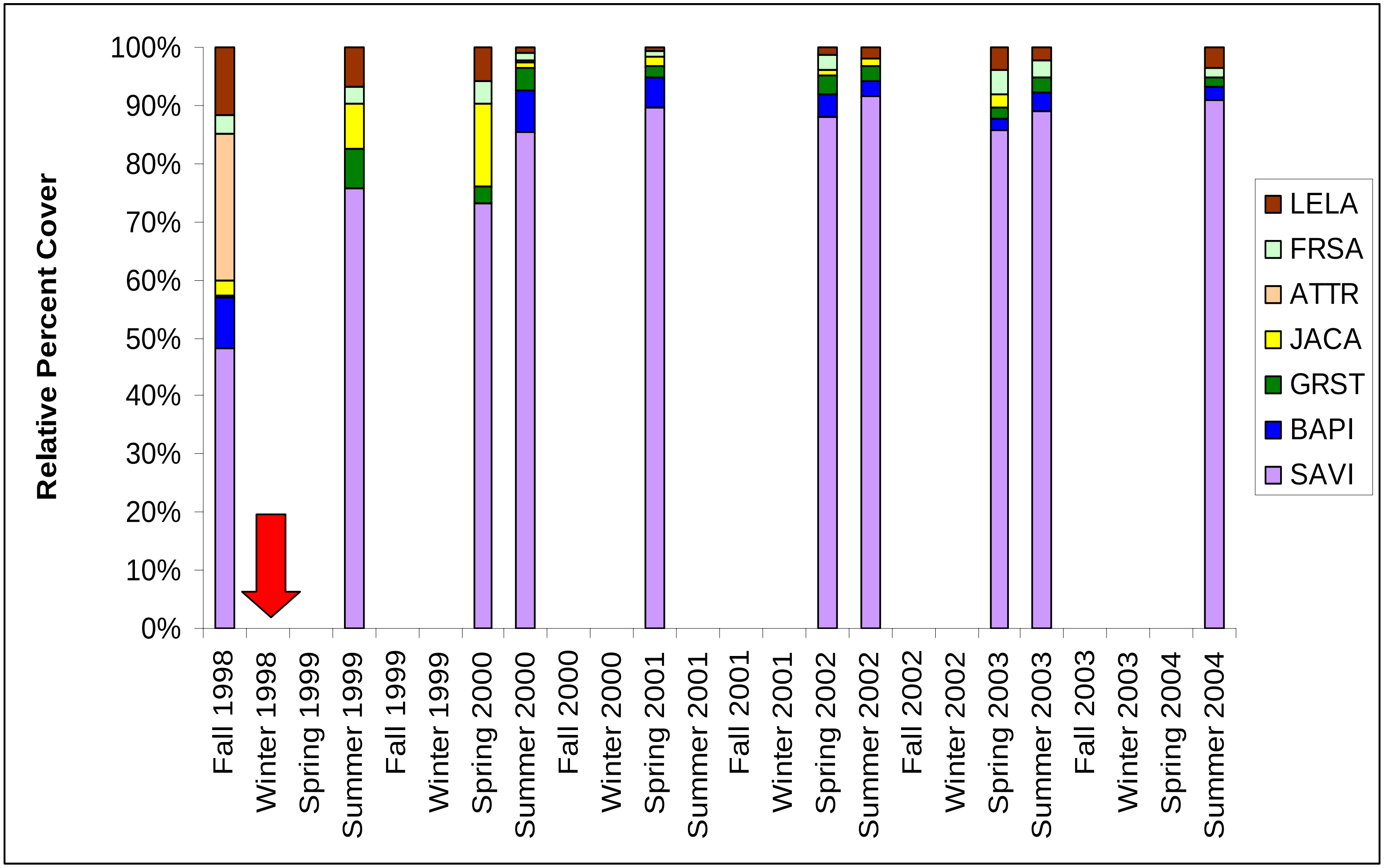
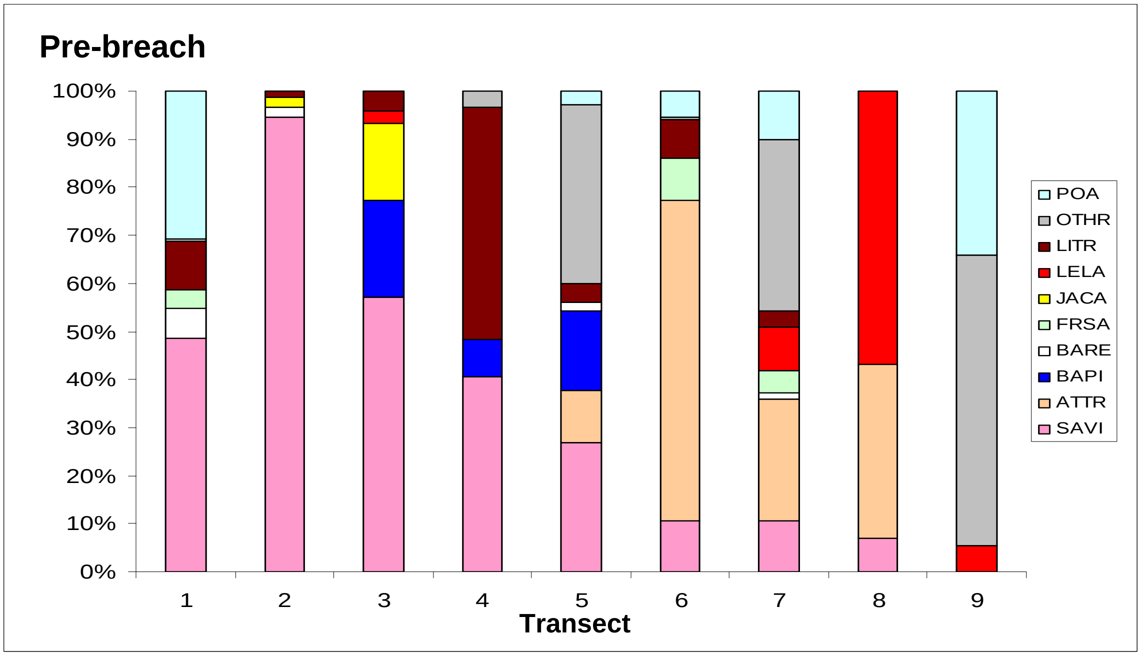


Figure 16. Relative percent cover for major plant species along 9 transects in the Tolay Creek Project, fall 1998 – summer 2004. Plant codes include: *Lepidium latifolium* (LELA), *Frankenia salina* (FRSA), *Atriplex triangularis* (ATTR), *Jaumea carnosa* (JACA), *Grindelia stricta* (GRST), *Baccharus pilularis* (BAPI), and *Salicornia virginica* (SAVI). The red arrow shows when the breach occured.

a.



b.

