THE PHYSICAL, CHEMICAL AND BIOLOGICAL MONITORING OF LOS PEÑASQUITOS LAGOON

July 1, 2009- June 30, 2010

Prepared for

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Los Peñasquitos Lagoon (LPL) is a relatively small estuary (252 hectares) in northern San Diego County, situated at the coastal outlet of the ~260 km^2 Peñasquitos watershed. Los Peñasquitos, Carroll Canyon and Carmel Valley creeks drain three sub-watersheds comprising areas of 180.5, 42.5 and 40.6 km^2, respectively (Greer 2001). Over 50% of the land within the Peñasquitos watershed is urbanized (SANDAG 1998). Historically, Peñasquitos Creek was the only tributary that flowed year-round, while Carroll Canyon and Carmel Valley Creeks were ephemeral, flowing only during the winter months. However, beginning in the late 1980's, coincident with development in the watershed, Carroll Canyon and Carmel Valley creeks also began flowing year-round. A recent study (Greer 2001) has demonstrated that shifts in vegetation occurring in the lagoon (salt marsh to brackish species) are correlated with increased urbanization of the watershed.

Like all wetlands in southern California, LPL experiences a Mediterranean climate, which is characterized by highly seasonal precipitation events occurring primarily during the winter months and little to no rainfall during the dry summer. As a result, most coastal lagoons in southern California experience a seasonal salinity cycle, with high salinities in summer and lower salinities during wet winter periods (Purer 1942). Flooding potential in winter is high due to high regional variability in precipitation and runoff.

Historic evidence, including mollusc middens left by indigenous peoples, notes by Spanish explorers, railroad maps from 1888, and photographs, indicate that LPL may have once remained open to the sea persistently. However, increased erosion and the resultant sediment loads due to agriculture and grazing in the early part of this century, combined with railroad line construction across the lagoon in 1925, cut off many tidal channels and reduced the lagoon's tidal prism. A pattern of seasonal mouth closure emerged that was further aggravated by coastal highway construction in 1932-3.

In the 1960's, dumping of treated effluent containing nitrates and phosphates from upstream sewage treatment facilities reached new highs. This nutrient addition contributed to algal growth in lagoon waters, and with decomposition of senescent vegetation, led to the depletion of dissolved oxygen and hypoxic conditions. Mosquitoes and midges proliferated, and the odors associated with decaying organics increased.

An LPL Enhancement Plan was developed in 1985 by the California Coastal Conservancy to deal with these problems, with partial funding provided by local developers and homeowners' associations in the watershed. A lagoon management program, administered by the Los Peñasquitos Lagoon Foundation, was formulated that called for the monitoring of channel water quality and the mechanical opening of the mouth before water quality became poor enough to kill channel organisms.

As part of this management program, the Pacific Estuarine Research Laboratory (PERL), based at San Diego State University, was contracted to monitor lagoon resources and use the data in its studies of regional wetland ecosystems. PERL monitored the physical and chemical characteristics of Los Peñasquitos Lagoon channel water from 1987 - 2004, and sampled benthic invertebrates, fish, and saltmarsh vegetation from 1988 - 2004 (Covin 1987, Nordby and Covin 1988, Nordby 1989, Nordby 1990, Boland 1991, Boland 1992, Boland 1993, Gibson et al. 1994, Williams 1995, Williams 1996, Williams 1997, Williams et al. 1998a, Williams et al. 1999, Ward et al. 2000, Ward et al. 2001, West et al. 2002). These studies led to the timely opening of the mouth and an increase in our knowledge of the biology of southern California's estuaries (e.g., Nordby and Zedler 1991, Zedler 2000, Noe 2001a,b). In July 2004, LPL monitoring was transferred to the Southwest Wetlands Interpretive Association (SWIA) and the Tijuana River National Estuarine Research Reserve (TRNERR).

II. METHODS

Study Site Descriptions

Water quality was sampled at three stations (W1-3) that have been monitored since 1987: Station W1 (Via Grimaldi (formerly Milligan House)), W2 (Railroad Trestles), and W3 (Mouth) (Fig. 1). Physical descriptions of the sampling sites are as follows: Station W1 is located along Carmel Valley Road (at the Via Grimaldi intersection) in the northern arm of the estuary. This station consists of a channel approximately 20-m wide and 1-m deep and sediments composed of clay covered with a shallow layer of organic matter. Station W2 is located at the large railroad bridge that crosses the main lagoon channel; water quality readings are taken from the catwalk near the middle of the channel, where water depths are approximately 2.0 m. Station W3 is located in one of the channels closest to the lagoon's Pacific Ocean outlet and is most directly exposed to ocean flows. This site is fairly shallow (~0.6 m), with sandy sediments and a highly variable width (8- 40 m) because of its dynamic hydrology.

Water quality - physical and chemical characteristics of lagoon water

Local rainfall data was collected at the weather station located near water quality sampling station W2. Relative humidity and temperature values were also taken at the weather station. The regional rainfall data was obtained from the National Weather Service at Lindbergh field. Both monthly rainfall and long term means (1905- present) are taken from the Lindbergh field weather station.

Conditions at the Lagoon mouth were obtained by direct observation and data collected using the YSI 600xlm multi-parameter water quality datalogger. Intensive water quality sampling was conducted at the railroad trestle (station W2; Fig. 1) using a YSI model 600xlm multi-parameter datalogger installed at a fixed position approximately 0.30 m off the channel bottom. The datalogger measured salinity (psu), water temperature (°C), DO (mg/L) and water level (m) from July – December 2008. Starting in January 2009, turbidity (NTU), pH, and chlorophyll (µg/L) were added. All water quality parameters were measured every 30 minutes. We were not able to deploy a surface logger during a brief mouth closure event in late March / early April.

Spatial water quality monitoring was conducted approximately every 2 weeks at stations W1-3 (Fig. 1). Measurements were made at the surface, middle, and bottom of the channel using a YSI 600xlm multi-parameter water quality datalogger connected to a YSI 650 MDS (Multiparameter Display System): water temperature, salinity, and DO were taken. In addition, the condition of aquatic vegetation, the presence of channel organisms, and water clarity were noted.

The flow rates of LPL's major tributaries (Carroll Canyon Creek and Los Peñasquitos Creek - southeast of the lagoon and Carmel Valley Creek - directly east of the lagoon) were measured monthly to identify the volume and rate of freshwater flows entering the lagoon. Stream cross-sectional areas were determined through a series of steps:

- Depth was measured at every 0.25 m across the width of the channel for all channels not exceeding a width of 2 meters. Depth was measured at 0.50 m intervals at all channels greater than 2 m.
- Depending on the channel width, the stream cross-section was divided into a series of 0.25 or 0.50 m - wide columns, which, in turn, were divided into triangles and rectangles.
- The area of each of these shapes is easily calculated; their sum represents the total stream cross-sectional area. Water column velocity is quantified in each cross-section using a hand-held current velocity meter. Discharge rates are determined using the equation $Q=Av$, where Q equals discharge, A is the stream cross-sectional area, and v is the mean water column velocity.

<u>Vegetation</u>

Vegetation monitoring was conducted to document changes in species composition and to determine the magnitude of historic saltmarsh habitat invasion by upland/exotic species. Vegetation is monitored in nine areas (Fig. 1) during the fall. Five of these areas have been monitored since 1986 (transects 1- 5), four since 1990 (transects 9, 11, and 12) and one since 2001 (transect 13A and B).

Two (or more) stakes mark the position of each permanent transect, which vary in length from 40 to 665 m; transects #1, 2, and 3 are comprised of two 50-m sections (100 m total). A 0.25-m^2 circular quadrat was laid down at five meter intervals along each transect and percent cover of each species and total percent cover were recorded.

