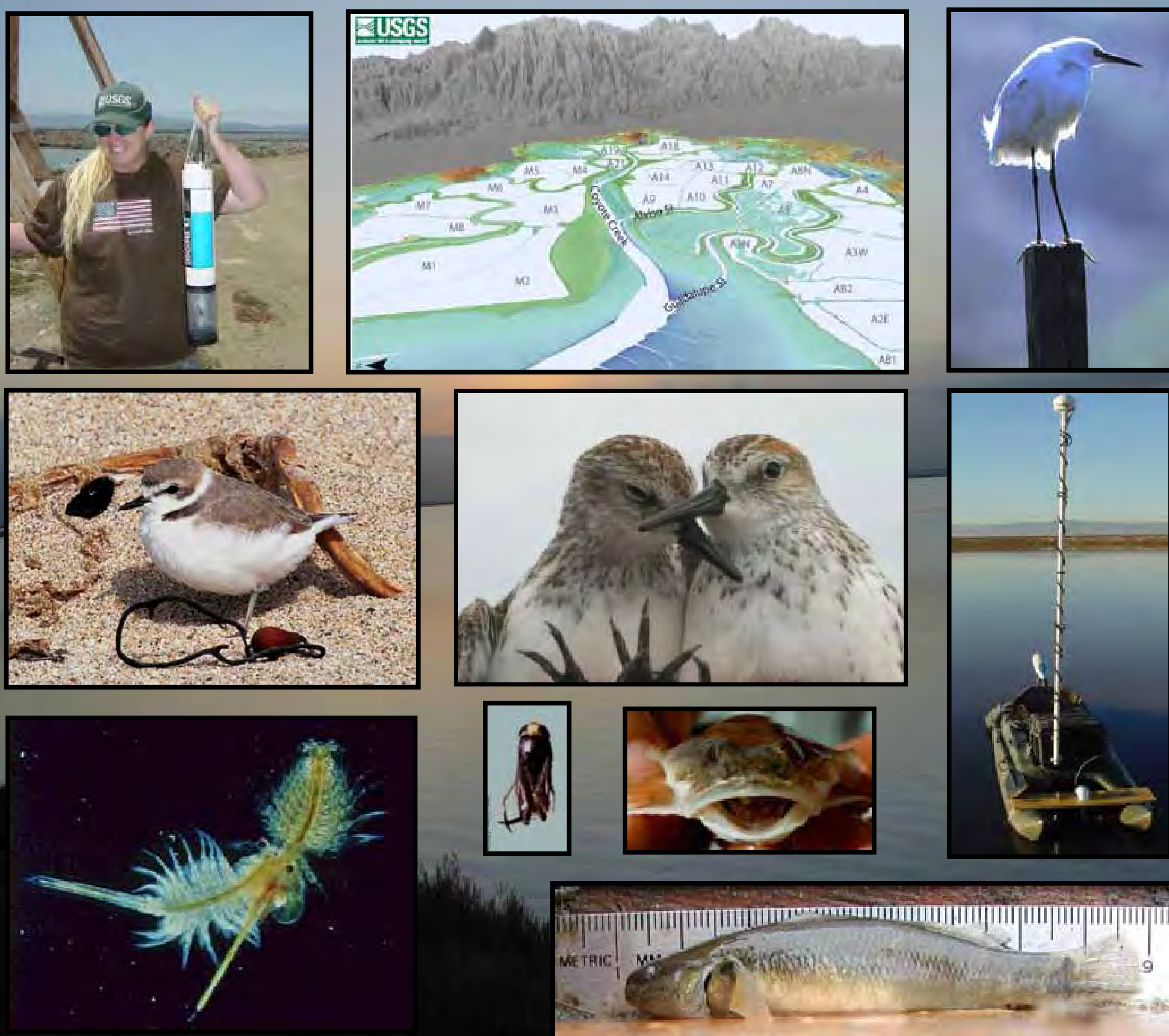
South Bay Salt Ponds Restoration Project
Short-term Data Needs, 2003-2005
Draft Final Report



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U. S. Geological Survey, Western Region

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South Bay Salt Ponds Restoration Project, Short-term Data Needs, 2003-2005 Draft Final Report

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EXECUTIVE SUMMARY

- A partnership of federal, state, and non-profit agencies purchased 15,100 acres of South Bay salt evaporation ponds for management by the U. S. Fish and Wildlife Service (FWS) and California Department of Fish and Game (DFG) in 2003. These ponds represent an opportunity to restore lost tidal marsh habitat, but they also support large numbers of waterbirds and have become an integral part of the ecosystem over the past 150 years. Restoration planning and early actions are now underway to create a mixture of managed pond and tidal wetland habitat, but several data gaps have been identified that are essential to the planning and restoration process.

- The U. S. Geological Survey (USGS) began data collection efforts to fulfill priority project data needs in the spring 2003. These efforts were discussed with and funded by the State Coastal Conservancy (SCC), FWS, and DFG, supplemented by USGS science programs including the Priority Ecosystem Science (PES) Initiative, under which USGS has been studying salt pond ecosystems in the Bay since 1998. The interdisciplinary USGS science support team is providing the restoration project with a comprehensive assessment of the ecology of the San Francisco Bay salt ponds, baylands, and linked shallow water wetlands, such that optimal management strategies can be exercised that maximize benefits to wildlife. These data will provide a scientific basis for decisions supporting further research and monitoring as well as adaptive management actions. The short-term needs data provided in this report are intended to provide resource managers with critical baseline data for the restoration project.

- We developed 3 different bathymetry datasets: ponds, LIDAR, and seabed. Pond datasets were derived for 35 inundated salt ponds with a specialized shallow water sounding system created by USGS (Water Resources and Biological Resources) for the task. In 2004, point data along transect lines spaced at 50-100 m were interpolated to 25-m grid files, and converted to GIS coverages. Water depths were converted to the NAVD88 datum on the basis of staff-gage surveys from Fremont Engineers contracted by Cargill Corporation. These staff-gage surveys were distributed without metadata, so the bathymetry datasets were distributed in August 2004 with metadata files that noted the limited staff-gage information. An engineer with the consultant team found a discrepancy in the extrapolated elevations in January 2005, which was brought to our attention in May 2005. After determining that staff gages were measured differently, we sent a correction notice and revised elevation dataset for some ponds although the original water depths did not change.

- A LIght Detecting And Ranging (LIDAR) laser system (Terrapoint, Inc., managed by USGS Coastal and Marine Geology) was used to generate one of the most detailed elevation maps ever created of mud flats in an estuary. A grid of returns was created at

1-m resolution in an ASCII file, and those points were converted into 1 m and 25 m coverages, partitioned into tiles. Contours generated at 50-cm intervals were made available in AutoCAD (DWG) format. One-meter resolution hill-shaded images of both the bare earth and full feature data sets were created in GeoTIFF format. In addition, digital video imagery was collected at 2 frames per second during all flight missions and geo-referenced in AVI format with accompanying GPS files designed for viewing with Trident 3D Vision software.

- A seabed bathymetry survey of the South Bay was conducted by Sea Surveyors from 10 January to 5 April, 2005 under direction of Coastal and Marine Geology. The survey area was 250 km^2, extending northward from Coyote Creek in the south to San Leandro Marina on the east and Coyote Point on the west, encompassing the three purchased pond systems (Eden Landing, Alviso, and Ravenswood). A database of 450,000 seabed classification records was generated from an area of 78 km^2. Ten acoustic classes were identified representing the spatial distribution of estuary sediments segmented into tidal flat, nearshore, shelf, channel, and dredged sediments. Sediment data from 180 grab and core samples, and benthic community composition data from 10 bottom samples were collected to refine the classification scheme.

- Because the salt ponds were created with dredge materials, the soil types in the majority of ponds were found to have high clay, moderate silt content, and lower sand content, with the exception of West Bay ponds, which had higher sand content than the other areas. Slough sediment samples were generally lower in salinity and organic carbon content. Slough sediments were mainly silty clay loam, having higher sand and silt content than pond sediments.

- Organic carbon levels detected in Alviso ponds ranged from 1.15 – 4.46 mg/L, mean 2.76 mg/L; Eden Landing ponds ranged from 1.52 – 4.30 mg/L, mean 2.64 mg/L, and Ravenswood ponds ranged from 0.92 – 2.93 mg/L, mean 1.46 mg/L. As salt ponds are converted to marshlands, high organic carbon may be a determining factor for invertebrates and contaminants. Most NH4-N and NO3-N nutrient levels were relatively low, similar to those associated with unpolluted surface lake waters. Concentrations well above 10 mg/L are associated with anaerobic or polluted conditions, but only Pond B6B approached the 10 mg/L level.

- Water quality was collected monthly in all 53 purchased salt ponds. Temperature in the ponds follows a seasonal signal with highest temperatures in the summer. Between-pond temperature differences were typically less than 5ºC, except during the fall when the differences can exceed 6ºC. Salinity in the ponds is influenced primarily by rainfall during the wet winter season, and evaporation and water transfers during the dry season. Highest salinities are typically seen in the late summer and fall, especially for the higher salinity ponds. Water quality (salinity, temperature, pH, and dissolved oxygen) of ponds changed under the Interim Stewardship Plan are available in separate reports.

- Opening the salt ponds to tidal action will create multiple new sediment sinks in South Bay and will affect suspended sediment concentrations (SSCs) and net sedimentation in the Bay. In order to evaluate sediment sources, sinks, and deposition, a sediment budget for South Bay was developed using a sediment transport box model. A 10% predicted decrease in South Bay SSCs from opening additional South Bay area to tidal action will increase the likelihood that South Bay could experience a phytoplankton bloom in any given year. However, the effect of the increased likeliness of a bloom is less than the inter-annual variability in water column clearing rates caused by inter-annual variability in benthic grazing rates.