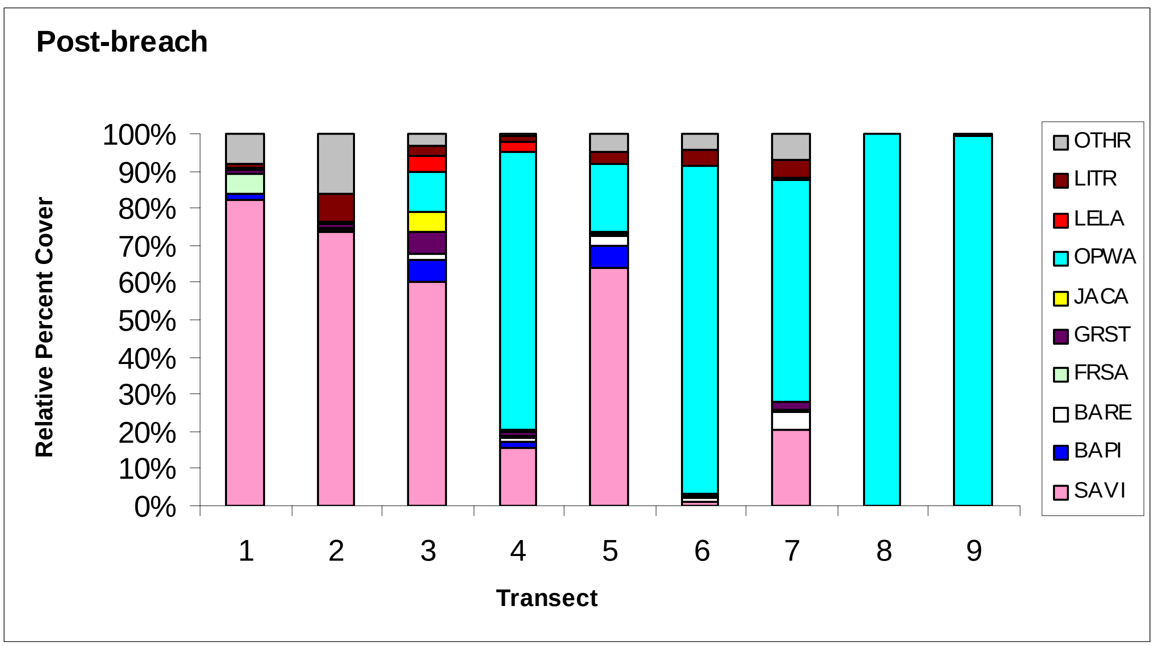
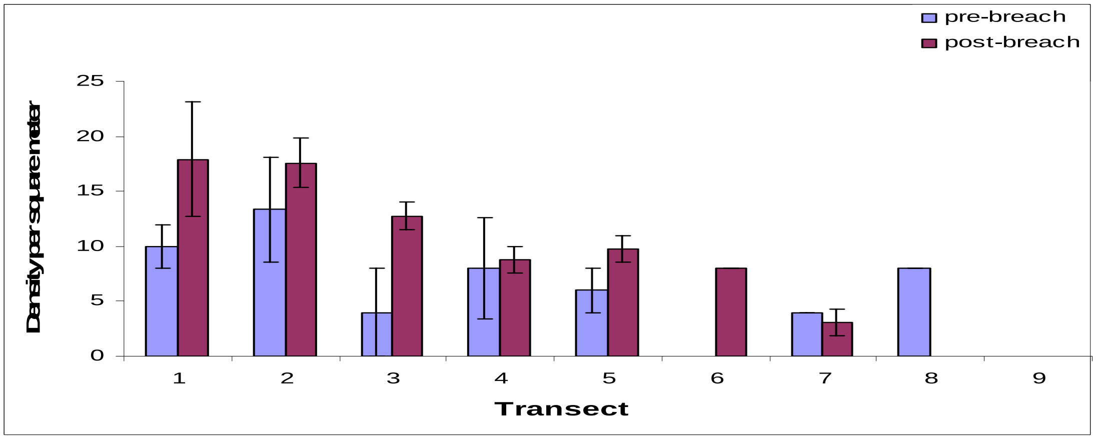
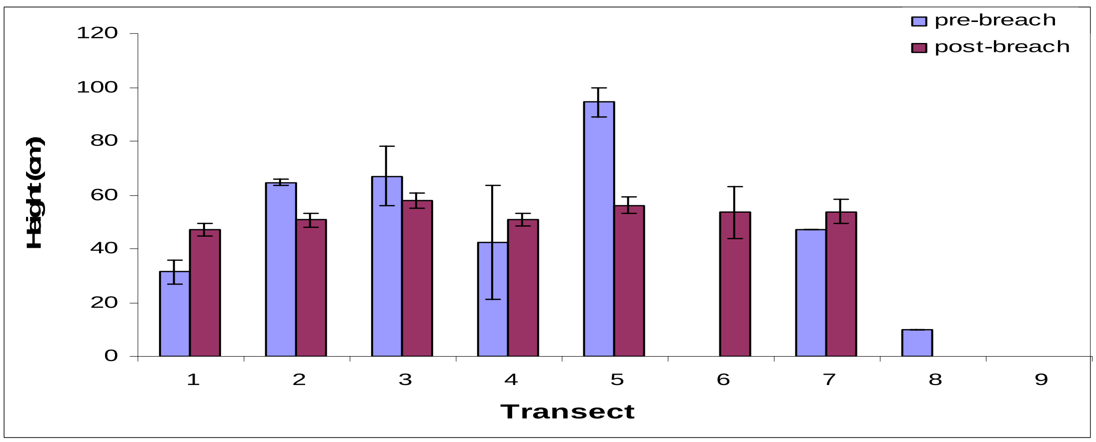


Figure 17. Relative percent cover of major plants species (transect surveys), pre-breach (a) versus post-breach (b). Due to the reintroduction of tidal influence, there is an obvious increase in water inundation in post-breach surveys. Plant codes include: *Poaceae Sp.* (POA), other (OTHR), dead plants (LTR), *Lepidium latifolium* (LELA), *Jaumea carnosa* (JACA), *Frankenia salina* (FRSA), areas without plants (BARE), *Baccharus pilularis* (BAPI), *Atriplex triangularis* (ATTR), *Grindelia stricta* (GRST), *Salicornia virginica* (SAVI), and inundated with water (OPWA). Refer to Table 2 for species included in other (OTHR) categories pre- and post-breach.

a.



b.



c.

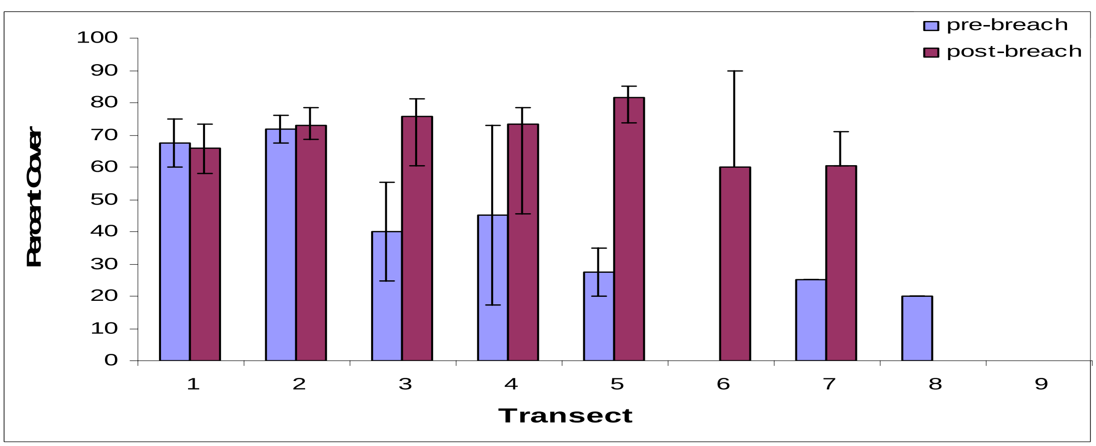


Figure 18. Mean density (a) (stems/m^2), height (b), and percent cover (c) of pickleweed (*Salicornia viriginica*) from quadrat surveys pre-breach (1998) and post-breach (1999-2004) in the Tolay Creek Restoration Project. Transects 7 and 8, pre-breach, are based off of one measurement and therefore have no standard error values.