In March 2008, we added an additional springtime transect to monitor *Lasthenia glabrata ssp. coulteri*, an annual native plant placed on the 1B List (Plants Rare, Threatened, or Endangered in California and Elsewhere) with a threat ranking of 0.1 (seriously threatened in California) by the California Native Plant Society. The transect is located along the eastern portion of the lagoon in an area of expanding freshwater influence. It is designed to describe the changing vegetation communities associated with the increased freshwater. It extends 140 meters along a trail between two patches of *L. glabrata*. The presence of *L. glabrata* was recorded at five meter intervals on either side of the trail. *L. glabrata* was most abundant on the western portion of the transect. In order to better characterize the *L. glabrata* and associated vegetation, percent cover of all species within a 1m^2 square quadrant was recorded every five meters along the western portion of the transect.

Soil salinity measurements were made along each vegetation transect during fall vegetation monitoring. Prior to 1996, soil salinities were determined in the field. In 1996 a switch was made to the use of soil pastes to better account for inconsistencies in measuring the salinity of dry and wet soils. Using a 2-cm diameter corer, at least three 10-cm deep soil cores were obtained at equally-spaced intervals along each transect. Saturated soil pastes (Richards 1954) were prepared in the laboratory. We extruded water from the soil pastes using 10-ml syringes fitted with filter paper and measured salinity with a temperature-compensated refractometer. Recent comparisons show that this method, while consistent across all samples, results in elevated salinity readings relative to field measurements of expressed interstitial waters.

III. RESULTS & DISCUSSION

A. WATER QUALITY

Rainfall. The cumulative rainfall at Lindbergh field for the monitoring period (July 2009 – June 2010) was 268 mm, which is close to the long-term average for the region (262.9 mm; Table 1). The rainfall record at the Los Peñasquitos Lagoon weather station was not complete, but was similar to Lindbergh field for the months measured. Daily rainfall values, as well as relative humidity and air temperature values, are shown in figure 2.

Table 1. Cumulative monthly rainfall (mm) for July 2009 – June 2010 at Los Peñasquitos Lagoon and Lindbergh Field, and long-term monthly means (1905-2010) from Lindbergh Field

	Los Peñasquitos Lagoon	Lindbergh field	Lindbergh long term average
July-09	x	0.0	0.5
Aug-09	x	0.0	2.3
Sept-09	x	0.0	4.6
Oct-09	x	0.0	10.7
Nov-09	x	3.0	28.7
Dec-09	x	57.9	48.5
Jan-10	96.3	85.9	52.1
Feb-10	43.9	57.9	48.8
March-10	5.3	17.3	40.9
April-10	30.5	45.2	19.3
May-10	0.3	0.3	5.3
June-10	0.0	0.5	1.3
Total	**(incomplete)**	**268.0**	**262.9**

Tributary flow rates: Sampling of flow rates from the three main tributaries (Carmel Valley, Los Peñasquitos, and Carroll Canyon creeks) indicates that significant freshwater input appears to flow into the lagoon year-round (Table 2). Flow rates were generally highest at Los Peñasquitos Creek.

Table 2. Estimated flow rates of major LPL tributaries ($m^3 \bullet sec^{-1}$) between July 1, 2009 – June 30, 2010.

Date	Carmel Valley Creek	Los Peñasquitos Creek	Carrol Canyon Creek
07-17-09	0.028	0.012	0.049
08-14-09	0.017	0.014	0.044
09-28-09	0.028	0.032	0.013
10-27-09	0.015	0.010	0.068
11-25-09	0.020	0.010	0.136
01-08-09	0.035	0.016	0.123
02-05-10	0.019	0.019	0.220
04-29-10	0.023	0.024	0.240
05-25-10	0.015	0.018	0.082
06-25-10	0.013	0.021	0.077
average	**0.021**	**0.018**	**0.105**

Lagoon Mouth Conditions: The mouth was closed from March 16th until April 4th, 2010, when it apparently opened naturally. However, tidal flow remained restricted until the mouth was widened mechanically starting May 6th.

Lagoon Water Conditions.

Water conditions in the lagoon are assessed with both periodic spatial sampling and data retrieval from the datalogger deployed at the railroad trestle. The real-time data delivery system at this logger site greatly facilitates water quality assessments as well as indicates problems which need rapid attention. Overall, the water quality was generally good throughout the monitoring period.

The spatial sampling data shows the difference in water quality parameters at varying depths. The surface water samples are generally lower in salinity than near bottom samples due to the density differences between lighter, fresher water and denser, more saline water (Fig. 4). However, water quality parameters at sampling station W3 were generally similar between surface and near bottom samples because the water at this site is generally shallow and well mixed.

B. MOUTH SEDIMENTATION

The opening of the mouth occasionally shifted to the south, but was typically found toward the north side of the bridge (Fig. 5).

E. VEGETATION

Fall 2009 Vegetation Monitoring

Vegetation transects throughout the lagoon were established in 1991 to serve as long-term monitoring areas; the rationale for each transect's establishment, brief description, change in mean percent cover of dominant vegetation types, and soil salinity trends are described below. It should be noted that *Sarcoconia pacifica* is now the current name for *Salicornia virginica,* and all references to *S. virginica* have been updated to reflect this change.

Transect 1 is located in the northwestern portion of the lagoon, west of the railroad and near the north beach parking lot (Fig. 1). It is composed of two parallel 50 meter transects running approximately east-west. This site receives no tidal flushing and the soil tends to remain quite dry except following rainfall events or during a mouth closure. These transects were originally established to document the invasion of upper-marsh and remnant dune habitat by upland weeds and exotic iceplant/hottentot fig (*Carpobrotus edulis*). Dominant vegetation types (mean % cover) when the transect was established in 1991 encompassed a mixture of saltmarsh, transition, and exotic species, including *Cressa truxillensis* (25%), *Distichlis spicata* (23%), *Sarcocornia pacifica* (22%), *Carpobrotus edulis* (16%), and *Ambrosia* sp. (5%). A manual removal program adopted in 1996 virtually eliminated *C. edulis* from this site (Fig 6a). Since then *D. spicata* has remained the dominant saltmarsh species (23% in 2009). Exotic species included *Mesembryanthemum crystallinum* (1%) and *Polypogon monspeliensis* (2%). Average salinity along transect 1 was 13 psu with a minimum of 4 psu and a maximum of 22 psu (Table 3).

Transect 2 is located in the northwestern part of the lagoon near the entrance to the north beach parking lot, to the east of the railroad (Fig. 1). It consists of two parallel 50 meter transects running north-south under utility lines. The site receives tidal water via a narrow channel which runs under the road at the parking lot entrance connecting to the main tidal channel approximately 175 meters to the southeast. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including *Jaumea carnosa* (46%), *S. pacifica* (31%), *F. salina* (19%), *D. spicata* (18%), and *C. truxillensis* (14%). Species composition at transect 2 has remained similar to what it was in 1991 though percent cover of each species has fluctuated. *S. pacifica, J. carnosa*, *F. salina*, *D. spicata*, and *C. truxillensis* have been present at this site since 1991. The obligate parasite, *Cuscuta salina* was not found on this transect prior to 1995, and has shown a decline from a maximum of 61% in 1996 to 2% in 2006 (Fig 6a). However, in recent years, *C.salina* has increased to the current level of 26% (Table 3). *S. pacifica* was the dominant species in 2009 with a percent cover of 48%. Average soil salinity along transect 2 was 30 psu with a minimum of 14 psu and a maximum of 49 psu (Table 3).

Transect 3 is located in the western lagoon, just east of N. Torrey Pines Road (Fig. 1). This transect is 100 meters long, with 21 quadrats. It was established to document how *S. pacifica* and *F. salina* dominance were correlated with periods of tidal exclusion and changes in soil salinity. From 1991-2002, three species have shared dominance at this site: *S. pacifica* , *D. spicata* and *F. salina* (Fig 6a). Since then, *F. salina* has become the dominant species (68%) followed by *S. pacifica* (38%) and *D. spicata* (5%). There are many freshwater species just west of transect 3 where runoff from Pacific Coast Highway enters the lagoon via a drain pipe. During the rainy season, this is likely a significant source of freshwater; continued monitoring will indicate any vegetative changes associated with this. Average soil salinity along transect 3 was 44 psu with a minimum of 24 psu and a maximum of 63 psu (Table 3).