- A salt pond box model (SPOOM) was created to predict how water transfers will affect the salinity and depths in the ponds. Both salinity and depth are critical parameters for habitat modification and restoration. The same sediment transport box model was used to simulate the affect of adding breached ponds to the system to learn how it could change the sediment budget. These simulations allowed a landscape-scale geomorphic assessment of restoration alternatives.

- Distribution of wetland vegetation was studied along three slough sites (Corkscrew Marsh, Bird Island and Palo Alto Baylands) to predict evolution of wetland plants during pond restoration. Salt marsh vegetation ranged in elevation from 0.98 to 2.94 meters above MLLW. *Spartina foliosa* and *Salicornia virginica* were the most frequently observed plant species. *Atriplex patula*, *Deschampsia cespitosa* and *Limonium californicum* were each recorded at only one of the three sites.

- We identified 58 different taxonomic groups of macroinvertebrates in ponds. The most abundant and diverse group was the Crustacea with 17 different taxa, followed by 12 different genera of Annelids, mostly in ponds with salinity levels below 60 ppt. There were 5 different species of bivalves, and 9 insect families. Ponds with lowest salinity (27-44 ppt) had greatest taxa richness. There was a relationship between increasing salinity and decreasing richness in benthic grabs. Insecta taxa (Corixidae, Diptera and Ephydra) were positively correlated with salinity ($R^2 = 0.37$, $P<0.001$) as was Artemia ($R^2 = 0.41$, $P<0.001$); Crustacean genera Ampelisca and Corophium were negatively correlated with salinity ($R^2 = 0.56$, $P<0.001$) as were Capitella, Polydora, *Streblospio*, and Tubificoides ($R^2 = 0.50$, $P<0.001$).

- Samples from 8 sloughs in 2004 were dominated with *Heteromastus*, *Streblospio* and Tubeficoides. *Gemma gemma* was abundant in Mt. Eden Creek (162.6 per Ekman) and Alameda Creek (29 per Ekman) and *Macoma balthica* was present in all sloughs with largest numbers found in the Alameda Control Channel (25 per Ekman). Insecta were present in only 3 sloughs with greatest taxa richness in Mt. Eden Creek (4 species). Chironomidae was present in Mt. Eden Creek and the Alameda Flood Control Channel. Corixidae and Diptera were detected in Mt. Eden Creek and Alameda Creek. *Cumacea* were present in all sloughs and were the most abundant Crustacean in slough samples.

- A total of 10,258 fish representing 19 species and 16 families was caught during 2004. Of the 19 species, 13 were caught in ponds and 16 in sloughs. The greatest numbers of fish were captured with bag seines, followed by gill nets, then by minnow traps. Fish abundance was highest in June and lowest in November.

- Avian use of salt ponds varied by foraging guild, pond, and season. Alviso constituted 57% of total pond area, but supported 92% of gulls and terns and 90% of dabbling ducks counted between November 2003 and June 2005. Alviso also supported 73% of diving ducks, 72% of eared grebes, 66% of herons, and 63% of fish eaters and phalaropes. Eden Landing ponds were shallower and supported the highest proportion of shorebirds -- 52% of large shorebirds and 44% of small shorebirds between November 2003 and June 2005, despite comprising only 31% of total pond area. Eden Landing also supported 35% of fish eaters, 32% of herons, 27% of eared grebes, 24% of divers, 12% of phalaropes, 10% of dabblers, and 7% of gulls and terns. Ravenswood comprised only about 11% of total pond area and supported 31% of small shorebirds between November 2003 and June 2005. Ravenswood also supported 26% of phalaropes and 12% of medium shorebirds – counts of all other foraging guilds made up less than 5% of the total salt pond count.

- We completed Interim Stewardship Plan (ISP) analyses requested by the Project Management Team. We created extensive spreadsheets for birds, fish, and benthic data appended with physical data (temp, DO, salinity, pH, size, depth, bay distance) for each pond (available to the PMT on request). We analyzed relationships of bird use to pond conditions and provided information for estimates of richness on the spreadsheets. ISP bird survey results and subsampling questions were presented in the Bird Modeling Workshop, and results from multivariate analyses (Canonical Correspondence Analysis) of physical features of similar ponds were presented in the Pond Management Workshop. We initiated analyses that related birds to fish and invertebrate populations and refer to completed analyses in the North Bay (Takekawa et al., *in press*). Relationships of mercury, pond depth, and salinity were included in the interim mercury report, and we summarized foraging behavior of birds by pond. Finally, we are continuing analyses within grids to relate bird use to pond depths.

- The short-term needs data collected during the first two years of the SBSP Restoration Project has provided baseline information to develop a sound scientific foundation upon which management plans and actions may be based. Effective adaptive management of this complex restoration effort will require regular monitoring to detect changes and responses of the resources.

- The wetland mosaic of the entire South Bay will be changing; thus, scientific assessments should include analyses at the regional scale. For example, open bay mud flats are critical resources for migratory birds, but South Bay mud flat elevations may decrease in response to the restoration process. The SBSP Restoration Project will extend for 50 years, but the most valuable scientific investment will be in early phases of the project, since it will influence more of the major restoration decisions. We look forward to the challenge of continuing the USGS science support role for the restoration project.

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INTRODUCTION

During the past 200 years, the San Francisco Bay Estuary has undergone topographical and ecological changes resulting from human growth and development. Nearly 79% of historic salt marshes have been lost, resulting in diminished habitat for native marsh species (Goals Project 1999) and fragmentation of remaining marshlands. Commercial salt ponds were constructed around the fringes of the bay and have been a part of San Francisco Bay's landscape since 1856 (Josselyn 1983). Today, these salt ponds represent not a chance to make commercial use of unusable land but an unprecedented opportunity to reclaim and restore vital habitat for native wildlife. However, salt ponds are also important for migratory birds, and maintaining some land as managed ponds will provide refuge and foraging habitat for hundreds of thousands of wintering shorebirds and waterfowl, as well as unique assemblages of invertebrates and native fishes (Harvey *et al*. 1992, Takekawa *et al.* 2000, Takekawa *et al*., *in press*).

One of the largest wetland restoration projects in North America commenced in March 2003 with the purchase of 6,111 ha (15,100 acres) of former salt evaporation ponds in the South Bay of the San Francisco Bay estuary (Figure 1). A consortium of public and private partners acquired the wetlands, which included 3,236 ha (7,997 ac) in the Alviso complex (25 ponds), 2,206 ha (5,450 ac) in the Baumberg or Eden Landing complex (22 ponds), and 655 ha (1,618 ac) in the Redwood or Ravenswood complex (7 ponds). Alviso and Ravenswood are managed by the U. S. Fish and Wildlife Service, while Eden Landing is managed by the California Department of Fish and Game. The South Bay Salt Ponds (SBSP) Restoration Project was quickly recognized as the largest and most complex wetland restoration undertaking in the Bay; Siegel and Bachand (2002a) identified several complicated issues that could impede restoration actions or increase costs. Subsequently, Siegel and Bachand (2002b) identified short-term information needs that need to be met within the first few years for effective project planning. These needs included biophysical data collection both within the ponds and in the adjacent sloughs and were reviewed by the project management team to determine priorities.

Project objectives include maintaining current migratory bird use of salt ponds while supporting increased populations of native species that use tidal marsh habitat. Only a few descriptive studies (Carpelan 1957, Anderson 1970, Lonzarich and Smith 1997) of ecological processes of the salt ponds had reported on their value for wildlife. Although hypersaline systems such as salt ponds typically support simple assemblages of biota, the physical and biological processes affecting these assemblages may be quite complex (e.g., Rodriquez-Valera *et al*. 1985, Caumette *et al*. 1994; Pinckney and Paerl 1997). Ecological interactions and physical processes in these artificial salt ponds are poorly understood (*see* Lonzarich and Smith 1997), but the importance of lower trophic organisms and their use by migratory waterbirds has been supported by our prior research (Miles *et al.* 2000, Takekawa *et al*. 2000, Miles *et al.* 2004, Takekawa *et al. in press*) and identified in similar systems (e.g., Herbst and Bradley 1993, Elphick and Rubega 1995; Herbst and Castenholz 1995).

Managers and conservation organizations have supported conversion of most salt ponds to tidal wetlands to benefit tidal marsh resident species of concern. Additionally, the project management team has acknowledged that some ponds should remain as managed salt ponds, as artificial salt evaporation pond systems have become integral habitat for wildlife in the estuary during the past century and currently support massive diverse and unique communities of migratory birds, invertebrates, and fishes (Ver Planck 1958). However, no guidelines, model, or management strategies exist for converting ponds to tidal wetlands, nor for maintaining salt ponds at desired depths and salinities when ponds are no longer part of a salt-making system. Because very high bird densities have been observed on a few ponds, managers hope to optimize features of the managed ponds remaining after restoration to support past numbers of migratory and wintering birds. However, avian pond selection criteria are not fully understood, and seemingly similar ponds often show high variation in bird use. More information will be needed to successfully manage habitat that will support the historic bird numbers that make San Francisco Bay an important migratory stopover site on the Pacific Flyway and a Western Hemispheric Shorebird Reserve Network area of hemispheric importance.

The restoration of subsided ponds to tidal wetlands presents many challenges as well, particularly due to a lack of detailed and reliable information on project area elevations and sediment supply. Siegel and Bachand (2002a) identified sediment supply as a key constraint to salt pond restoration. Some of the South Bay sloughs are filling with sediment according to several observations, perhaps because subsidence caused by groundwater overdraft has ceased. An evaluation of sediment sources, sinks, and deposition is necessary to understand how these processes may affect restoration timing, project costs, and potential action to minimize erosion of South Bay mud flats.