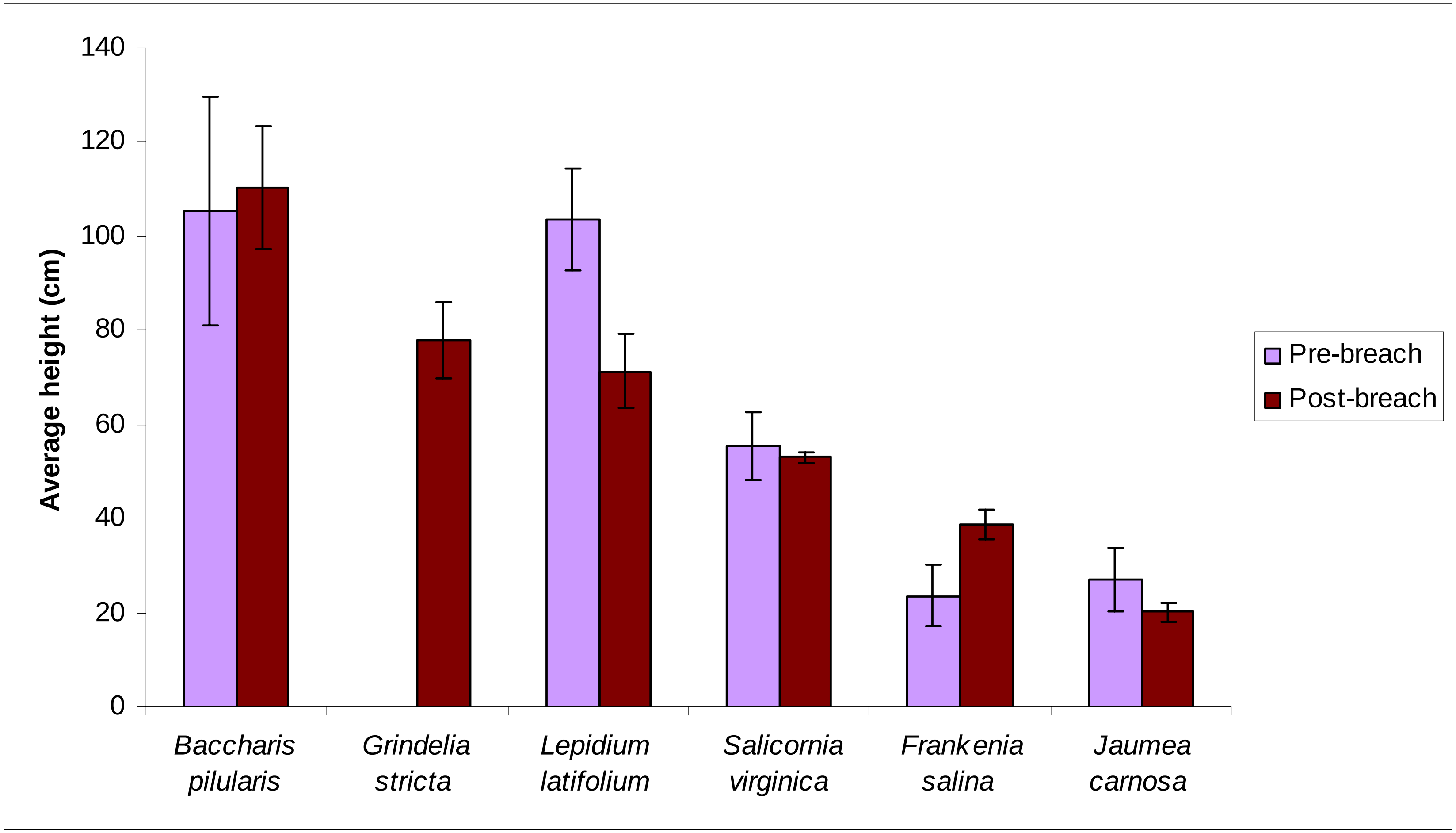


Figure 19. Average height of major plants, pre-breach (1999) and post-breach (1999-2004) at 9 transects in the Tolay Creek Restoration Project. Plant codes include: *Lepidium latifolium* (LELA), *Frankenia salina* (FRSA), *Atriplex triangularis* (ATTR), *Jaumea carnosa* (JACA), *Grindelia stricta* (GRST), *Baccharus pilularis* (BAPI), and *Salicornia virginica* (SAVI).

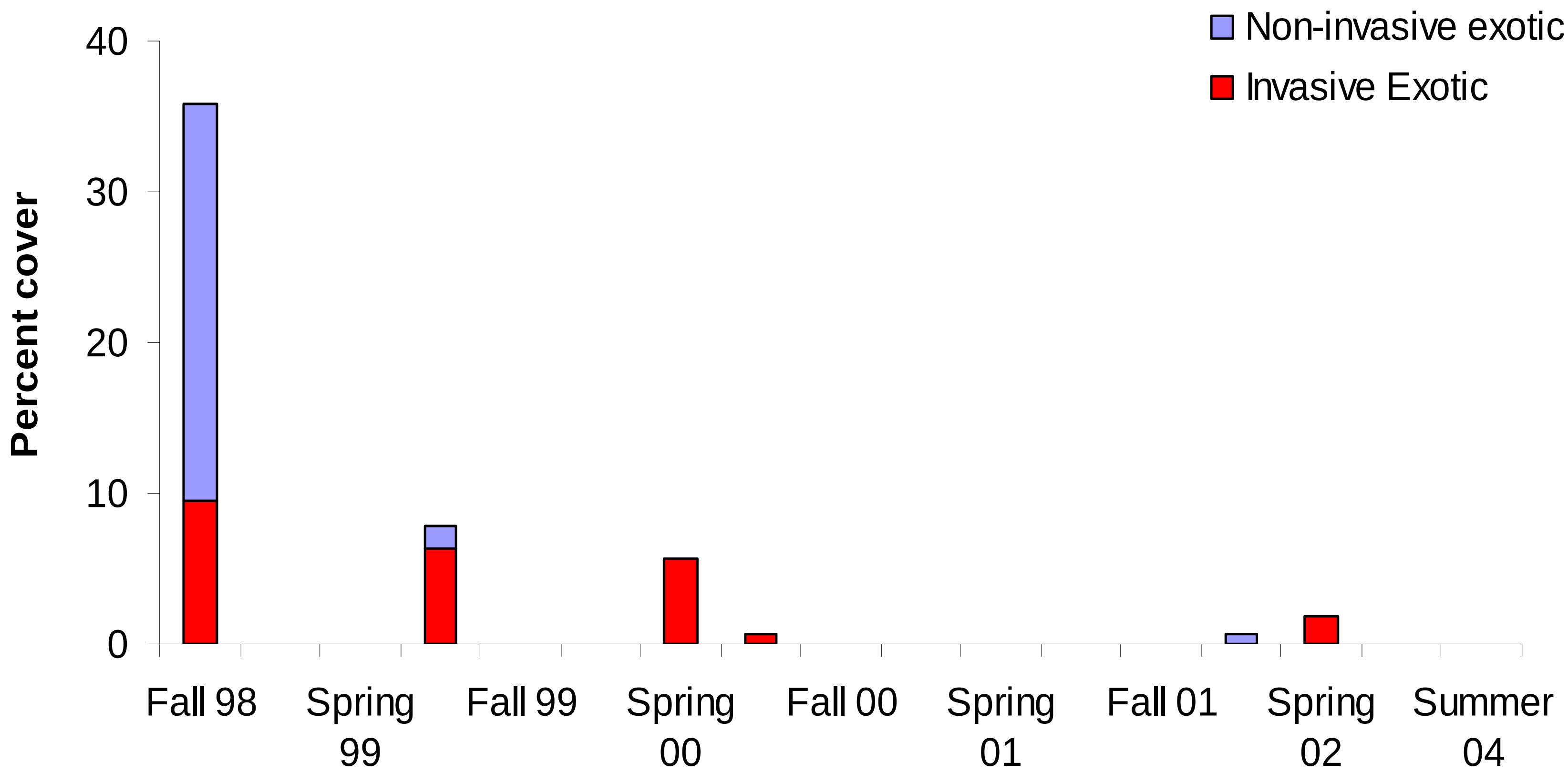


Figure 20. Percent cover of exotic plants from quadrats at Tolay Creek, Fall 1998 to Summer 2004. Exotic plant cover was grouped by "invasive" or "non invasive" categories as defined by the CA Pest Plant Council. The percent cover of exotic plants has steadily declined since the breach in 1998. Though invasive species were not detected in quadrats in 2004, they were detected in low abundance on line transects.