Transect 4 is also located in the western portion of LPL, east of transect 3 (Fig. 1). It is 80 meters long, oriented north-south, composed of 17 quadrats, and was established for the same reasons as transect 3. From the time monitoring began in 1991 until 2001, only two species, *Sarcocornia pacifica* and *Frankenia salina*, were found along the transect. Throughout the course of the monitoring program, increases in *S. pacifica* cover have generally been mirrored by decreases in *F. salina* and vice versa (2a). Average soil salinity along transect 4 was 46 psu with a minimum of 30 psu and a maximum of 66 psu (Table 3).

Transect 5 is located in the southwestern portion of the lagoon, close to the upland transition zone (Fig. 1). This transect is 50 meters long with 11 quadrats. Dominant species in 1991 were *F. salina* (44%), *S. pacifica* (39%), and *Monanthochloe littoralis* (34%); *Distichlis spicata* was also present (9.8%). From 1991 to 1998, *S. pacifica* coverage steadily increased to 89%, and has remained the dominant species since (75% in 2009) (Fig. 6a., Table 3). Average soil salinity along transect 5 was 59 psu with a minimum of 26 psu and a maximum of 88 psu (Table 3).

Transects 9, 11 and 13 are all located in the northeast corner of the lagoon, near the Sorrento Valley and Carmel Valley Road intersection (Fig. 1). Extensive development within the watershed has greatly increased disturbance, predominately through an increase in freshwater inflows. These three transects were established to monitor the expansion of exotic species near increased freshwater inflows along Carmel Valley Creek.

Transect 9 is 40 meters long and comprises 9 quadrats**.** Dominant species in 1991 were *S. pacifica* (81%) and *Typha* sp. (20%) (Fig. 6b). *Typha sp*. cover has increased in recent years to 49% in 2009 (Table 3). *S. pacifica* has decreased along the transect over the past 11 years to 3% cover in 2009. *J. carnosa* was first present in the transect in 2000 (13%) and has since increased to 63% cover in 2008 (Fig 6b). Average soil salinity along transect 9 was 34 psu with a minimum of 28 psu and a maximum of 40 psu (Table 3).

Transect 11 is 25 meters long and comprises 6 quadrats (Fig. 1). When originally set up in 1991, transect 11 ran west to east 60 meters starting east of a small creek in an area now dominated by *Typha* sp. and *Salix* sp It was dominated by *S. pacifica* and *F. salina* (36% and 64% mean total transect cover, respectively) although several exotic and transition species were also present, including *Atriplex triangularis* (16%), *Rumex crispus* (2%), and *Typha* sp. (1%). By 1999, the eastern portion of the transect resembled a brackish marsh/riparian community and *Typha sp*. had reached the edge of the creek. Assuming that *Typha sp*. may not easily ‘jump’ the creek, in 2000 the transect was extended 30 meters to the west to further document the invasion of transitional and brackish species onto the marsh plain in this area of the lagoon. Since 2000, the eastern 60 meters of transect has been impassable due to extremely thick *Typha* and *Salix* cover. The use of aerial photography and remote sensing data is needed to more accurately document the spread of *Typha* sp. and *Salix*. Since 2004, the transect includes only the area west of the creek, and in 2008, only 25 meters of the 30 meter transect could be measured due to changes in the creek. *Jaumea carnosa* was the dominant species in 2009 (80%) (Table 6). Average soil salinity along transect 11 was 17 psu with a minimum of 14 psu and a maximum of 20 psu (Table 3).

Transect 12 runs the length of the eastern marsh, using SDG&E utility lines as an overhead guide (Fig. 1). It is the longest of the vegetation transects (665 meters) and has 141 quadrats. It was originally established to provide a rough estimate of exotic species invasion within the middle of the marsh. Dominant vegetation types at establishment (1991) were *S. pacifica* (63%) and *F. salina* (15%) (Fig. 6b). Upland transition species, including *R. crispus*, *A. triangularis*, *C. canadensis*, *Xanthium strumarium*, and annual grasses were also present**.** In 2009, *S. pacifica* (34%) was still the dominant species. The exotic species *L. muliflorum* was the dominant invasive in 2009 (3%). Other exotics present along this transect in 2009 were *Polypogon monspeliensis* (2%), *R. crispus* (<1%) and *Helminthotheca echioides* (<1%)(Table 3). Average soil salinity along transect 12 was 28 psu with a minimum of 10 psu and a maximum of 46 psu (Table 3).

Transect 13 was established in 2001 to enhance the ability to detect the expansion of exotic species near increased Carmel Valley freshwater inflows and to replace transect 10, which became impassable when *Typha* sp. expanded to the creek edge. Transect 13 is approximately 50 meters west of transect 9 in the northeastern portion of the lagoon (Fig. 1). It was originally 100 meters long and was comprised of two parallel 50 meter transects, 13A and 13B, which ran approximately south (adjacent to channel edge) to north (towards Carmel Valley Road). The exact location of transect 13A could not be found and was discontinued in 2004. In 2001, *S. pacifica* overwhelmingly dominated the transect, at ~85% cover, and has since dropped to 7% cover in 2009. At the same time, *J. carnosa* has increased from 6% cover in 2001 to become the dominant species in 2009 (89%). Average soil salinity along transect 13 was 37 psu with a minimum of 26 psu and a maximum of 54 psu (Table 3).

Spring 2010 Vegetation Monitoring

Annual *Lasthenia glabrata ssp. coulteri* monitoring took place for the third year in March 2010 on transect 14. The dominant species was *S. pacifica* with 46 percent cover, followed by *Lasthenia glabrata ssp. coulteri* with 14 percent cover (Table 4). Lower quantities of several native salt marsh species were present (*F. salina* 7%, *D. spicata* 9%, and *J. carnosa* 9%). *Cotula coronopifolia* and *Parapholis incurva,* both non-native species, were also present in low numbers (5% and 3%, respectively).

Transect 1 was also re-sampled in March 2010 in order to better count the non-native annuals found during the spring. There were a total of 9 non-native species found on the transect in the spring, compared to only 2 non-native species in the fall sampling. Dominant non-native species included *Ehrharta longiflora* (4%) and *Oxalis pes-caprae* (4%). The dominant native transition species was *I. menziesii* (15%) and the dominant native salt marsh species were *D. spicata*(11%) and *S. pacifica* (10%) (Table 4).

IV. CONCLUSIONS

The conditions in Los Peñasquitos Lagoon appear to be fairly typical of recent years. The primary concern remains the closure of the river mouth, which can quickly lead to deteriorated water quality. This last year saw a mouth closure event that appeared to reopen naturally (although some have speculated that local residents may have helped breach the mouth). Tidal flow was reestablished after this event and further mechanical clearing of the mouth occurred in May. This also improved tidal circulation.

The continued discharge of freshwater during the dry season also remains a problem. Several vegetation transects near the back of lagoon continue to indicate a type conversion from salt- to brackish-water habitats. This represents the most apparent long-term biotic change seen in the lagoon.

In recent years, the monitoring program has been shifting to accommodate management needs while preserving core long-term elements. Such changes include monitoring of mouth condition, installation of a weather station, and development of real-time data delivery. In addition, Los Penasquitos Lagoon has been a focal location in a region-wide assessment of eutrophication in coastal lagoons, and continuing analyses of the results of this work will provide a better picture of both abiotic and biotic responses to nutrient loading. Consideration of further adaptation of the monitoring program is also warranted. Future directions should include periodic use of CRAM, the California Rapid Assessment Method (after appropriate CRAM training). Also, monitoring efforts should increasingly use continuous monitoring, use of sensors to obtain better quantification of freshwater inputs, and expanded water quality monitoring with dataloggers in order to better characterize the temporal and spatial dynamics of hypoxic events. Through such efforts the LPL monitoring program can continue to provide the tools necessary for successful adaptive management of this urban lagoon.