After consultation with management agencies, the U. S. Geological Survey (USGS) began a program to fulfill priority project data needs in the spring of 2003. These efforts were supported by the State Coastal Conservancy (SCC) and supplemented by the USGS Priority Ecosystem Science Initiative, under which we have been studying salt pond ecosystems in SFB since 1998. Data provided from this multidisciplinary effort are intended to provide resource managers with a comprehensive assessment of the ecology of the South Bay salt ponds and linked shallow water systems, such that optimal management strategies can be exercised that maximize benefits to wildlife. These data will provide a scientific baseline for decisions supporting further research and monitoring during the restoration, as well as for adaptive management actions. Beyond this USGS final report, we also have provided interim products including the following:

- Jan04 – Salt Pond Nutrient Report
- Feb04 – South Bay Sediment Budget (presented at American Society of Limnology and Oceanography meeting)
- Mar04 – Draft Data Gaps Summary Report
- Jun04 – South Bay Mud Flat Invertebrate Report
- Jul04 – Salt Pond and Slough Sediment Report
- Jul04 – Draft Channel Marker 17 Data Report
- Aug04 – Pond Bathymetry Data and Metadata (CDROM)
- Sep04 – Sediment Synthesis for the SBSP Restoration Project (delivered to the National Science Panel)
- Nov04 – GIS Coverages of the Pond Bathymetry (delivered to the project consultants)
- Apr05 – Coyote Creek Suspended Sediment Report
- Mar05 – Pond Bathymetry Correction Memorandum
- Aug05 – USGS Open-File Report (OFR-2005-1284) on 2004 LIDAR Survey

OBJECTIVES

The primary goals of the short-term data needs studies were to provide baseline data for the SBSP Restoration Project and to provide a scientific basis for adaptive management decisions.

Objective 1. Complete bathymetry and levee habitat mapping of ponds in the purchase agreement for interim management and hydrological modeling of restoration scenarios.

Objective 2. Characterize sediments, primary productivity, invertebrate composition, and fishes in ponds for salinity reduction and initial phases of restoration.

Objective 3a. Continue monthly monitoring of water quality concurrent with bird surveys to document baseline levels and to track changes.

Objective 3b. Complete Self-Monitoring Program (SMP) sampling and reports to document compliance with discharge requirements during the initial desalination.

Objective 4. Assess the hydrology and present morphology of the South Bay sloughs by analyzing existing data augmented with collection of new data.

Objective 5. Characterize invertebrate and fish communities in the slough systems and compare with South Bay pond communities.

Objective 6. Assist in development of a land surface elevation map for the South Bay region and map South Bay open bay and slough bathymetry.

METHODS

Objective 1. Complete bathymetry and levee habitat mapping of ponds in the purchase agreement for interim management and hydrological modeling of restoration scenarios.

Scientists from Water Resources and Biological Resources developed a shallow-water sounding system comprised of a single beam echosounder (Navisound 210, Reson), a differential global positioning system unit (DGPS, Trimble) and a laptop computer in a water-resistant case affixed to a shallow-draft, double-hulled kayak with a salt water trolling motor. This system proved effective in measuring water depths with a precision of 1 cm. Twenty depth readings and one GPS location were recorded each second; we obtained the average of twenty depth values per location during post-collection processing (SAS Institute, 1990).

Where ponds contained water of sufficient depth to use the equipment, we obtained sample transects at 100-m intervals. Because sample depths were converted to elevation based on water surface elevation, we obtained staff gage readings at 15-20 minute intervals to ensure that pond water levels did not change during the survey. We successfully sampled 35 inundated ponds, most sampled between August 2003 and March 2004. Each required 1-4 days to sample depending on pond size and sampling conditions. Prior to and following each sampling event, we checked the equipment for accuracy by performing a physical measurement of depth (with a bar check system or measuring pole) and compared it to the transducer reading. Raw data were compiled, reformatted, and converted to latitude, longitude, and depth measurements based on staff gage readings and known staff gage elevations (see individual pond metadata files for details). Data were converted to point shapefiles (ArcGIS, ESRI, Redlands, CA) and interpolated to 25-m ESRI grids (ESRI Spatial Analyst) using the inverse distance weighting method with barrier polylines to more realistically represent known topographical features.

Objective 2. Characterize sediments, primary productivity, invertebrate composition, and fishes in ponds for salinity reduction and initial phases of restoration.

Our goal was to develop a baseline characterization of the physical and biological parameters of all 53 ponds in the South Bay salt pond systems (Alviso, Eden Landing, and Ravenswood). We sampled primary productivity and nutrients in water, basic structure and chemistry of sediments, and invertebrate composition from April - June 2003. Some ponds were dry during the initial sampling period and were sampled the following spring after recent rains left standing water in the ponds.

Sediments

Sample Collection.-- Sediments were sampled from a motorized 3.7-m flat bottom boat, using a standard Ekman dredge (15.2 cm wide x 15.2 cm long x 15.2 cm high), also known as a benthic grab sampler. Samples were collected from 3 randomly selected accessible locations within each pond. Some ponds were not sampled due to inaccessibility and or dry conditions. If the water level was too low for a boat to traverse the pond, ponds were sampled from the borrow ditches which run along the inner perimeters of these ponds or by wading out to the nearest inundated areas to collect samples. In dry ponds, we traversed across the dry pond bottom until we reached the nearest inundated areas. GPS coordinates of sampling locations were recorded.

For each sample, 2 kg of sediment were collected. Samples were collected by lowering the dredge into the water, holding it level on the substrate and releasing the trigger. Soft, muddy substrates consistently produced samples that filled the Ekman, whereas on hard substrates only a portion of the sampler was filled. When substrate was deemed too hard for the Ekman, samples were collected using hand trowels or shovels. Grab samples were placed in a ziplock bag and transported to the University of California, Davis, Department of Natural Resources Laboratory (DANR) for processing.

*Soil Salinity Sample Analysis.--*The soil was saturated with water and subsequently extracted under partial vacuum of the liquid phase for the determination of dissolved salts. Soil moisture at complete saturation was estimated as the maximum amount of water held when all the soil pore space is occupied by water and when no free water has collected on the surface of the paste. The saturation percentage was twice the Field Capacity (FC) or -33kPa soil water potential and four times the Permanent Wilting Point (PWP) or –1500 kPa soil water potential for soils of loam to clay loam texture. From the saturated paste extract, estimates of Na^+ were completed with a reproducibility within 8%.

Physio-Chemical Analyses.--Organic Matter (OM) was quantified by potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement (modified Walkley-Black). The amount of oxidizable organic matter was quantified in which OM was oxidized with a known amount of $Cr_2O_7^{2-}$ in the presence of sulfuric acid. The remaining Cr^{3+} chromate was determined spectrophotometrically at 600nm wavelength. The calculation of organic matter is based on organic matter containing 58% carbon. The method had a detection limit of approximately 0.01% and was reproducible within 8%.

Physio-Chemical Analyses.--Particle size analysis (sand/silt/clay) quantified the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size was based on the dispersion of soil aggregates using a sodium hexametaphosphate solution and subsequent measurement based on changes in suspension density. The use of the ASTM 152 H-Type hydrometer was based on a standard temperature of 20°C and a particle density of 2.65 g cm^{-3} and units were expressed as grams of soil per liter. Corrections for temperature and for solution viscosity are made by taking a hydrometer reading of a blank solution. The method had a detection limit of 1% sand, silt, and clay (dry soil basis) and was generally reproducible within 8% (relative).

Primary Productivity and Nutrients

Sample Collection.--Water and most other samples were obtained using a motorized 3.7 m flat bottom boat. Water samples were collected from 3 randomly selected locations within each pond, depending on access. If the water level was too low for a boat to access, ponds were sampled by wading to wet areas or from barrow ditches found along the inner perimeters of ponds. Some ponds were not sampled initially due to inaccessibility or dry conditions. GPS coordinates of all sampling locations were recorded.

Water was collected over a 5-day period (20, 21, 28 May, and 10, 11 June). Water samples were collected in dark Nalgene bottles and kept on ice. On site or *in vivo* fluorescence was measured in samples with a Self-Contained Underwater Fluorescence Apparatus (SCUFA); these samples were then filtered and frozen for chlorophyll extraction within 8 hours usually at the U. S. Geological Survey Laboratory in Menlo Park (courtesy of Cary Lopez, Tara Schraga) and then processed at the Goldman Limnology Laboratory, University of California, Davis (UCD). Samples for water chemistry were kept cool and dark and transported to the UCD Division of Agriculture and Natural Resources Laboratory (DANR) where nitrogen as nitrate (NO_3-N) and ammonium (NH_4-N), soluble (SP) and phosphorus total (TP) in water, and sulfate (SO_4) were determined.

Chlorophyll Analysis.--The 53 pond complex was expected to have a high range in chemical and biological constituents, therefore fluorescence was measured with the SCUFA, and these readings were calibrated using a complete chlorophyll extraction process. Calibration of the SCUFA can usually occur periodically but because of the high variability among the 53 ponds, the SCUFA was calibrated after each pond was sampled. The SCUFA required calibration against the absolute concentration measured by the spectrophotometer due to changes in sampling environments. Temperature corrected fluorescence was determined with a SCUFA linked to a laptop in shaded conditions. The water from each pond was then filtered using a hand-pump vacuum manifold onto glass fiber filters. The water was filtered onto 25mm GF/F or GF/C filters. Filtration for each day took up to 7 hours depending on sample set, filter type, and filtration apparatus. Filters were frozen until processing. Following at least 48 hours of frozen storage, samples had 100% acetone added as extracting solution. After a 24 hour extraction period, the samples were then analyzed on a spectrophotometer to measure optical density at absorbance wavelengths of 750µm, 665µm, and 664µm before and after acidification with 0.1M HCl. The concentration of chlorophyll in each sample was then determined using the equation:

chl a =[26.7(664b-665a)*V1]/V2*L

where:

V1 = volume of extract, L
V2 = volume of sample, m^3
L = light path length or width of cuvette, cm and
664b, 665a = optical densities of acetone extract before and after acidification, respectively. These values are "corrected turbidity and are based on the spectrophotometer measurements for all 3 wavelengths (750, 665, and 664).