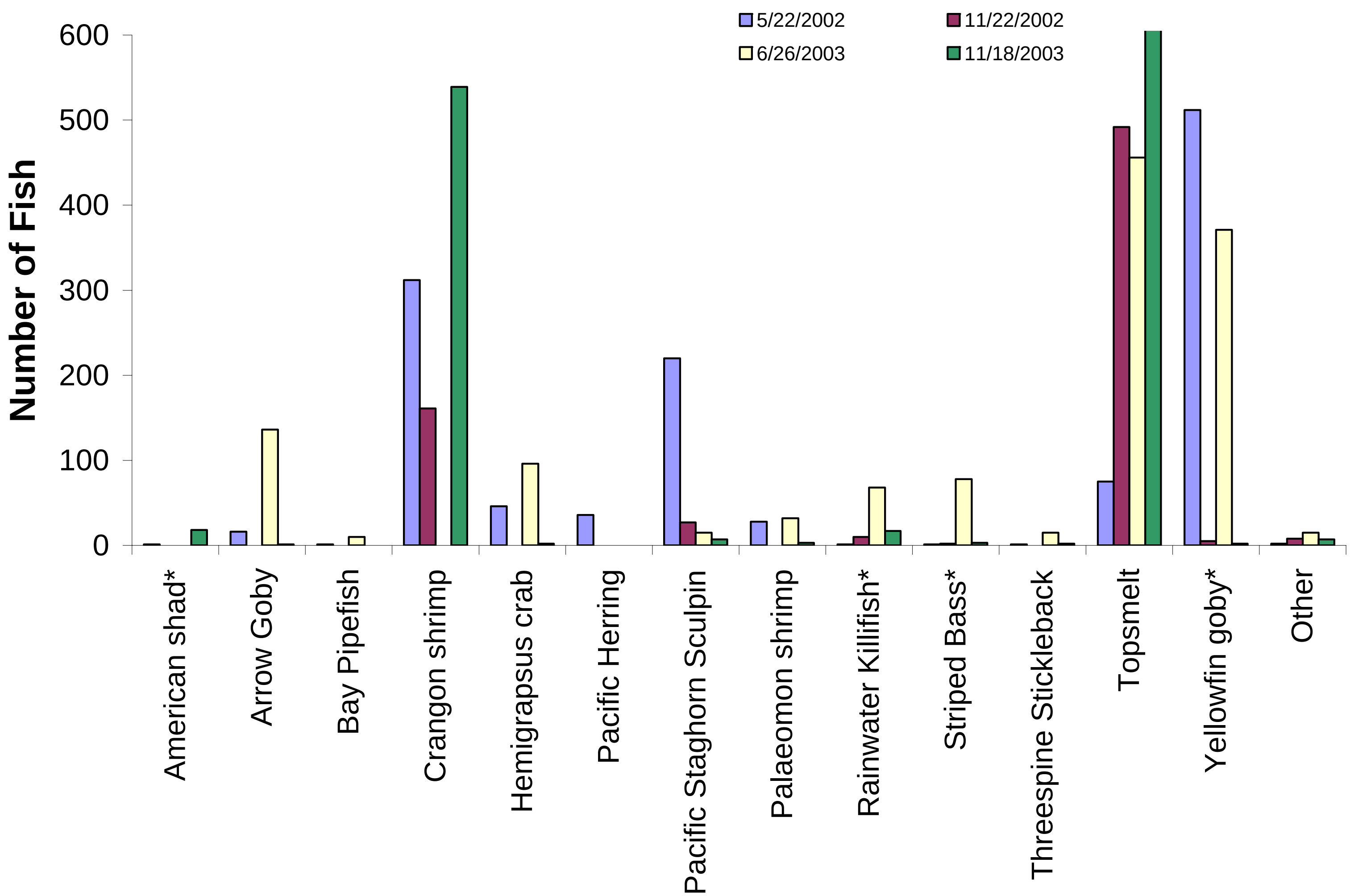


Figure 21. Fish captured in beach-seines at Tolay Creek. Other includes; Chinese Mitten Crab*, Dungeness Crab, Green Crab, Jellyfish, Prickly Sculpin, Shimofuri Goby*, Speckled Sanddab, Starry Flounder and Wakasagi goby*.