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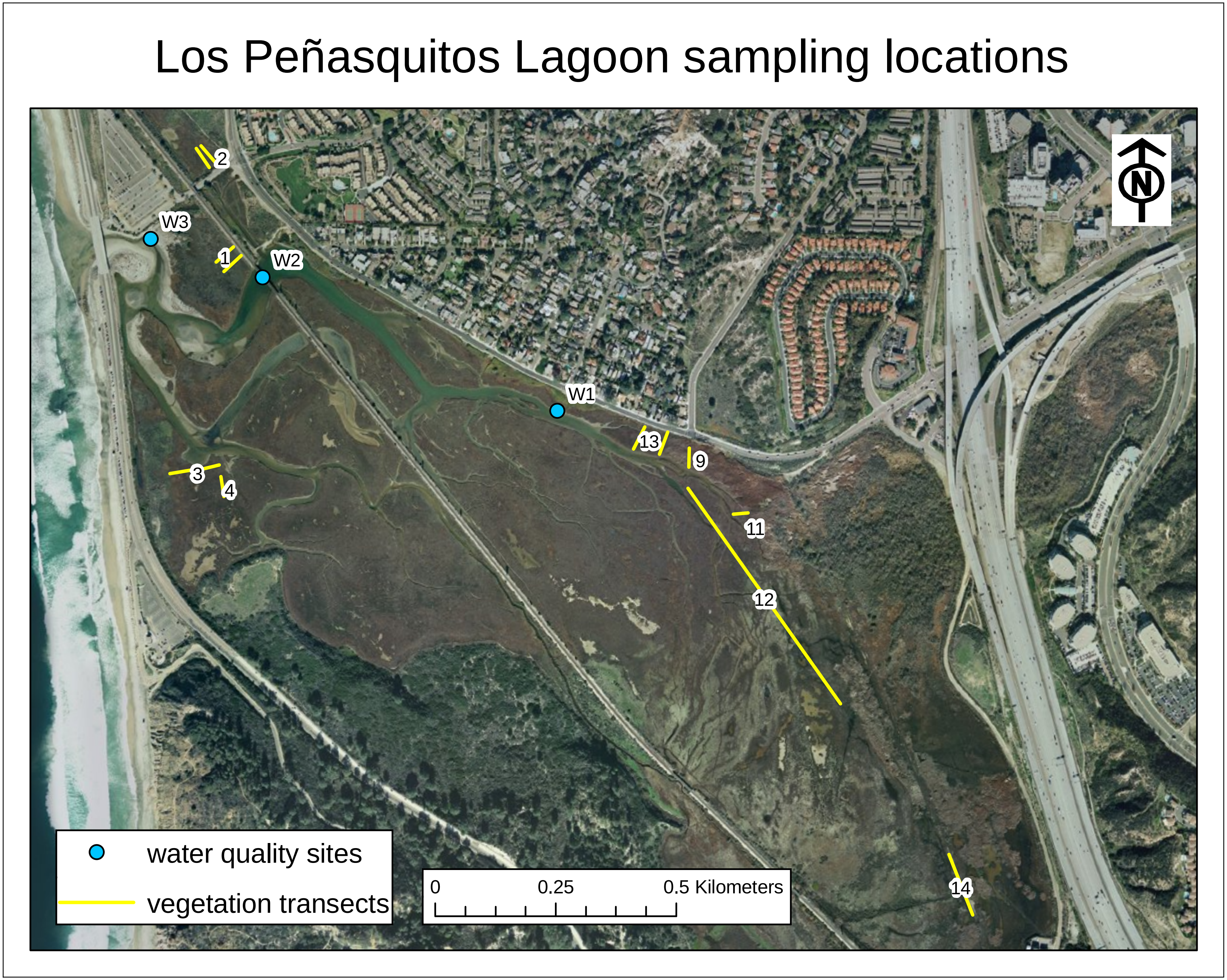


Figure 1. Location of Los Peñasquitos Lagoon sampling stations

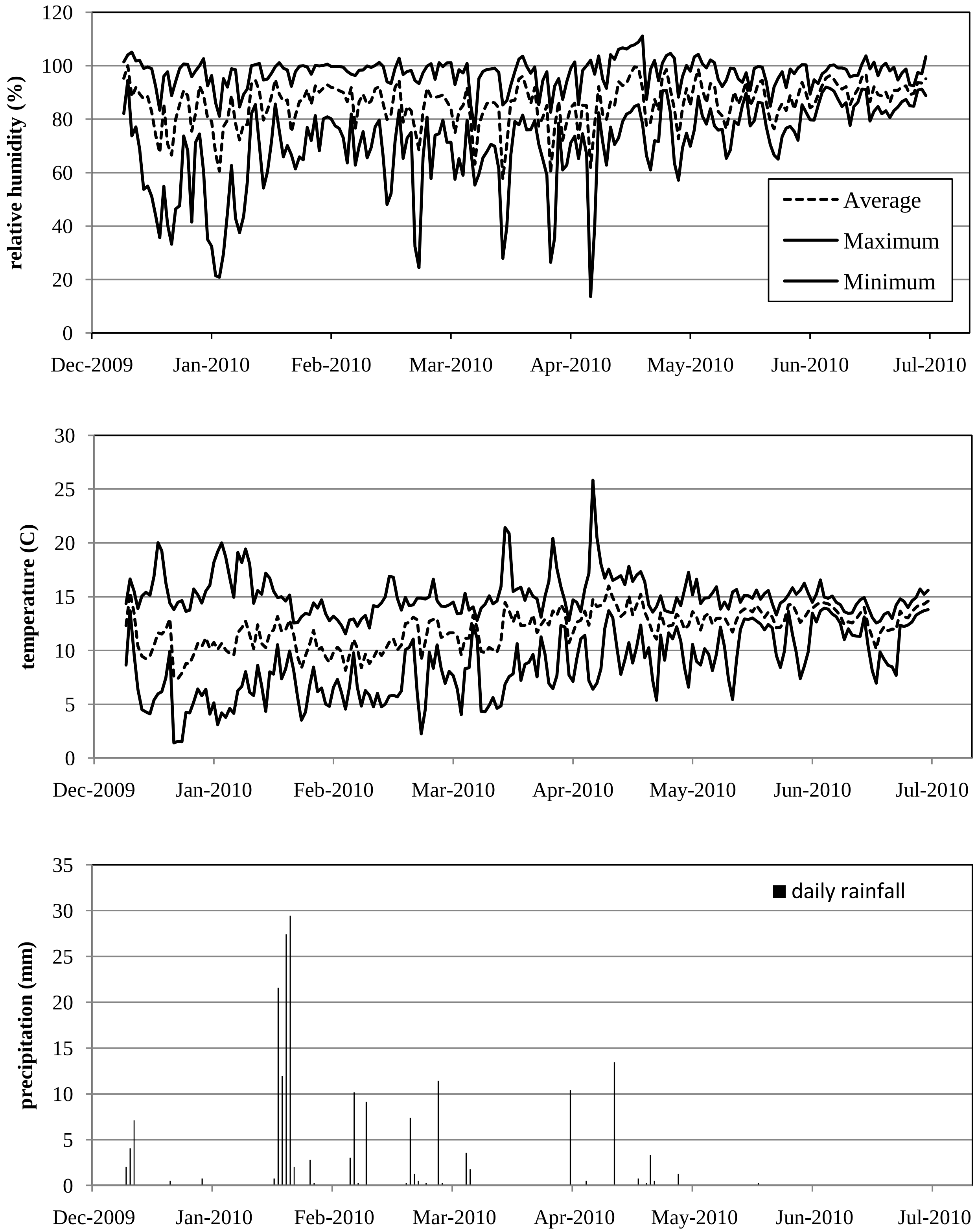


Fig 2. Relative humidity, temperature, and precipitation values from the Los Peñasquitos Lagoon weather station.