The value 26.7 is the absorbance correction A*K where:
A = absorbance coefficient for chlorophyll a at 664 nm = 11.0 and
K = ratio expressing correction for acidification.

The relationship between *in vivo* fluorescence recorded by the SCUFA and calculated chl *a* concentration recorded by the spectrophotometer provided a calibration coefficient.

*Nitrate and Ammonium Analysis.--*Nitrate was determined by reduction to nitrite via a copperized cadmium column. The nitrite was then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethlyenediaminie dihydrochloride. The absorbance of the product was measured at 520 nm. Ammonia was heated with salicylate and hypochlorite in an alkaline phosphate buffer. The presence of EDTA prevented precipitation of calcium and magnesium and sodium nitroprusside was added to enhance sensitivity. The absorbance of the reaction product was measured at 630 nm and was directly proportional to the original ammonia concentration. Samples could be stored for up to three weeks at low temperature (<4°C). For longer term storage, toluene or thymol was added to the sample to prevent microbial growth. The method used had a detection limit of approximately 0.05 mg L^{-1} and was generally reproducible within 7%.

*Soluble Phosphorus Analysis.--*The amount of soluble phosphorus in water was determined spectrophotometrically by reacting with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex was reduced with ascorbic acid to form a blue complex which absorbs light at 880 nm. The absorbance was proportional to the concentration of phosphorus in the sample. Samples were analyzed using an automated Flow Injection Analyzer (Lachat). The method had a detection limit of 0.05 mg L^{-1} and was generally reproducible within 5%.

<u>Total Phosphorus and Sulfur Analysis.</u>-The concentration of P and S (*as* SO_4) and a variety of other elements were determined with nitric acid/hydrogen peroxide microwave digestion and Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) with vacuum spectrometer. The methodology used a pressure digestion/dissolution of the sample incomplete relative to the total oxidation of organic carbon. The method had detection limits ranging from 0.1 mg Kg^{-1} to 0.01% and was reproducible within 8%.

Benthic Macroinvertebrates

<u>Sample Collection.--</u>Benthic macroinvertebrates were sampled from a motorized 3.7-m flat bottom boat with a standard Ekman dredge. Samples were collected by lowering the dredge into the water slowly, holding it level on the substrate and triggering the release. Muddy or soft substrates consistently produced samples that filled the dredge, whereas only a portion of the dredge was filled on hard substrates. Sampling was conducted at four locations in each pond, each location situated within a quadrant of each pond. Four dredge samples were taken at each location; 3 of these were sieved through 1.0-mm mesh screens and the fourth through a 0.5-mm mesh screen to determine invertebrate composition and abundance. Sweep samples were collected from the slowly moving boat by placing a D-ring dip net (0.5-mm mesh) in the water column for a distance of 10m. Samples were stored in ethanol until processing. Processing entailed sorting invertebrates from debris, and then identifying and enumerating each organism to lowest practical taxon by lab technicians under the guidance of the project coordinator. The project coordinator validated identification of at least 20% of samples or 2 samples per sorter for each pond per sample period, whichever was greatest. Taxonomic identification was mostly to species, genus, or higher (family, order) classification when identification of organisms required an exorbitant amount of time (Smith and Carlton 1975, Merrit and Cummins 1996).

Fishes

We measured or sampled selected environmental variables and fish species in salt ponds during March, June, September, and November 2004. A subsample of ponds was chosen from each system to represent the salinity range across which fish would be present (i.e., <80 ppt). These ponds were A2E, A2W, A9, A10, A11 and A12 in the Alviso complex, and B1, B2, B4, B5, B6C and B7 in the Eden Landing complex. Four sampling sites or reaches were randomly established in each salt pond. Water temperature, dissolved oxygen, pH, salinity, and turbidity were measured with a Hydrolab DataSonde 3 multiprobe (Hach-Hydrolab Company, Loveland, CO). In addition, we measured water depth by using a calibrated cord attached to the multiprobe unit.

Fish were sampled with two floating monofilament gill nets fished for 2 hrs, five baited minnow traps fished for 1 h, and one bag seine hauled over a 15-m distance. The gill nets were 38-m long by 1.8-m deep, and consisted of square-mesh measuring 12.7 mm, 15.4 mm, 38.1 mm, 50.8 mm, and 63.5 mm. The minnow traps were 25.4-cm high, 25.4-cm wide, and 43.2-cm long, with 0.3-cm square mesh. Each minnow trap was baited with fish-flavored canned catfood. The bag seine was 5.5-m long and 1.8-m deep, with a mesh size of 3.2 mm. Seining was not feasible at some pond sites due to active dredging operations, an excessively soft mud bottom, extremely shallow water depths, or a combination of these situations. Sampling times in ponds were not influenced by tidal conditions.

At each site, captured fish were identified to species and measured for total length. In addition, the first 25 individuals of each species were weighed and preserved in 99% isopropyl alcohol for subsequent analysis of gut contents. Leopard sharks were exceptional because their gut contents were typically obtained by flushing the foregut with water pressure, then releasing the shark alive at the capture site (however, for any sharks near death or dead when removed from nets, gut contents were obtained by dissection). Scales from the first 25 individuals of bony fish species were removed and stored in coin envelopes for subsequent age determinations.

Objective 3a. Continue monthly monitoring of water quality concurrent with bird surveys to document baseline levels and to track changes.

Avian Diversity

Waterbirds were counted monthly at all 53 Alviso, Ravenswood, and Eden Landing salt ponds included in the March 2003 land transfer from November 2002 through June 2005. Counts were conducted during the high tide when numbers were at peak. Species and flock size were mapped on a 250 m x 250 m grid to document spatial distribution of birds and associate water depth. To increase our understanding of how birds use ponds, we documented whether birds were foraging or not foraging (but on the pond), or roosting on a levee, island, or man-made structure such as a duck blind. Data were entered for each pond according to grid number and species, and species were assigned to foraging guilds for analysis. Primary foraging guilds included: 1) dabbling ducks – e.g. northern shovelers (*Anas clypeata*) and American wigeons (*A. americana*); 2) diving ducks –e.g. ruddy ducks (*Oxyura jaimaicensis*); 3) eared grebes (*Podiceps nigricollis*) 4) fish eaters – e.g. double-crested cormorants (*Phalacrocorax auritis*) and American white pelicans (*Pelecanus erythrorhynchos*); 5) gulls and terns – e.g. ring-billed gulls (*Larus delawarensis*) and Forster's terns (*Sterna forsteri*); 6) herons – e.g. great egrets (*Ardea alba*); 7) medium shorebirds – e.g. marbled godwits (*Limosa fedoa*), willets (*Catoptrophorus semipalmatus*), and long-billed dowitchers (*Limnodromus scolopaceus*); 8) phalaropes – e.g. Wilson's phalaropes (*Phalaropus tricolor*); and 9) small shorebirds – e.g. western sandpipers (*Calidris mauri*) and dunlin (*Calidris alpina*).

Analyses were performed by season, because migratory patterns obscure trends in selection of pond characteristics. We analyzed all bird and environmental data in April (2003-2005) together to examine pond selection criteria during the spring migration period, then analyzed September and winter (December through February) data separately. We performed multiple linear regressions to determine the effects of monthly pond depth, water quality parameters, and pond size on abundance of birds in each foraging guild (Statistica 7). We then used CANOCO 4 (ter braak and Smilauer 1998) to perform forward stepwise canonical correspondence analyses (CCA; ter Braak 1986, ter Braak 1988) to reveal gradients in species composition and relate log-transformed species abundance values to environmental variables.

Pond Water Quality

Water quality measurements were collected monthly in all 53 purchased Alviso, Ravenswood, and Eden Landing salt ponds from August 2003 through June 2005. Two to five sampling locations were established for each salt pond (depending on pond size and access restrictions) with measurements typically collected near the corners of the ponds. A Hydrolab Minisonde

(Hydrolab-Hach Company, Loveland, CO) was used to measure conductivity (internally converted to salinity using the 1978 Practical Salinity Scale), pH, turbidity, temperature and dissolved oxygen at each location. The sensors on the Hydrolab were calibrated prior to each use and a calibration check was performed after sampling. Since the salt ponds are known to stratify under certain conditions, readings from the near-surface and near-bottom of the water column were collected at sampling locations where the water depth exceeded 60 cm. The specific gravity of each pond was measured with a hydrometer with a precision of 0.0005 (Ertco, West Paterson, New Jersey), scaled for the appropriate range, in addition to the Hydrolab measurement. Hydrometer readings provided an alternative salinity measurement for ponds 40-70 ppt because Hydrolab meters may not accurately measure conductivity where salinities are above 40 ppt. At salinities above 70 ppt, the Hydrolab was considered to be inaccurate (these values lie outside of the calibration curve) and only the hydrometer was used to measure salinity. The hydrometer data were corrected for temperature and converted to salinity.

Objective 3b. Complete Self-Monitoring Program (SMP) sampling and reports to document compliance with discharge requirements during the initial desalination.