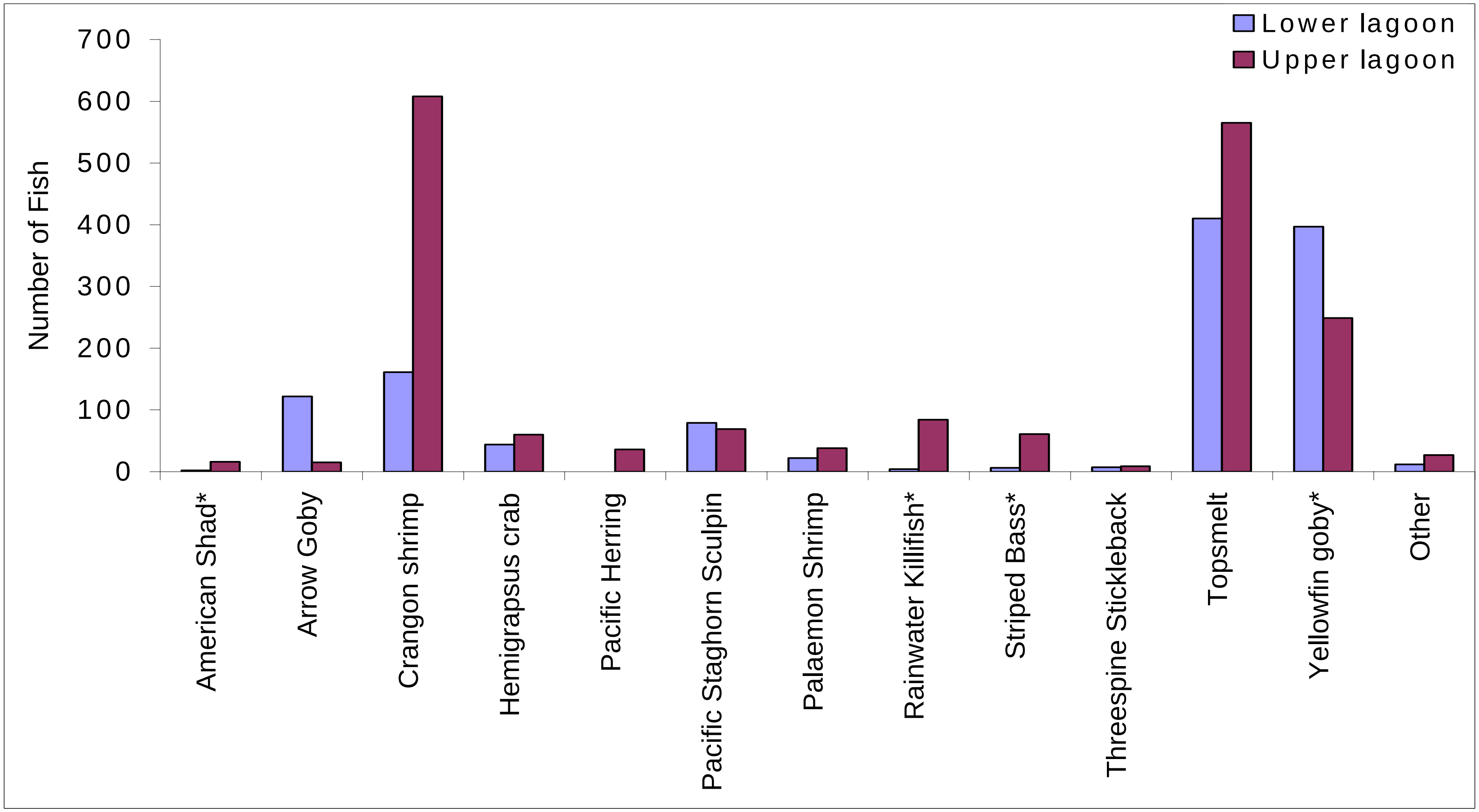


Figure 22. Comparison of fish species in the Lower and Upper Lagoons from spring and fall surveys in 2002 and 2003. Variation of species populations and abundance between the Upper and Lower Lagoons may be indicative of the habitat requirements of individual species. Other includes; Bay Pipefish, Chinese Mitten Crab*, Dungeness Crab, Green Crab, Jellyfish, Prickly Sculpin, Shimofuri Goby*, Speckled Sanddab, Starry Flounder, Wakasagi gobi* (* signifies invasive species).

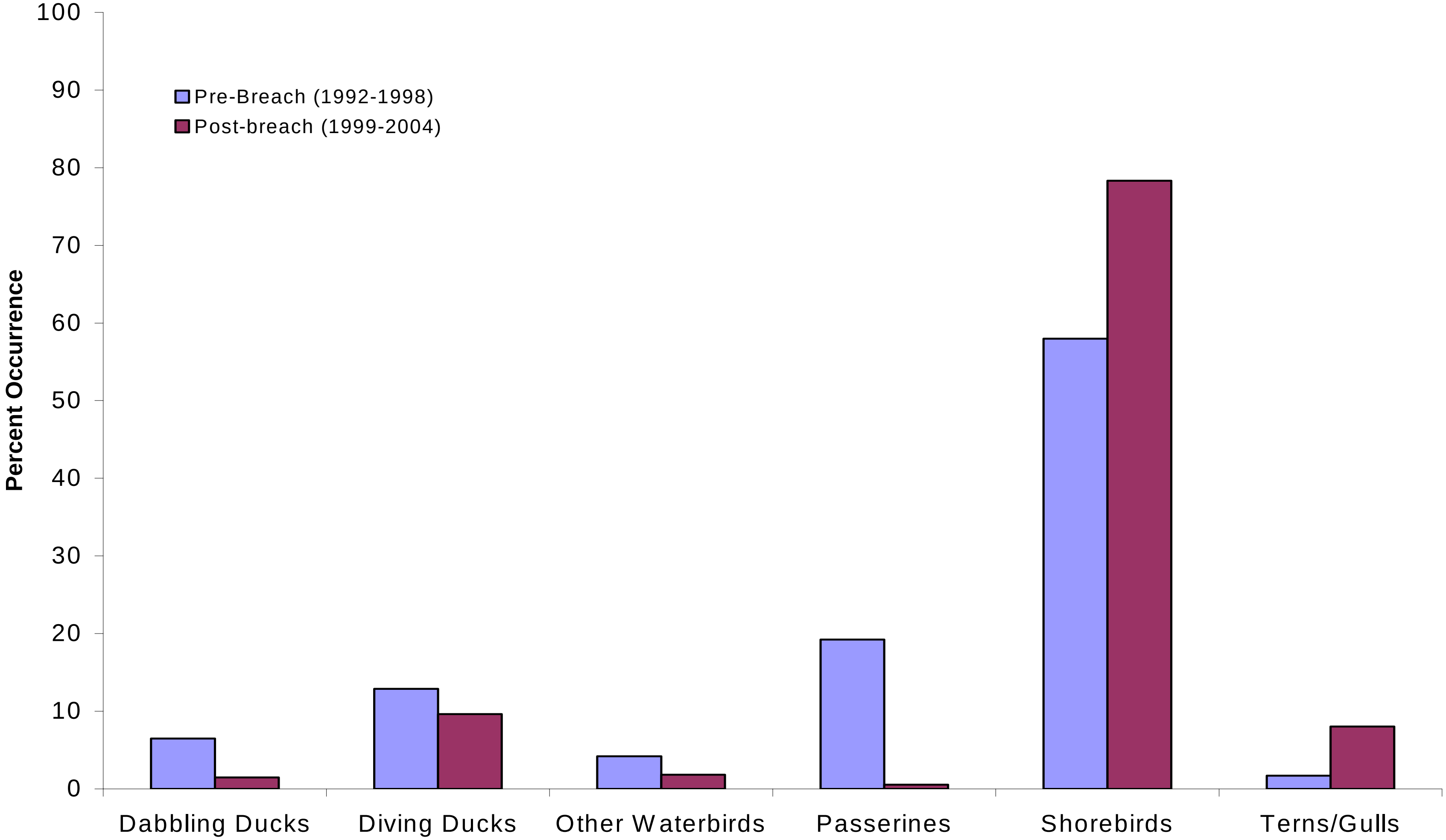


Figure 23. Overall percent occurrence of avian guilds during area surveys, pre-breach (1992-1998) and post-breach (1999-2004). Percentage of shorebirds, terns and gulls observed has increased since the breach while percentages of ducks (dabbling and diving), other waterbirds and passerines have declined. Other waterbirds includes: pelicans, grebes, coots and cormorants.