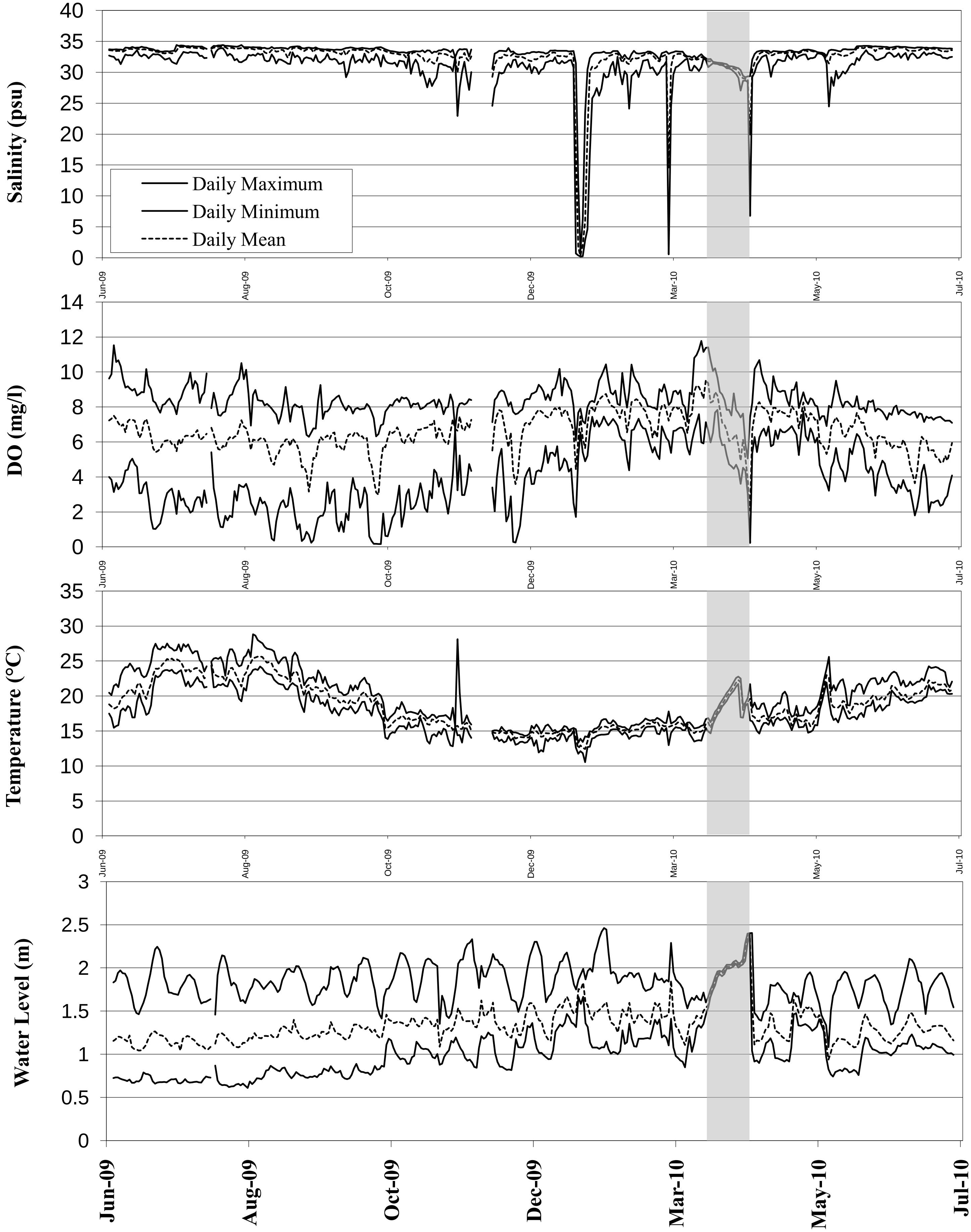


Figure 3. Daily mean, maximum and minimum water quality values taken at station W2 using a YSI model 600xlm datalogger from July 1, 2009 - June 30, 2010. Level readings are relative to sensor depth which is located approximately 0.3 m above channel bottom. Gray bars indicate when the mouth was closed.

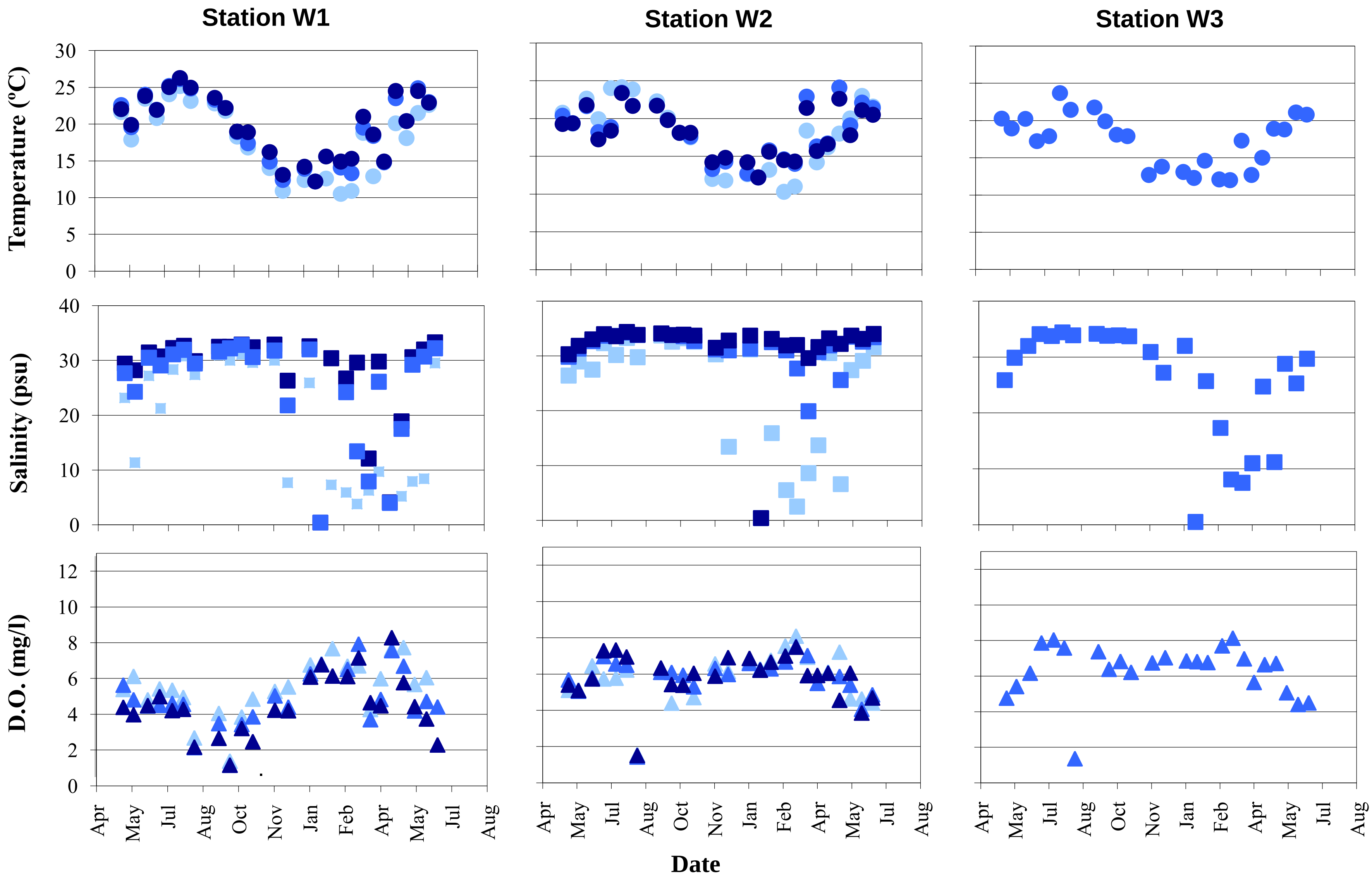


Figure 4. Channel surface (light blue), middle (blue) and bottom (dark blue) water quality parameters at Los Peñasquitos Lagoon from July 1, 2009 - June 30, 2010.