In addition to monthly water quality sampling of all 53 ponds, we conducted water quality sampling required of USFWS and CDFG under the Self-Monitoring Plan administered by the Regional Water Quality Control Board (RWQCB) beginning in May 2004. Ponds open for discharge in summer 2004 were Alviso ponds A2W, A3W, and A7 and Eden Landing ponds B2 and B10. Methodology and results from sampling conducted during 2004 were detailed in annual self-monitoring reports submitted by the agencies to the RWQCB (CDFG 2005, USFWS 2005). In April 2005, Alviso ponds A14 and A16 were opened along with B2C and B8A in Eden Landing and also were sampled.

Ponds were sampled either by Initial Release Monitoring (IRM) or Continuous Circulation Monitoring (CCM) schedules according to initial pond salinity. All ponds open to discharge were monitored with a continuously logging Hydrolab Datasonde (Hydrolab-Hach Company, Loveland, CO) for salinity, pH, DO, and temperature. Receiving waters were sampled upstream and downstream of discharge points both 25 cm below the surface and at the near-bottom of the water column. IRM was required when pond salinity exceeded 44ppt at the time of discharge or when other pond conditions (e.g., dissolved oxygen or pH) did not meet required limits. Ponds sampled under IRM were required to be sampled one week before initial discharge, 1, 3, and 7 days following initial discharge, and weekly thereafter. Benthic invertebrate sampling was also required 7 days before discharge and 14 and 28 days following discharge, with another sample in the late summer.

CCM was required when pond salinity was below 44 ppt at the time of discharge. Ponds sampled under CCM were sampled for receiving water monthly from May through October, and ponds in the CCM circulation system were measured monthly during 2004 for water quality and chl *a*. Ponds were sampled annually for water column metals (total and dissolved arsenic, chromium, nickel, copper, zinc, selenium, silver, cadmium, lead, and mercury).

Management Sampling

USGS conducted water quality measurements twice monthly in Alviso salt ponds A2E, AB2, A2W, A3W, and A7, and in Eden Landing salt ponds B2 and B10, from May through July 2004 (i.e., two months prior to the initial release of ponds A2W, A3W, A7, B2, and B10). Management sampling in ponds A2E, AB2, A3N, and B4 were continued monthly during 2004 following the initial release of ponds A3W and B2, according to the CCM schedule. Twice monthly management samples were also conducted at A14, A16, B2C, and B8A beginning in February 2005. To complete management sampling, one sample location was established for each salt pond and samples were collected between 0800 and 1000 hours. A Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) was calibrated prior to each use and measured salinity, pH, turbidity, temperature, and dissolved oxygen. Readings were collected from the near-surface at a depth of approximately 25 cm. Because sondes may not measure salinity accurately at concentrations greater than 40 ppt, an additional method was used. USGS measured specific gravity of each pond (corrected for temperature and converted to salinity) with an appropriately-scaled hydrometer (Ertco, West Paterson, New Jersey) to a precision of 0.0005 specific gravity units. At hypersaline ponds (>70 ppt), only hydrometers were used to measure salinity.

Discharge Sampling

USGS installed continuous monitoring Datasondes (Hydrolab-Hach Company, Loveland, CO) in Alviso ponds A2W, A3W, and A7, and in Eden Landing ponds B2 and B10, prior to their initial release dates and through October (A2W, B2, and B10) or November (A3W and A7) 2004. These sondes were reinstalled before 1 May 2005 for the 2005 release year, and new sondes were installed at A14, A16, B2C, and B8A prior to their releases (beginning in April 2005). Datasondes were installed on the water control structures at the outflow of the discharge into the slough or San Francisco Bay with a PVC holder attached to a pole to allow for free water circulation around the sensors. The devices were installed at a depth of at least 25 cm to ensure that all sensors were submerged, and these depths were monitored and adjusted to maintain constant submersion as the pond water level fluctuated.

Salinity, pH, temperature, and dissolved oxygen were collected at 15-minute intervals with a sensor and circulator warm-up period of 2 minutes. Data were downloaded weekly and sondes were serviced to check battery voltage and data consistency. A recently calibrated Hydrolab Minisonde was placed next to the Datasonde in the pond at the same depth, and readings of the two instruments were compared. Any problems detected with the Datasonde were corrected through calibration or replacement of parts or instruments. The sensors on the Datasonde were calibrated prior to deployment into the salt pond and were calibrated and cleaned on a biweekly schedule unless otherwise noted in service records. During the cleaning and calibration procedure, simultaneous readings were collected with a recently calibrated Hydrolab Minisonde to confirm data consistency throughout the procedure (initial, de-fouled, post cleaned, and post calibration). The initial and de-fouled readings were also used to detect shifts in the data due to accumulation of biomaterials and sediment on the sensors.

Receiving Water Sampling

Receiving waters were measured outside pond discharge locations one week prior to discharge, one, three and seven days after initial discharge, and then weekly by USGS at sites along Guadalupe Slough adjacent to Alviso pond A3W (8 sites) and Alviso Slough adjacent to Alviso pond A7 (7 sites) from July 2004 through November 2004. Additionally, water quality measurements were collected after initial discharge and then monthly in San Francisco Bay outside the water control structure in pond A2W, B2, and B10 (3 sites each) from July 2004 until October 2004. Receiving water sampling has continued to be conducted weekly to monthly during 2005 (depending on pond conditions) outside ponds A2W, A3W, A7, A14 (Coyote Creek, San Francisco Bay), A16 (Artesian Slough), B10, B2C (Alameda Flood Control Channel), and B8A (in Old Alameda Creek outside the B8A discharge to North Creek). Sampling locations were marked using a GPS waypoint. We accessed receiving water sampling sites via boat from San Francisco Bay and used a GPS to navigate to sampling locations. When the boat was approximately 50-25 meters from the site, the engine would be cut or reduced to allow for drifting caused by current and wind to the site location. Every effort was made to ensure that the sample reading was collected from the center of the slough. A recently calibrated Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) was used to measure salinity, pH, turbidity, temperature, and dissolved oxygen at each location. From July 2004 through September 2004, readings were collected only from the near-surface at a depth of 25 cm. From October 2004 through November 2004, samples were collected from the near-bottom of the water column in addition to the near-surface at each sampling location. Depth readings of sample locations were collected at the completion of each Minisonde measurement to account for drift during the reading equilibration period. The specific gravity of each site was additionally measured with a hydrometer (Ertco, West Paterson, New Jersey) scaled for the appropriate range. This sample was collected concurrently with the near-surface Minisonde measurement. The majority of the samples were collected on the rising or high tide in order to gain access to the sampling sites, which were not accessible at tides less than 1.07 m (3.5 ft) MLLW. Alviso pond A2W receiving water sites could only be accessed during high tides over 1.83 m (6.0 ft) MLLW. Standard observations were collected at each site. These were:

A) Observance of floating and suspended materials of waste origin.
B) Description of water condition including discoloration and turbidity.
C) Odor – presence or absence, characterization, source and wind direction.
D) Evidence of beneficial use - presence of wildlife, fishing, and other recreational activities
E) Hydrographic conditions – time and height of tides, water column depth, sampling depths.
F) Weather conditions – air temp, wind direction and velocity, and precipitation.

Observation A, B, C, D and E were recorded at each sampling location, but F was recorded at the beginning and ending of each slough, unless weather had noticeably changed.

Sonde Calibration and Maintenance

All the instruments used for SMP sampling were calibrated and maintained according to USGS standard procedures. Datasondes were calibrated pre-deployment and maintained on a biweekly cleaning and calibration schedule unless they required additional maintenance. Dissolved oxygen sensors were particularly problematic due to the addition of self-cleaning brush attachments on the equipment which tended to damage the surface of the membrane more frequently. The problem of algae and other substances interfering with the moving parts such as on the self-cleaning brush and circulator was improved with the use of nylon sleeves. This allowed for maximum water flow past the sensor but stopped algae from wrapping around and binding the moving parts. Comparison tests indicated that the sleeves were not adversely affecting readings. Copper mesh and wire was used to inhibit growth in ponds with high concentrations of barnacles and hard algae, which could interfere with sensor function. We performed a biweekly fouling check to detect shifts in data due to the accumulation of biomaterial and sediment on the sensors. A calibration and maintenance log was maintained for each pond.

Chlorophyll *a* Sampling

USGS collected chlorophyll samples monthly in Eden Landing salt pond B4 and Alviso salt ponds A2E, AB2, and A3N in September and October 2004. Chlorophyll was not required for 2005 sampling. Two to three sampling locations were established for each salt pond and water quality measurements were collected between 0800 and 1000 hours of the same day or within one day of chlorophyll sample collection. A recently calibrated Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) was used to measure salinity, pH, turbidity, temperature, and dissolved oxygen at each location. Readings were collected from the near-surface at a depth of approximately 25 cm.

USGS determined Chl *a* levels using a TD700 fluorometer. Water samples were collected at 2-3 established sampling locations per pond using a water collection pole and 500ml dark Nalgene bottles. Samples were packed in ice for transport, and filtered by USGS staff within 24 hours of collection. Samples were filtered with 25 mm Whatman GF/F (glass fiber filters) (Whatman International, Maidstone, England) and filters were frozen at least 24 hours. Extraction solvent (90% acetone) was then added to the filters at least 48 hours after filtration. Absorbance of the extracts was read using a TD700 fluorometer. Chlorophyll concentration was calculated using the Fluorometric equations for extracted chlorophyll-*a* and pheopigments (Holm-Hansen et al.1965).