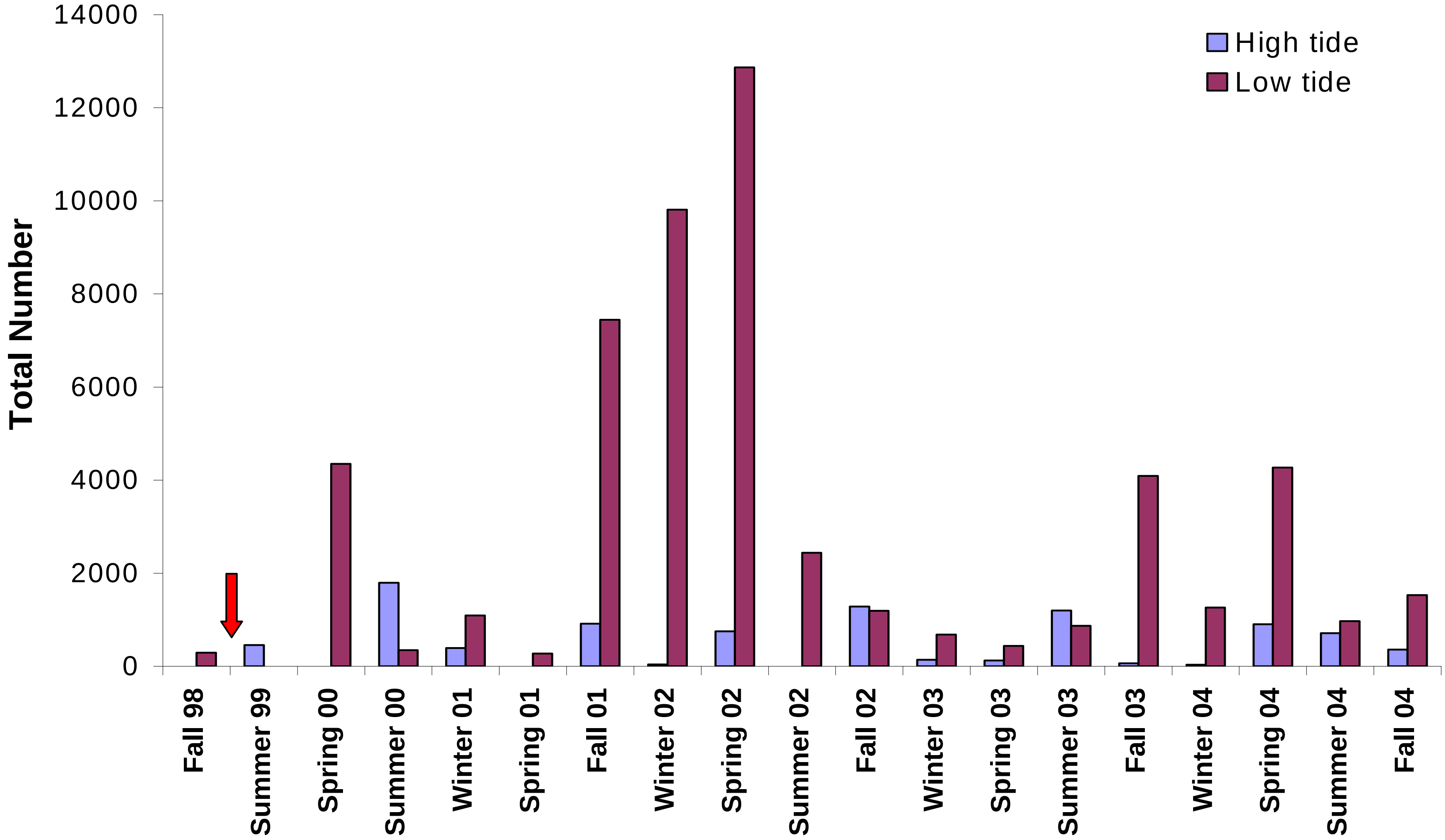


Figure 24. Total number of shorebirds observed on low and high tide surveys at the Tolay Creek Restoration Project, 1998-2004. More shorebirds were observed during low tide surveys. From Fall 2001 through Spring 2002 there was a large increase in shorebird numbers, this may be due to migration patterns or annual variation, long-term monitoring is required to accurately assess trends. Red arrow indicates when the breach occurred.

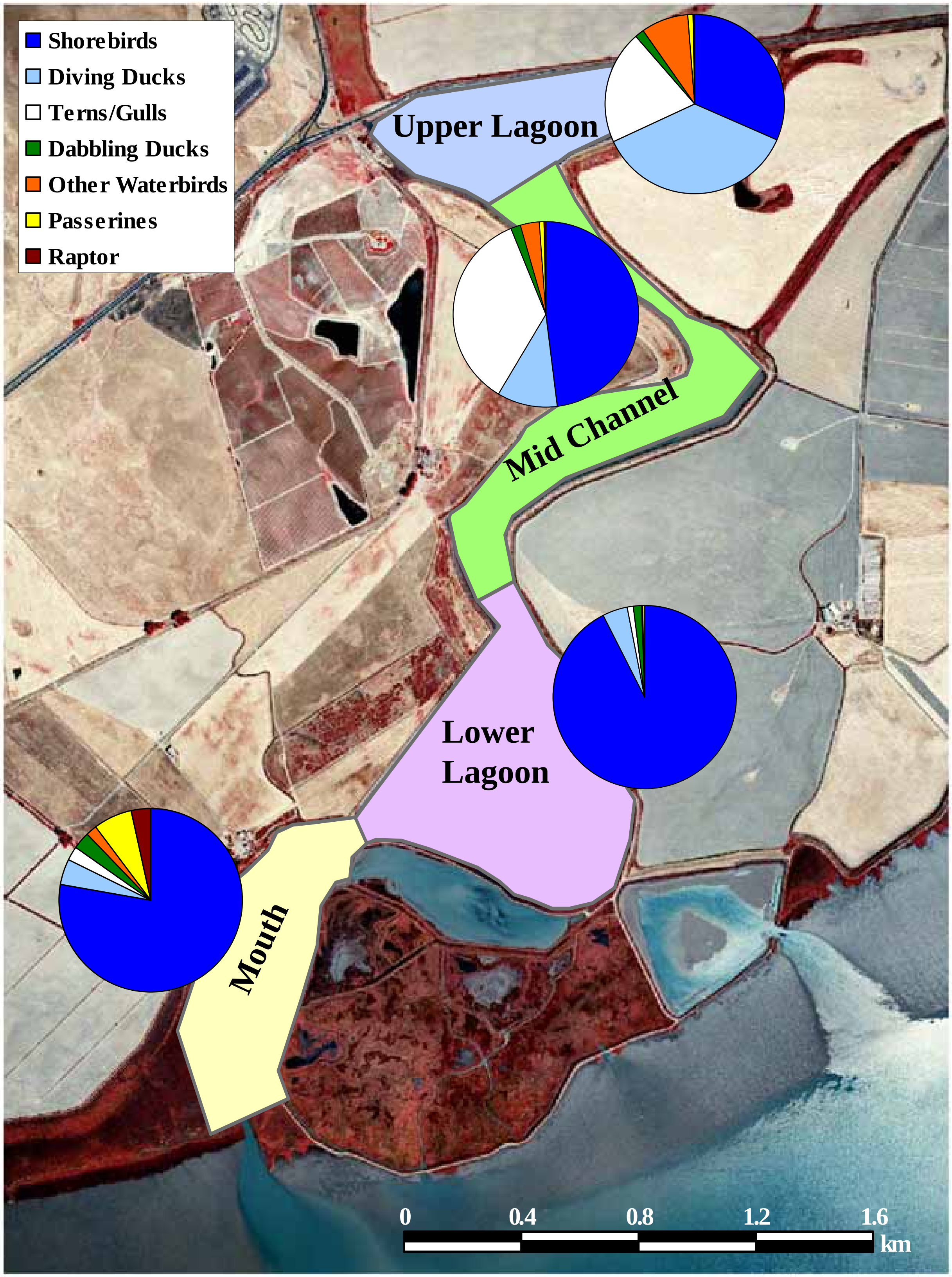


Figure 25. Percent occurrence of avian guilds in the Mouth, Lower Lagoon, Mid Channel and Upper Lagoon of the Tolay Creek Restoration Project (1999-2004).