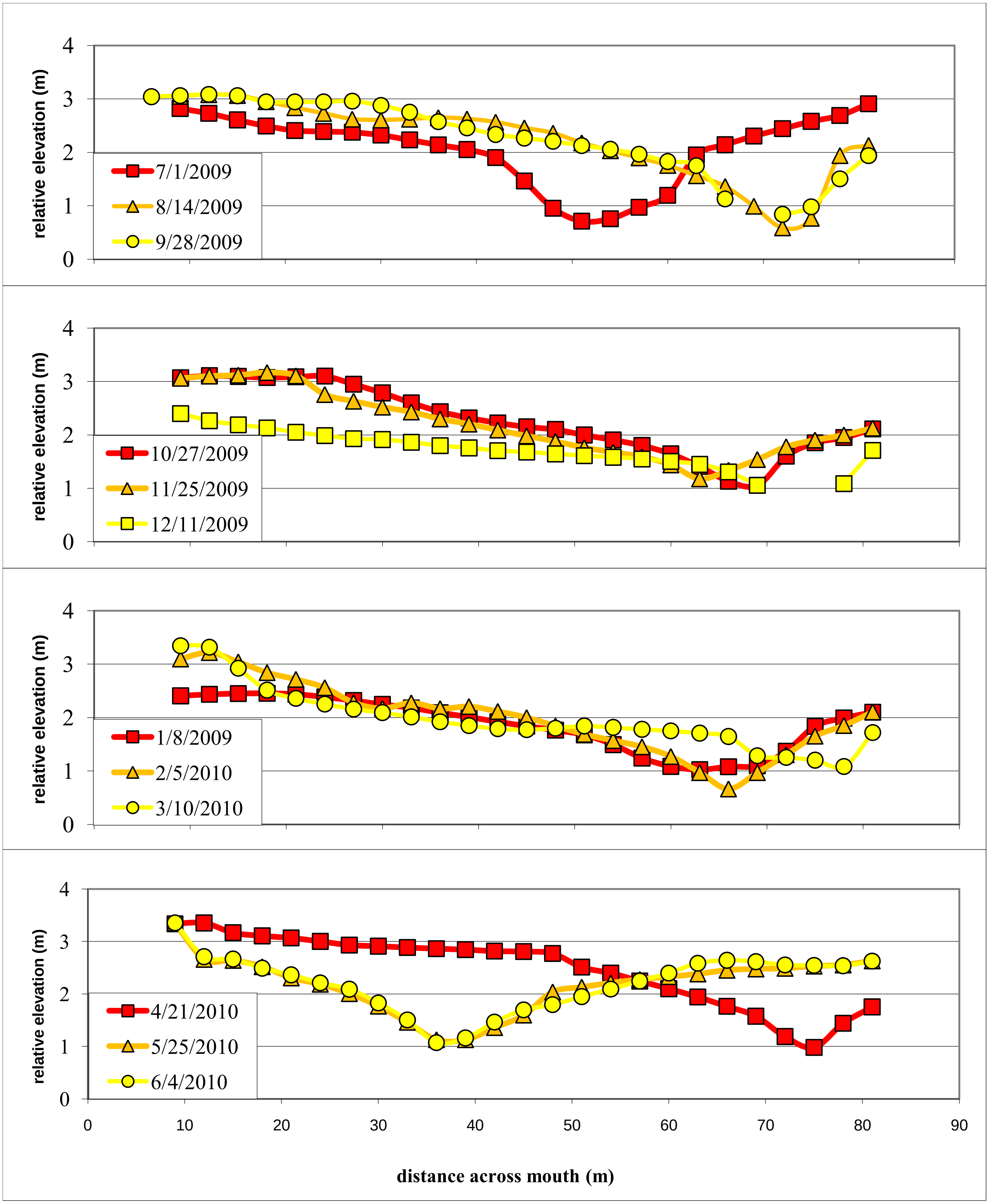


Figure 5. Monthly depth profiles at the Los Peñasquitos lagoon mouth, July 2009 - June 2010. Distance across mouth is shown from south (0m) to north (90m).

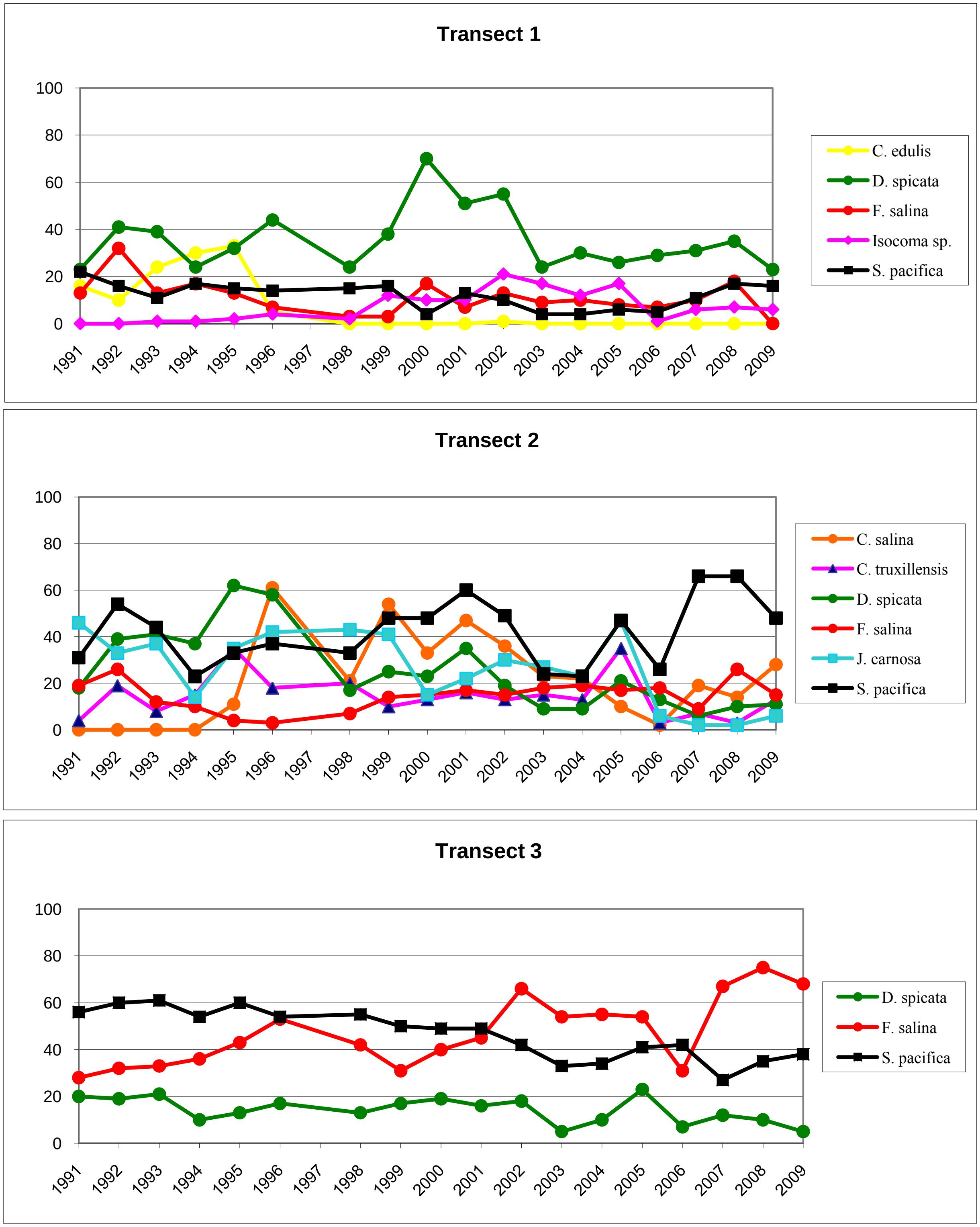
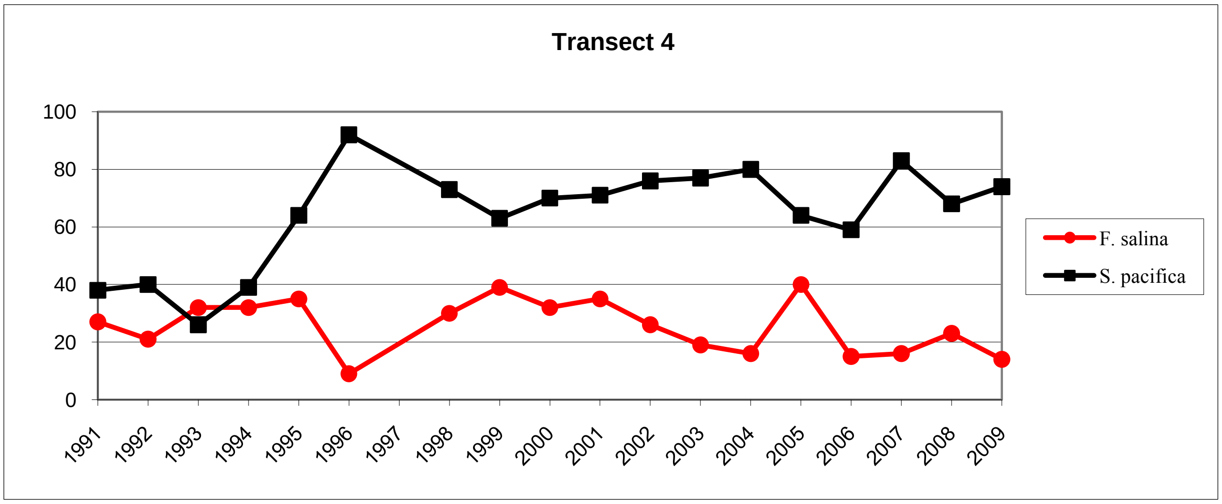
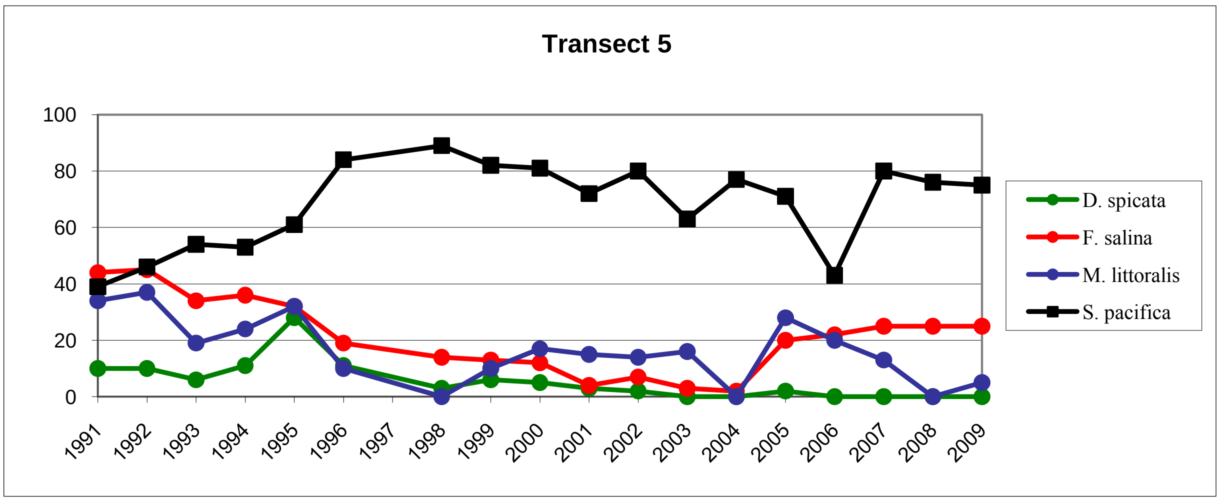