Benthic Invertebrate Sampling

Benthic slough samples were collected at Guadalupe and Alviso Slough receiving water sampling in 2004 locations concurrently with receiving water quality samples on three occasions. Benthic sampling was conducted in 2005 at Artesian Slough (A16), Alameda Flood Control Channel (B2C), and Old Alameda Creek (B8A). Late summer samples were also collected from established sampling locations at Guadalupe and Alviso Sloughs. Benthic macroinvertebrates were sampled from the boat using a standard Eckman grab sampler (3,512 cm^3). Samples were collected by lowering the dredge into the water slowly, holding it level on the substrate, and releasing the “jaws.” Soft substrates consistently produced samples that filled the dredge; whereas on harder substrates, only a portion of the dredge was filled (the dredge cannot as deeply penetrate a hard surface). Sampling locations with vegetative debris on the substrate produced samples with high concentrations of vegetation. Grab samples were washed in the field using a 0.5mm mesh sieve and preserved in 70% ethanol and rose bengal dye.

Samples were sorted and invertebrates enumerated using dissecting microscopes and appropriate taxonomic keys (Usinger 1971, Pennak 1989, Merritt and Cummins 1996, Smith and Johnson 1996). Sorted samples and associated sample debris were stored at USGS SFB Estuary Field Station, Vallejo, California.

Objective 4. Assess the hydrology and present morphology of the South Bay sloughs by analyzing existing data augmented with collection of new data.

Sediment Budget of the South Bay

A sediment budget was developed to evaluate sediment supply components. Sediment input was estimated from the local watersheds. Previous USGS analyses of sediment transport (Lacy *et al.* 1996, Cheng *et al.* 1998), bathymetric change (Foxgrover *et al.* 2004) in South Bay, and a daily numerical box model of sediment transport (Lionberger 2003) were used to estimate sediment flux between South Bay and the rest of San Francisco Bay at the San Mateo Bridge.

Landscape-scale Geomorphic Assessment

Phil Williams and Associates (PWA) performed a landscape-scale geomorphic assessment to assess the rate at which restored salt ponds will evolve from tidal mud flat to marsh, and how changes in sediment dynamics will impact the morphology and extent of tidal mud flat and shallow-water habitat (May *et al.* 2005). The USGS assisted PWA with this work by modifying the South Bay numerical sediment transport box model to simulate the effects of opening the ponds to tidal action under different proposed restoration scenarios. These results were combined with a zero-dimensional marsh evolution model, and empirical analyses predicted geomorphic evolution over the next 50 years.

Potential Effects on Phytoplankton Populations

The numerical model used for the sediment budget can predict suspended sediment concentrations (SSC). We used the results of two runs of the model (before and after ponds are opened to tidal action) to predict if opening ponds to tidal action will increase or decrease the SSC in South Bay. Then, using a relationship between water column sediment clearing rates and the potential for phytoplankton blooms developed by May *et al.* (2003), we predicted the effect that opening up additional area in South Bay to tidal action will have on the potential for phytoplankton blooms to occur in this basin.

Conductivity and Temperature at Channel Marker 17

Two continuously operated conductivity-temperature-depth (CTD) sensors (one mid-depth, one near bottom) were deployed at Channel Marker 17 on December 2, 2003. The lower CTD was positioned about 1 m above the bottom, while the upper CTD was positioned about 5.5 meters above bottom. The sensors were deployed during the winter wet season in 2004 and 2005. Temperature and salinity time-series were cleaned, processed, and verified and provided to the

State Coastal Conservancy in electronic format for the winter seasons of water years 2004 and 2005.

Reconfigure SPOOM for the Alviso Pond System

The salt pond box model SPOOM was originally configured to simulate pond salinity and volume for the salt ponds in the North Bay. The model was reconfigured to simulate salinity and volume of Alviso ponds for USFWS management. Several improvements were made to upgrade the model that include temperature simulation, simultaneous simulation of multiple ponds, variable unit system and vertical datum, and management controls such as screw gates. The model was tested and refined, and a user manual was written. The model and documentation will be given to the USFWS in 2005.

Sediment Synthesis

USGS hydrologist David Schoellhamer, a member of the Science Team, led the writing of the restoration Science Plan issue 2 – Sediment Synthesis. This report answered questions regarding the sediment management issues and restoration of the South Bay salt ponds in order to assist the Project Team in developing a conceptual model of sediment transport in South Bay. The synthesis was completed in February 2005.

Coyote Creek Seasonal Suspended-sediment Loads

Seasonal, daily suspended-sediment load (October – April) were measured on Coyote Creek during winters 2004 and 2005. The station was maintained and serviced by the USGS Marina field office. Suspended-sediment time-series data were cleaned, processed, and verified and made available to the State Coastal Conservancy by USGS Hydrologist Larry Freeman in electronic format after data reviews were completed.

South Bay Hydrologic Summary and Data Gaps

Existing hydrologic and sediment datasets were obtained from all available sources in the South Bay. An annotated list of data sources was compiled. Sources of the datasets included Stanford University, Santa Clara Valley Water District, USGS, City of San Jose Environmental Services Department, Hydroikos, NOAA-NOS, Cargill, H.T. Harvey and Associates, CIMIS, and Fremont Engineers Inc. The summary of the hydraulic data gaps collection effort was given to the State Coastal Conservancy.

Water Quality Sampling and Bathymetric Surveying Support

Water Resources provided a Hydraulic Engineer to assist Biological Resources staff with the design and construction of a shallow draft vessel for bathymetric surveys of the salt ponds. In addition, WRD provided a Supervisory Hydraulic Technician to train BRD in water quality sampling.

Vegetation Colonization in the Salt Ponds

Little was known about how vegetation distributed along the sloughs of the South Bay salt ponds has changed through time. Such changes are a function of factors such as sediment load, salinity, and hydrodynamics in the South Bay, and may be an indication of how restoration will proceed subsequent to the conversion of salt ponds to salt marshes. For this reason, an analysis of wetland vegetation cover through time was collected as a complement to the current research concerning hydrologic flows, sediment load, and sedimentation processes.

Vegetation and elevation data were collected in 1983 by the California State Lands Commission at Corkscrew Marsh, Bird Island and Palo Alto Baylands in South San Francisco Bay. Marsh surface and tidal channel elevations were determined at a total of 962 stations by three-wire leveling to established tidal benchmark stations at each site and referenced to Mean Lower Low Water (MLLW) relative to the National Tidal Datum Epoch (1960-78). In addition, presence or absence of nine salt marsh species, percent plant cover, and percent bare soil were recorded for 1-m^2 quadrats at 648 stations. These data were used to determine historic patterns of vegetation colonization relative to elevation at these South Bay sites.

Objective 5. Characterize invertebrate and fish communities in the slough systems and compare with South Bay pond communities.

The current diversity of birds in the South Bay is strongly linked to the invertebrate resources in ponds, sloughs, and mud flats. Similarly, the abundance of fish is related to salinity conditions, cover, and available food-forage fishes. Pond restoration requires colonization from adjacent sloughs and bay mud flats. Thus, we conducted surveys to document existing invertebrates and fishes in salt ponds and in adjacent sloughs. Surveys were conducted in the major sloughs of the Alviso (Stevens Creek, Guadalupe Slough, Alviso Slough, Coyote Creek, and Mud Slough), and Eden Landing (Mt. Eden Creek, Alameda Creek, Alameda Flood Control Channel) systems.

Sediments

*Sample Collection.--*Sediments were sampled from a motorized boat, using a standard Ekman dredge (3,512 cm^3). Samples were collected from 3 locations within each slough (at mouth of slough, adjacent to salt ponds, and upriver from salt ponds). GPS coordinates of sampling locations were recorded. Each sample contained 2 kg of sediment. Samples were collected by lowering the dredge into the water, holding it level on the substrate and releasing the trigger. Soft, muddy substrates consistently produced samples that filled the Ekman, whereas on hard substrates only a portion of the sampler was filled. When substrate was deemed too hard for the Ekman, samples were collected using hand trowels or shovels. Grab samples were placed in a ziplock bag and transported to the University of California, Davis, Department of Natural Resources Laboratory (DANR) for processing.

*Sample Analysis.—*Procedures were defined in Obj. 2.

Benthic Macroinvertebrates

Invertebrate surveys were conducted in the major sloughs of the Alviso and Eden Landing systems. Three invertebrate sweep and three benthic samples were collected in the main sloughs in 3 locations (below, adjacent, above) relative to the ponds following methods outlined for invertebrate collections in the ponds. Invertebrate communities within ponds were determined following procedures in Obj. 2.

In the sloughs, sediment samples were collected from 3 locations below the ponds or at the mouth of the sloughs, adjacent or next to the ponds, and above or upstream of the ponds in Guadalupe, Alviso, Mallard, and Mud sloughs. At each location samples were taken at the edge of the mud flats for a total of 12 samples.

Sample Collection- Benthic macroinvertebrates were sampled from a motorized 3.7-m flat bottom boat, using a standard Ekman dredge. Samples were collected by lowering the dredge into the water slowly, holding it level on the substrate and triggering the release. Muddy or soft substrates consistently produced samples that filled the dredge, whereas only a portion of the dredge was filled on hard substrates. Sampling was conducted at four locations in each pond, each location situated within a quadrant of each pond. Four dredge samples were taken at each location; 3 of these were sieved through 1.0 mm mesh screens and the fourth through a 0.5 mm mesh screen to determine invertebrate composition and abundance. Sweep samples were collected from the slowly moving boat by placing a D-ring dip net (0.5mm mesh) in the water column for a 10 m distance. Samples were stored in ethanol until processing. Processing entailed sorting invertebrates from debris, and then identification and enumeration of each organism by lab technicians under the guidance of the project coordinator.

Fishes

During 2004, we measured or sampled selected environmental variables and fish species in sloughs on three occasions (June, September, and November). The sloughs consisted of Alviso Slough, Coyote Creek, Stevens Creek, Old Alameda Flood Control Channel, and Coyote Hills Slough. Four sampling sites or reaches were randomly established in each slough. Water temperature, dissolved oxygen, pH, salinity, and turbidity were measured with a Hydrolab DataSonde 3 multiprobe. In addition, we measured water depth by using a calibrated cord attached to the multiprobe unit.