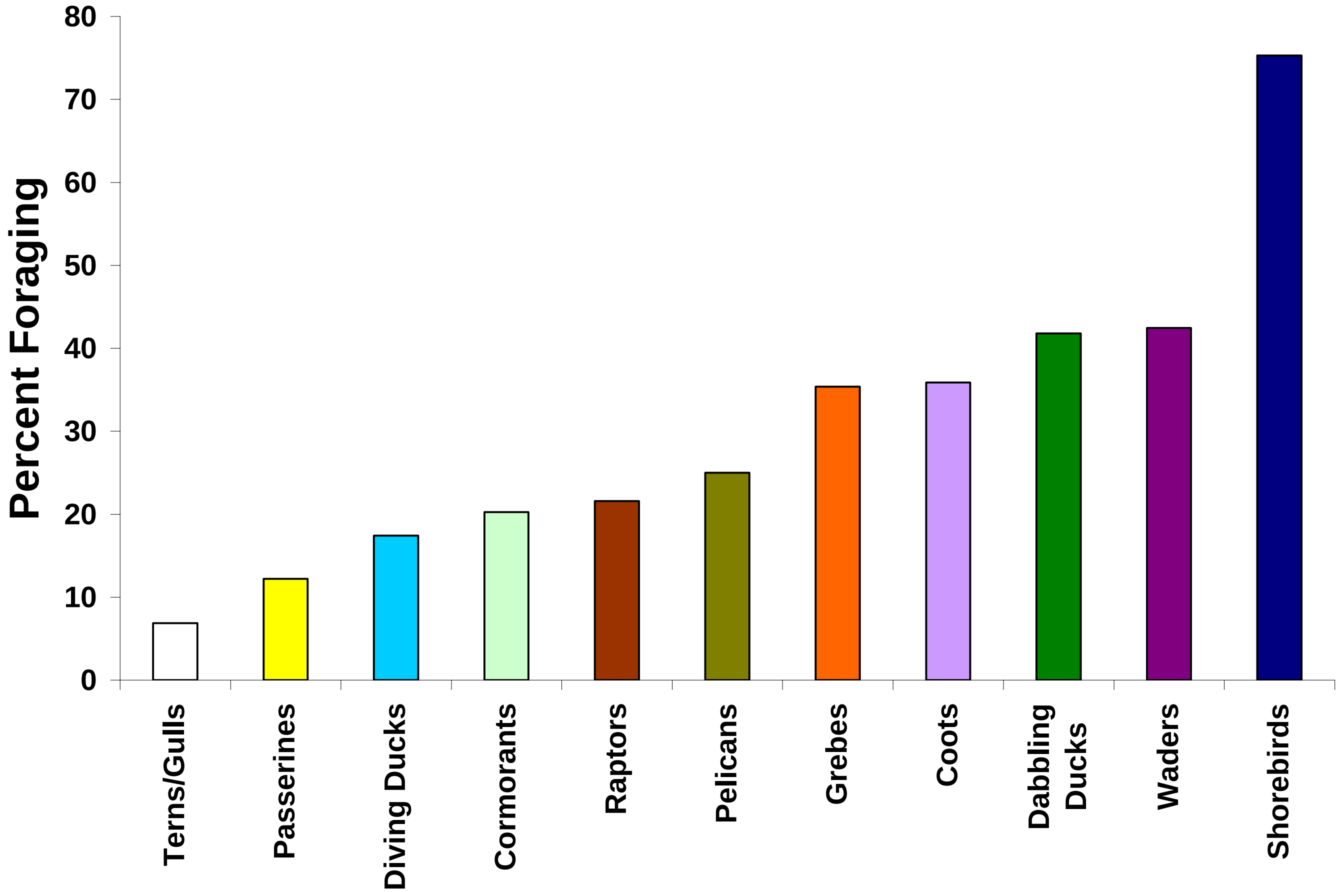


Figure 26. Percent of birds foraging by guild during area surveys in the Tolay Creek Restoration Project, 1999-2004.

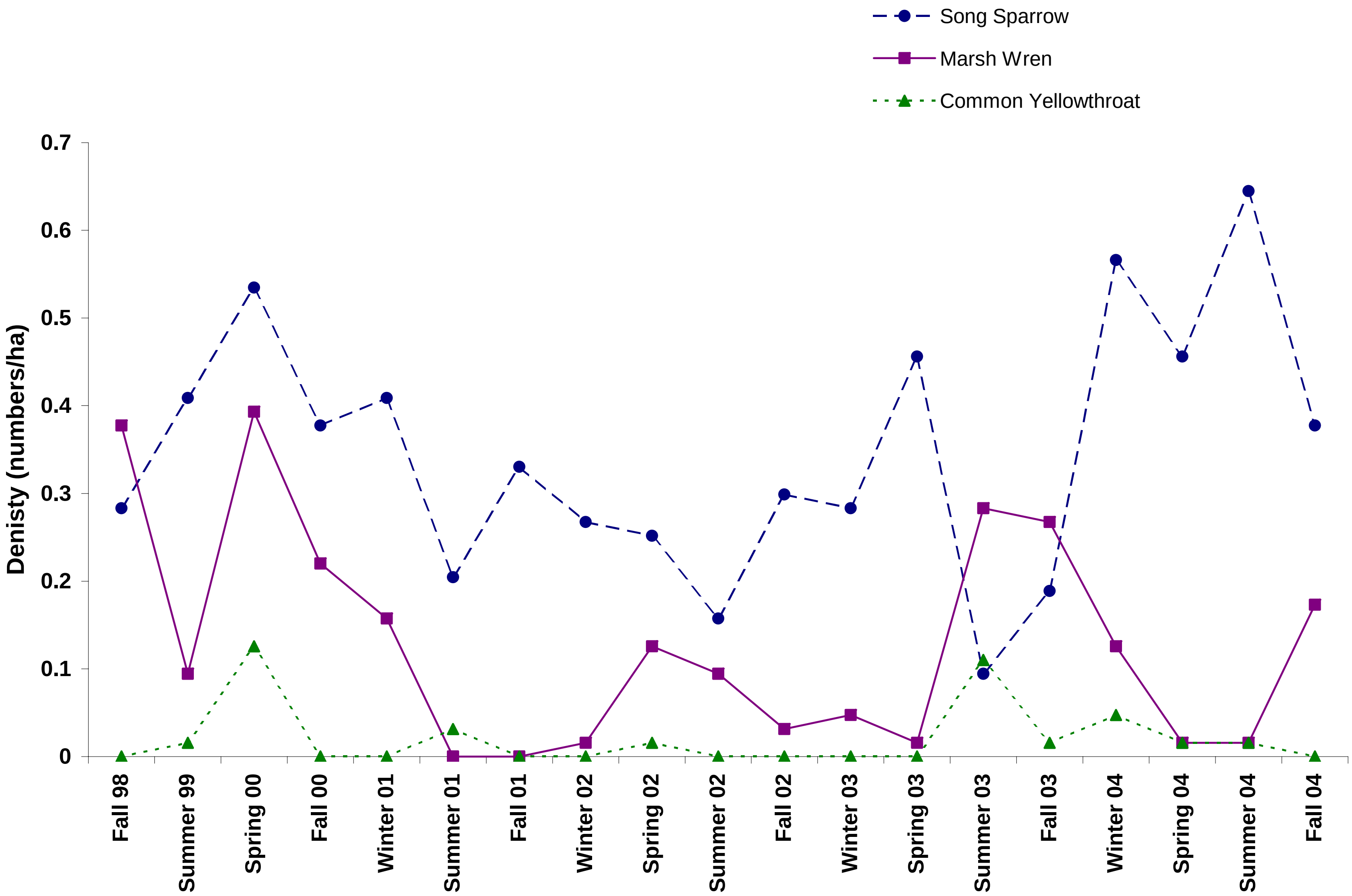


Figure 27. Density (numbers/ha) of three tidal marsh passerines (San Pablo song sparrow *Melodia melospiza samuelis*; marsh wren *Cistothorus palustris*; and common yellowthroat *Geothylypis trichas*) in the Tolay Creek Restoration Project, fall 1998 to fall 2004.