Figure 6a. Percent cover of dominant species along vegetation transects 1 - 3 at Los Peñasquitos Lagoon from 1991 through 2009.





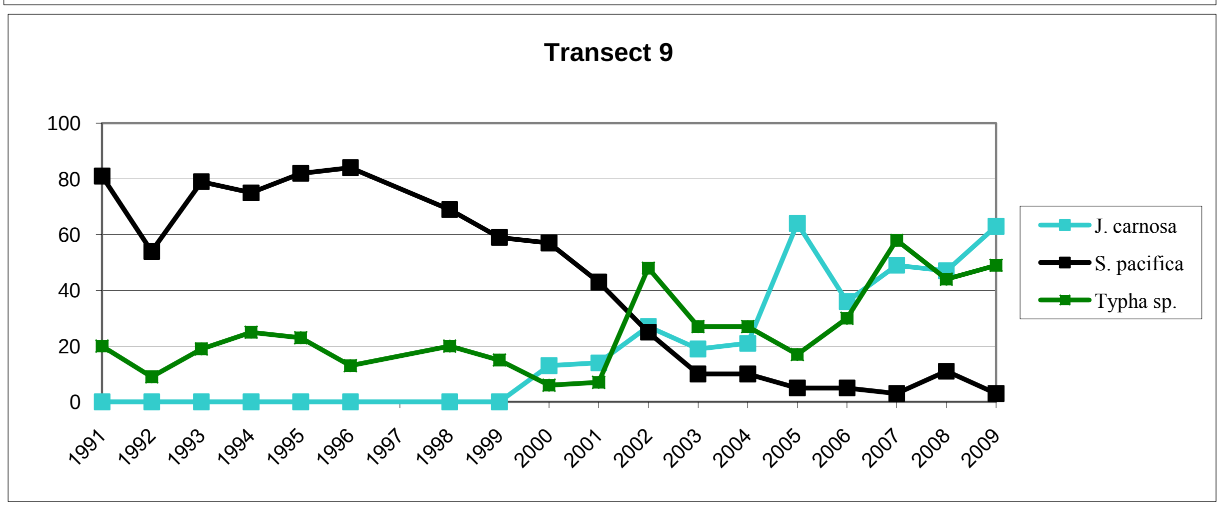
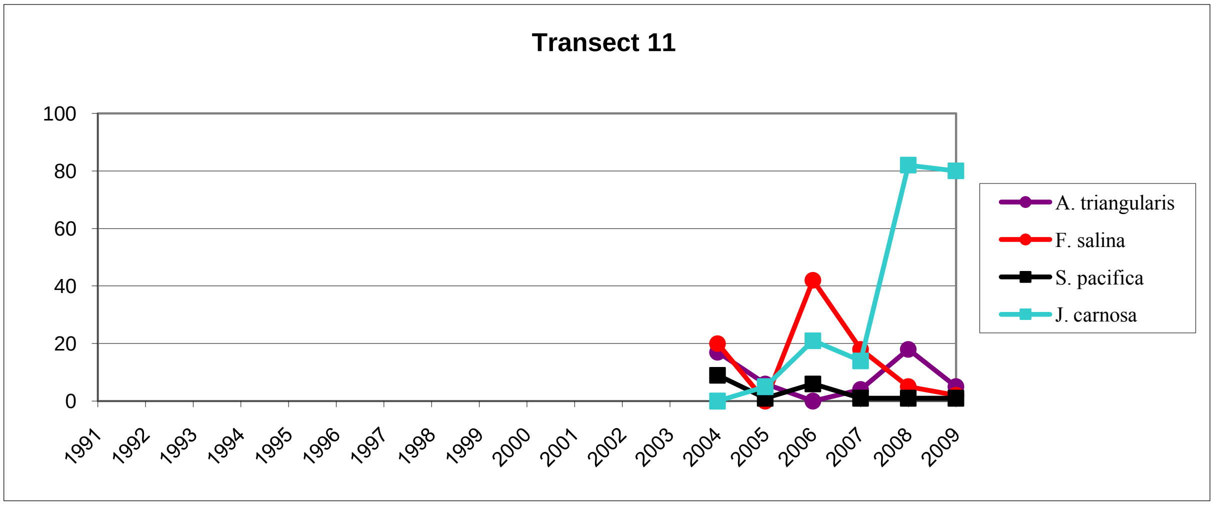
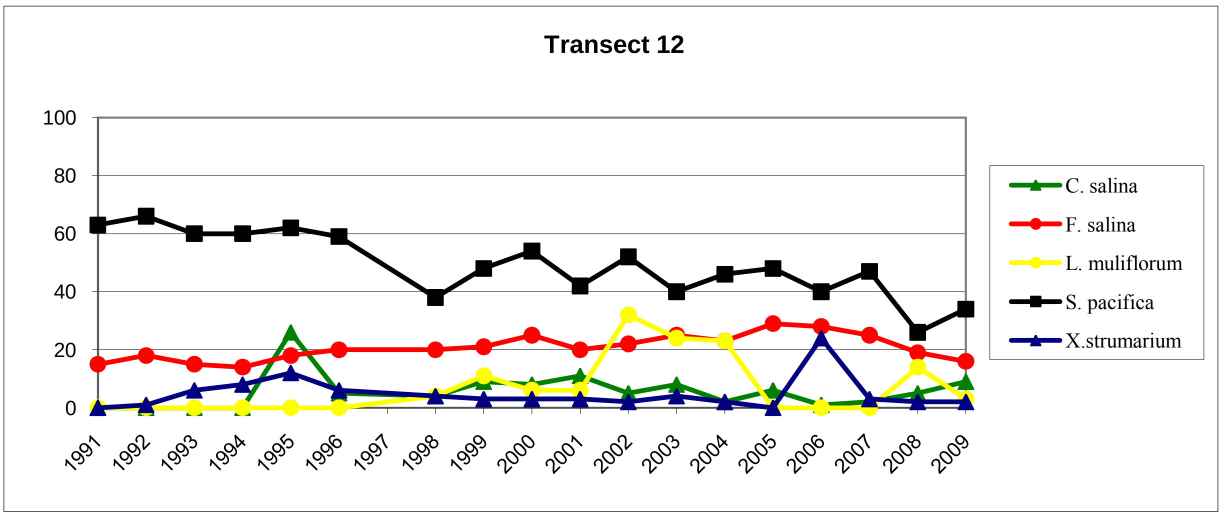