Fish were sampled with two floating monofilament gill nets fished for 2 h, five baited minnow traps fished for 1 h, and one bag seine hauled over a 15-m distance. The gill nets were 38-m long by 1.8-m deep, and consisted of square-mesh measuring 12.7 mm, 15.4 mm, 38.1 mm, 50.8 mm, and 63. 5 mm. The minnow traps were 25.4-cm high, 25.4-cm wide, and 43.2-cm long, with 0.3-cm square mesh. Each minnow trap was baited with fish-flavored canned catfood. Seining was not feasible in sloughs due to excessively soft mud bottoms. Sampling times in sloughs were restricted to periods of slack tide (little or no current).

At each site, captured fish were identified to species and measured for total length. In addition, the first 25 individuals of each species were weighed and preserved in 99% isopropyl alcohol for subsequent analysis of gut contents. Leopard sharks were exceptional because their gut contents were typically obtained by flushing the foregut with water pressure, then releasing the shark alive at the capture site (however, if sharks were near death or dead when removed from nets, gut contents were obtained by dissection). Scales from the first 25 individuals of bony fish species were removed and stored in coin envelopes for subsequent age determinations.

Objective 6. Assist in development of a land surface elevation map for the South Bay region and map South Bay open bay and slough bathymetry.

Land surface elevation and bay bathymetry are critical data for the tidal wetland restoration project. The USGS assisted in contracting airborne topographic LIDAR and bathymetry surveys to collect this data. Contracting took considerably more effort than anticipated because of the complexity of the surveys and the need for extremely accurate data. The USGS evaluated the data collected, and when necessary, directed additional efforts to remedy quality control or other data issues. We initiated the process of creating a grid (digital terrain model; DTM) of present-day land and bay. By comparing this grid with our 1983 grid (Jaffe *et al.*, unpublished data), we can determine whether the erosion rate in South San Francisco Bay has changed from the 1956-1983 period. This is essential information for developing a sediment budget and for landscape scale analysis of restoration alternatives.

A complete sediment budget includes sediment grain size as well as quantity. Bottom sediment grain size information allows evaluating whether sediment of the proper size is available from the natural system in the volumes needed for successful tidal wetland restoration. Sediment size at the surface and within the bed is used in sediment transport models to predict the geomorphic impact of restoration of the salt ponds on other parts of the Bay. Bed sediment size samples were recently taken to complement existing sediment samples. An acoustic seabed classification system was mounted the bathymetric survey vessel to map the bottom sediment size. We initiated work to create a sediment size map for South San Francisco Bay from data from this system and grain size analysis of bed sediment. Details on the data collection efforts and data evaluation are presented in sections on LIDAR, Bathymetry, Bed Sediment Size, and Sediment Budget.

LIDAR Mapping

The USGS was responsible for many aspects of LIDAR data collection and analysis including:

- Developing the LIDAR contract
- Aiding in definition of the survey area
- Setting parameters for flight times to ensure data collection at low tides
- Evaluating data collection schedule during survey
- Collecting ground-truth data (with TerraPoint)
- Organizing additional ground-truth efforts by other agencies
- Evaluating data quality
- Reviewing TerraPoint QA/QC report and suggested revisions
- Preparing LIDAR data for merging with bathymetry survey to create DTM

Foxgrover and Jaffe (2005) presented an overview of the LIDAR survey and a preliminary quality assessment.

LIDAR Survey.--The 2004 South San Francisco Bay LIDAR survey was conducted by TerraPoint from 5-21 May 2004. The time of the survey was chosen during a period of extreme low tides during daylight hours so that tidal flats would be exposed during data acquisition and video could be collected during the survey. Nominal flight line spacing was 99 meters, providing an overlap of 102% between flight lines. Data were collected over approximately 6,800 km on approximately 350 flight lines (Figure 2). Base stations and ground-truth sites were established to calibrate the survey (Figure 3), and satellite imagery was used in conjunction with the LIDAR surveys to eliminate overwater returns (Figure 4).

Bay Bathymetry

The USGS was responsible for many aspects of bathymetry data collection and analysis including:

- Developing the bathymetry contract
- Aiding in definition of the survey area
- Contacting NOAA for technical assistance with tidal reduction, tide gauge selection, and datum conversions
- Collaborating with NOAA on tide and datum issues

Pending funding for work to complete the study, the USGS will be responsible for:

- Evaluating data quality
- Reviewing Sea Surveyors QA/QC report and suggested revisions
- Preparing USGS report that presents bathymetry data overview and a preliminary quality assessment
- Preparing bathymetry data for merging with LIDAR survey to create DTM

Bathymetry Survey.--The 2005 South San Francisco Bay bathymetry survey was conducted by Sea Surveyors from 10 January to 5 April, 2005. The start of the survey was delayed until high accuracy tide gauges were installed and sending data to a NOAA data center using a GOES satellite to allow real-time monitoring of instrument performance. The survey area was approximately 250 km^2, extending from tidal sloughs and Coyote Creek in the south to approximately San Leandro Marina on the east shore and to Coyote Point on the west shore (Figure 5). Sounding data was collected every 0.3 m along track lines. Track line spacing was 100 m in the Bay and less in Coyote Creek and the sloughs.

Tidal Reduction and Datum Conversion.--NOAA played a key role in the bathymetric survey by selecting tide gauge type, loaning accurate acoustic tide gauges, determining optimum locations for tide gauges, aiding in installation of tide gauges, and developing tidal zoning to correct soundings to the 1983-2001 tidal epoch MLLW tidal datum. Referencing soundings to MLLW for the 1983-2001 tidal epoch allows comparison to earlier surveys to determine geomorphic change and whether the bay and mudflats are sinks or sources of sediment—a key question in restoration. NOAA also developed the conversion from MLLW datum to NAVD88, the LIDAR datum. This conversion makes it possible to merge the bathymetry and LIDAR survey to create continuous coverage of elevation and depth.

The soundings collected in South San Francisco Bay were corrected for vertical changes in the water surface elevation caused by tide. Corrections were done in 30 zones defined by NOAA (Figure 8), with each zone having a time correction and scale correction to apply to tides measured at one of three locations with high accuracy acoustic tide gauges. At each location, an AQUATRAK air acoustic tide gauge was housed in a 9.14-m (30 ft) long stilling well mounted to a vertical structure (Figures 6-9). Tide data was recorded using a SUTRON data logger and also transmitted it to the NOAA data center to allow real-time evaluation of data quality. These locations were:

- San Leandro Marina (NOAA Station 9414688)
- West Fishing Pier at San Mateo Bridge (NOAA Station 9414458)
- East Fishing Pier at Dumbarton Bridge (NOAA Station 9414509)

The original plan called for correction using five locations; however, the acoustic tide gauge at Coyote Creek did not work properly and the correction using the permanent NOAA tide gauge at Redwood City resulted in unacceptable errors. The malfunction of the acoustic tide gauge at Coyote Creek required Sea Surveyors to install less accurate gauges in Coyote Creek and the tidal sloughs. These gauges were used to correct soundings to NAVD88. The datum conversion from NAVD88 to MLLW, which is being done by NOAA has proven to be difficult and is taking more time than expected. It is possible that additional geodetic or tide data will need to be collected for this conversion.

Bed Sediment Size.--The USGS was responsible for determining baseline conditions for bed sediment size. Activities included:

- Developing the seabed acoustic classification system contract
- Bed surface sediment sampling
- Analysis of existing USGS sediment cores to determine sub-bottom sediment size
- Analysis of grain size of surficial and sub-bottom sediments
- Interpretation of seabed acoustic classification data
- Preparation of sediment size map for South San Francisco

Bed Surface and Sub-bottom Sediment Sampling.--The USGS collected 153 grab samples south of San Mateo Bridge from August to December, 2004 to determine the distribution of surface sediment grain size (Figure 10). During the December sampling cruise, the USGS tested new collection equipment for taking gravity and short box cores from a small boat. These tests resulted in successful collection of two short box cores and a short gravity core in the study area. In a companion study (not funded by the Conservancy, but that will benefit restoration planning), the USGS contracted SeaEngineering to collect short box cores and determine sediment erosion rates on the mud flats in front of the three restoration areas (core locations shown as red triangles in Figure 10).

Additional research on sub-bottom sediment size was done using sediment gravity cores the USGS collected in the 1990s (Figure 11). These cores were stored in USGS core refrigerator and are in good condition. As of early summer, nine cores had been logged. Information from these logs indicates that the sub-bottom sediment in the region of the cores primarily clays and contained little sand. Sand in the sub-bottom may not be available as natural fill because it may not be transported to restoration sites by tidal currents and wind waves. These cores are also useful for determining the long-term sediment history of South Bay. This history may be used to determine if the sediment dynamics of South Bay were different when there were large tidal wetlands along its shores.

Acoustic Seabed Classification

As part of the bathymetry survey of South San Francisco Bay, Quester Tangent was subcontracted to collect acoustic seabed classification data. These data were collected to improve the understanding of the distribution of seabed sediment types and their erodibility. This information is critical for planning the restoration of South San Francisco Bay salt ponds.

Acoustic seabed classification is the organization of the sea floor into discrete units based on the characteristics of its acoustic response. The acoustic response can be captured as an echo time series using a single beam echosounder with stand-alone or integrated digital acquisition hardware. A map of sea floor acoustic diversity can be generated using unsupervised classification techniques applied to time series or image data. Acoustic diversity is considered a proxy for geoacoustical parameters including acoustic impedance contrast, scatter and volume reverberation which all vary with sediment type. In addition biological and anthropogenic features can influence the acoustic response.