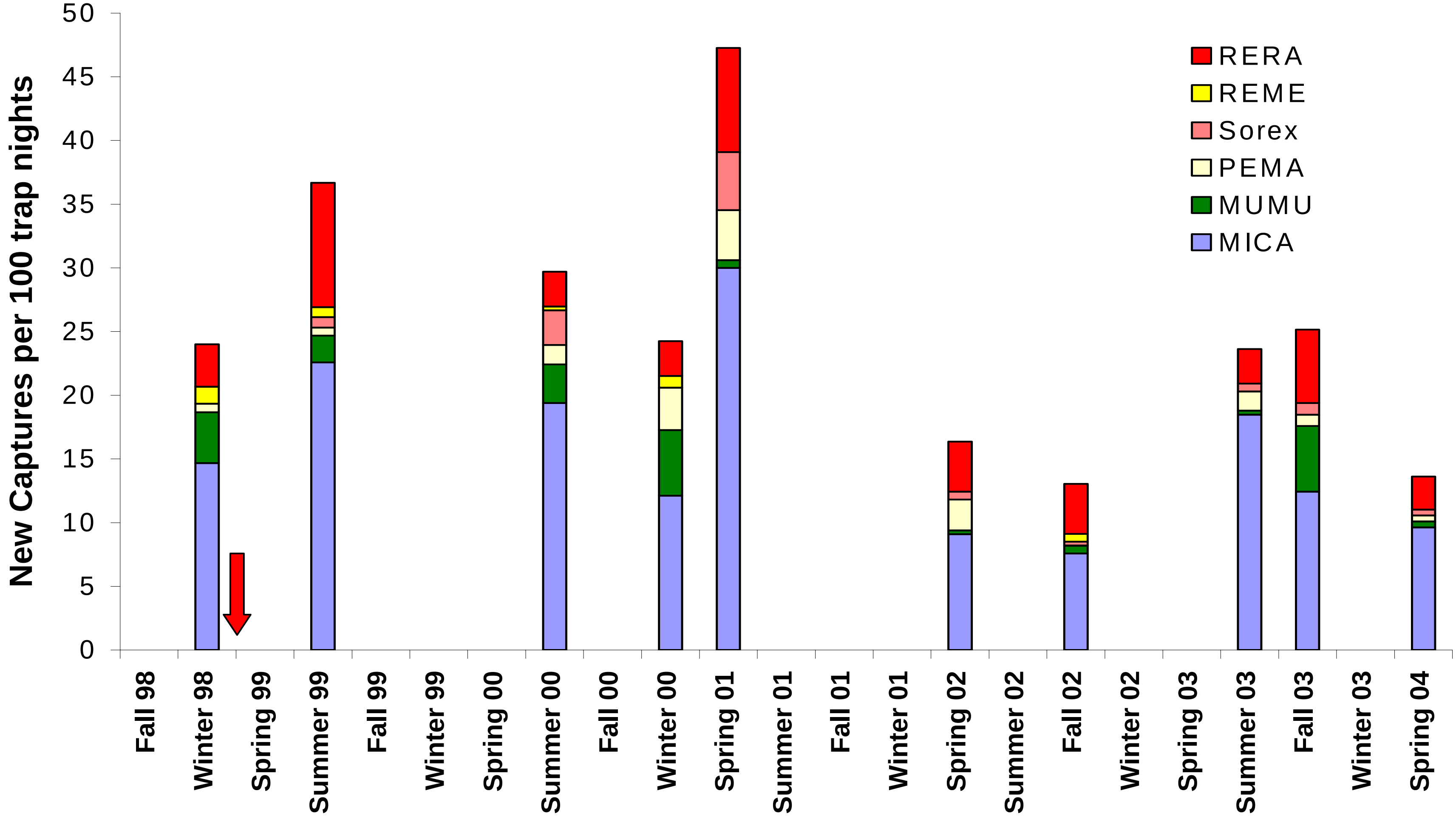
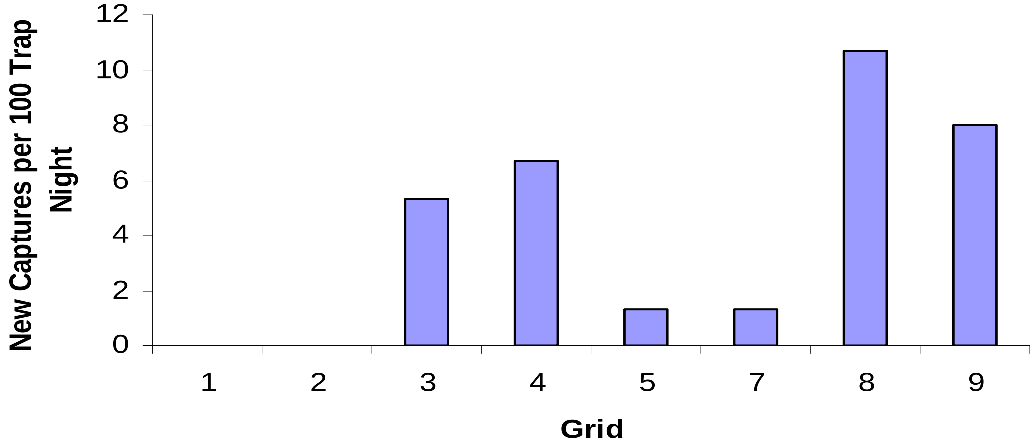


Figure 28. Small mammal abundance index. (new captures/ 100 trap nights). New captures were lower from 2002-2004 compared with higher numbers in 1998-2001 potentially indicating annual variations. Red arrow indicates when the breach occurred.

Pre-breach (n=2)



Post-breach (n=9)

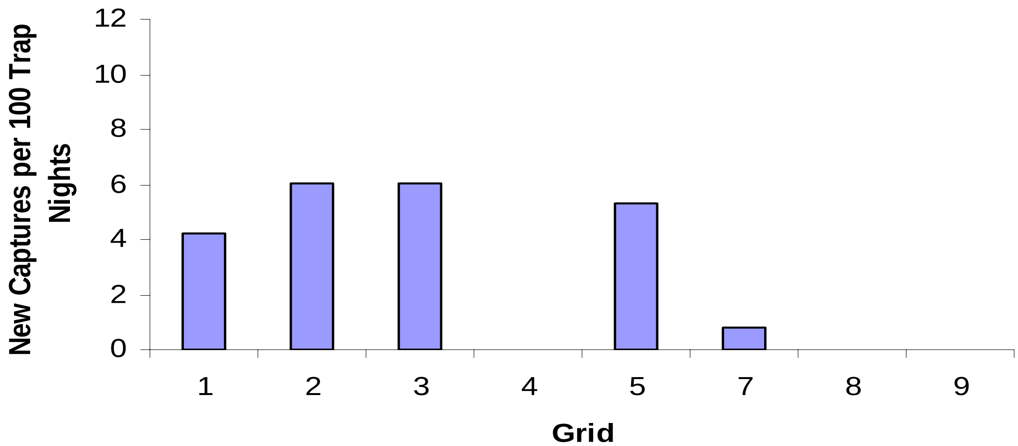


Figure 29. Abundance index (new captures/ 100 trap nights) of the salt marsh harvest mouse (*Reithrodontomys raviventris*) in the Tolay Creek Restoration Project across trapping grids, pre-breach (1998-1999) and post-breach (1999-2004).