Figure 6c. Percent cover of dominant species along vegetation transects 4 - 9 at Los Peñasquitos Lagoon from 1991 through 2009.





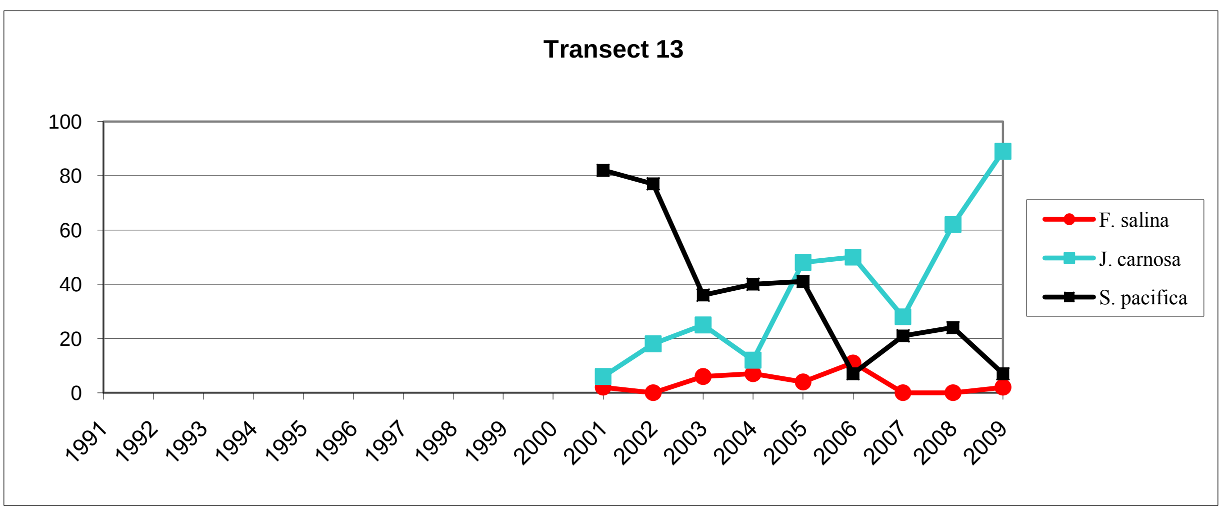


Figure 6c. Percent cover of dominant species along vegetation transects 11 - 13 at Los Peñasquitos Lagoon from 1991 through 2009.

Table 3. Mean percent cover and soil salinities on Los Peñasquitos Lagoon fall vegetation transects, fall 2009.
Asterisks indicate species that were completely or partially dead at the time of sampling.

Transect #	1	2	3	4	5	9	11	12	13
Mean soil salinity (ppt)	13	30	44	46	59	34	17	28	37
Range of soil salinity (ppt)	4 to 22	14 to 49	24 to 63	30 to 66	26 to 88	28 to 40	14 to 20	10 to 46	26 to 54
Mean total % cover	59	95	98	85	100	98	83	84	99
Mean % cover of individual species									
Saltmarsh species									
Arthrocnemum subterminale	4								
Cressa truxillensis	2	13	2		1			4	
Cuscuta ssp.		28	2	0.3	0.1		8	9	20
Distichlis spicata	23	11	5			33	2	1	3
Frankenia salina		15	68	14	25		2	16	2
Jaumea carnosa	3	6				63	80	19	89
Monanthochloe littoralis					5				
Salicornia bigelovii		7						1	
Sarcocornia pacifica	16	48	38	74	75	3	1	34	7
Transition species									
Atriplex triangularis	0.05					1	5	3	
Atriplex watsonii			0.2						
Baccharus sarothroides								0.1	
*Bolboschoenus maritimus**						1		2	4
*Cakile maritima**	0.5								
Heliotropium curassavicum	0.1								
Isocoma menziesii	6								
Juncus sp.									5
Pluchea odorata						1		5	
*Pterostegia drymarioides**	1								
Symphyotrichum subulatum								0.1	
*Typha sp.**						49		6	
*Xanthium strumarium**								2	
Exotic species									
Helminthotheca echioides								0.1	
*Lolium multiflorum**								3	
*Mesembryanthemum crystallinum**	1								
*Polypogon monspeliensis**	2							2	
*Rumex crispus**								0.2	
*unidentified Poaceae**								3	
Transect length	100	100	100	80	50	40	90	675	50
Number of quadrats	22	22	21	17	11	9	7	140	11

Table 4. Mean percent cover and soil salinities on Los Peñasquitos Lagoon vegetation , March 2010.

Transect #	1	14
Mean total % cover	78	88
Mean % cover of individual species		
Saltmarsh species		
Arthrocnemum subterminale	4	2
Cressa truxillensis	1	1
Cuscuta salina	0.1	0.3
Distichlis spicata	11	9
Frankenia salina	8	7
Jaumea carnosa	2	9
Monanthochloe littoralis		1
Sarcocornia pacifica	10	46
Transition/Upland species		
Amblyopappus pusillus	11	
Ambrosia sp.	0.2	
Atriplex triangularis	0.05	0.1
Encelia californica	0.5	
Gnaphalium sp.	0.5	
Heliotropium curassavicum	1	
Isocoma menziesii	15	
Lasthenia glabrata		14
Pterostegia drymarioides	12	
Rumex sp.	0.2	
Spergularia marina		0.03
Exotic species		
Bromus hordeaceus	0.1	
Cotula coronopifolia	1	5
Ehrharta longiflora	4	
Hordeum sp.		0.1
Medicago polymorpha	0.1	0.2
Oxalis pes-caprae	4	
Parapholis incurva		3
Raphanus sativus	1	
Sonchus sp.	0.2	0.03
Tetragonia tetragonioides	0.2	
unidentified Poaceae	0.3	1
Transect length	100m	140m
Number of quadrats	22	29