A QTC VIEW seabed classification system recorded echoes from a single beam 50 kHz echosounder. Approximately 450,000 seabed classification records were generated from an area of about 30 sq. miles. Ten distinct acoustic classes were identified (Figure 12). The ten classes represented the spatial distribution of estuary sediments broadly segmented into tidal flat, nearshore, shelf, channel, and dredged sediments. The classification scheme will be further refined using sediment data from more than 180 grab and core samples and benthic community composition data from 10 bottom samples collected in the study area.

Sediment Budget

A sediment budget is essential information for developing a plan for successful pond restoration. A sediment budget for the period 1956 to 1983 indicated that South Bay is losing large quantities of sediment. By calculating a budget for dynamically similar regions, sediment transport pathways and processes of sediment transport can be inferred, including cells during the 1956-1983 period (Figure 13). We created a grid (DTM) of the present-day bay. By comparing this grid with our 1983 grid (Jaffe et al., unpublished data), we plan to determine whether the erosion rate in South San Francisco Bay has changed from the 1956-1983 period.

RESULTS AND DISCUSSION

Objective 1: Complete bathymetry and levee habitat mapping of ponds in the purchase agreement for interim management and hydrological modeling of restoration scenarios.

Bathymetry datasets from 35 ponds (Table 1a-b, Figure 14) were distributed on CD in August 2004 and included detailed metadata files. Although the sounding system was effective at pond depth measurement, accurate conversion of those data to NAVD88 elevation values required that pond staff gages be present and recently surveyed to a vertical datum. We surveyed staff gages at ponds A9-A16 with a laser level and rod from benchmark H555 (1.137 m or 3.729 ft, surveyed by USGS with Bestor Engineers in 9/25/1996; Takekawa, unpubl. data) during August 2002, and used the resulting elevation values to convert the bathymetric surveys to NAVD88. For two ponds (A2W and A3W) for which we could not locate staff gages at the time of the bathymetric survey, we measured water height from temporary levee benchmarks that were later surveyed by Moffatt-Nichol (D. Trivedi). Conversion of these ponds to NAVD88 was accurate.

In most of the other ponds, Cargill, Inc. provided survey data for staff gages contracted through Fremont Engineers in 1999. Because we were unable to obtain metadata for this survey, we assumed that the staff gage values provided represented the top height measurement of the gage (the standard set for staff gage surveys of the North Bay salt ponds) and converted water depths to elevations as noted in the original pond metadata files, including the three conversion methods (Appendix A). Our surveys of the water depths were accurate; however in May 2005, we learned from K. Wheeler (Schaaf & Wheeler) through E. Gross that had they determined in January 2005 that the staff gage heights provided from Cargill represented the physical top of the gage rather than the top height mark. We released a correction memo (with adjustment values) later that same month, and the adjusted point data, GIS grid files, and metadata were made available.

We used pond outline shapefiles (digitized on-screen from georeferenced aerial photos) to overlap bathymetric grids (Figure 14) and derive pond elevation statistics (ESRI Spatial Analyst; Table 1a-b). We converted monthly staff gage readings to monthly water depth statistics by applying an adjustment calculated from staff gage surveys (see above) and subtracting pond bottom elevation statistics. These values were essential for association with water quality measurements and bird species and guild abundance measurements for use in multiple regression and canonical correspondence analyses, described in Objective 3. Additionally, we used pond grid shapefiles to overlap bathymetric grids and derive elevation statistics for individual 250-m grid cells.

Objective 2. Characterize sediments, primary productivity, invertebrate composition, and fishes in ponds for salinity reduction and initial phases of restoration.

Sediments

In an estuarine environment, soil particle size can be a major driver for invertebrate habitat selection. Texture classes of soils were interpreted via particle size analysis through the use of a soil texture triangle (Figure 15, USDA 2001). Because the salt ponds were created with dredge materials, the soil types in the majority of ponds tended to have high clay, moderate silt content, and lower sand content (Figures 16-18). Soil type at Ravenswood ponds had higher sand content than the other areas; with the exception of pond R3 (Figure 18), all ponds were sandy loam (Table 2a-b, Figure 15).

Increased organic carbon content in sediments is often associated with reduced invertebrate abundances as it accompanies low dissolved oxygen and elevated sulfide, ammonia, and contaminant levels (Thompson and Lowe 2004). Organic carbon levels were high relative to reference areas reported by Thomson and Lowe 2004 (0.86 – 0.91), but under salt pond conditions, these levels probably were not associated with affecting invertebrate abundance. However, higher organic carbon could be associated with an increased possibility of higher contamination (USFWS, unpublished report). As salt ponds are converted to marshlands, high organic carbon may be an impacting factor for invertebrates and contaminants. Organic carbon levels detected in Alviso ponds ranged from 1.15 – 4.46 mg/L, mean 2.76 mg/L (Table 2a). Organic carbon levels detected in Eden Landing ponds ranged from 1.52 – 4.30 mg/L, mean 2.64 mg/L (Table 2b). Organic carbon levels detected in Ravenswood ponds ranged from 0.92 – 2.93 mg/L, mean 1.46 mg/L (Table 2b).

Primary Productivity and Nutrients

The process to estimate primary productivity (chlorophyll *a*) was repeated twice for each pond and mean results were presented (Table 3). Nitrogen as nitrate and ammonium, and total and soluble phosphorus were determined by the DANR lab facility at UC Davis (Table 4a-c). Most NH_4-N and NO_3-N levels were low, similar to levels associated with unpolluted surface lake waters. Concentrations well above 10 mg/L are associated with anaerobic, polluted, or related conditions. Only Pond B6B was approaching the 10 mg/L level.

Benthic Macroinvertebrates

We identified 58 different taxonomic groups of macroinvertebrates, most at the family and genus levels. The most abundant and diverse group was the Crustacea with 17 different taxa, followed by 12 different genera of Annelids, mostly in ponds with salinity levels below 60 ppt. There were 5 different species of bivalves, and 9 insect families. Ponds with lower salinity (27-44 ppt) had greater richness, i.e., greater number of different taxa (Table 5). There was a relationship between increasing salinity and decreasing richness in benthic grabs (Figure 19). The most common species in the salt pond benthic samples were lumped into general groups and correlations between salinity and invertebrate abundance were calculated (Figure 20). Insecta taxa (Corixidae, Diptera and *Ephydra*) were positively correlated with salinity ($R^2 = 0.37$, $P<0.001$) as was *Artemia* ($R^2 = 0.41$, $P<0.001$); Crustacean genera *Ampelisca* and *Corophium* were negatively correlated with salinity ($R^2 = 0.56$, $P<0.001$) as were Annelida taxa *Capitella*, *Polydora*, *Streblospio*, and Tubificoides ($R^2 = 0.50$, $P<0.001$) (Figure 20).

Alviso.--We sampled 25 ponds in the Alviso complex, 21 between March and June of 2003 and 4 ponds (A20, 21, 22, and A6) in April 2004 that were dry in 2003. Salinity in Alviso ranged from 27 – 252 ppt. Nine of the ponds were characterized by relatively low salinity (<50 ppt), 10 medium (51 – 106 ppt), and 6 high salinity (180 – 252 ppt). Annelids, mainly *Polydora*, followed by *Capitella* and some Tubificoides and *Streblospio* were prevalent in low salinity ponds (Table 6, Figure 21). *Polydora* was present in large numbers in ponds less than 80 ppt and absent from all ponds above 80 ppt (Table 7). Other Annelids diminished in numbers when pond salinity was above 56 ppt. The 3 most common taxa of Insecta in Alviso ponds were Corixidae, Diptera, and *Ephydra* (Table 8). Diptera and *Ephydra* were present in substantial numbers in Pond A22, otherwise, all three species were not abundant in Ekman grab samples. The bivalve *Gemma gemma* was present in 4 Alviso ponds and most common in Ponds A10 and A2W (Table 7). *Tryonia* was present in Pond A2E with average 41.6 per benthic grab and AB2 with 17.1 per benthic grab (Table 9). The Crustacea, mainly *Ampelisca* and *Corophium*, were abundant in ponds of <40 ppt salinity (Table 10). *Ampelisca* was not present in any pond with salinity ≥ 56 ppt. Except for an individual *Corophium* present in one Ekman grab, this genus was absent from ponds ≥ 56 ppt as well. Average abundance of all taxa detected in Ekman grab samples from Alviso ponds were summarized (Tables 6, 8, 10, and 11). *Artemia* dominated sweep samples in medium to high salinity Alviso ponds, with an average of 900 – 3700 individuals per sweep (Table 12). Corixidae was present in medium salinity ponds ranging from a mean of 0.67 – 200 individuals per sweep.

Eden Landing.--We sampled 21 Eden Landing ponds in June 2003, except ponds B8A and B6A (dry) that were sampled March 2004. Eden Landing ponds ranged in salinity from 41 – 175 ppt, with the majority of the ponds averaging around 80 ppt salinity: 6 ponds averaged 40 ppt, 12 ponds averaged 60-100 ppt, and 3 ponds were greater than 115 ppt. Annelids were only detected in ponds lower than 67 ppt salinity (Table 13, Figure 22). The most abundant Annelids were Tubificoides and *Streblospio*, followed by *Polydora* and *Capitella* (Table 14). *Corophium* dominated 5 of the 6 ponds with less than 52 ppt and *Ampelisca* was also present, in lesser quantity (Table 13). *Artemia* was present in large numbers in ponds with higher salinity, generally if *Artemia* was present, *Coropium* and *Ampelisca* were absent and vice versa (Table 13). Ephydra was the most common insect species in Eden Landing ponds and was present in high salinity as well as moderate salinity ponds (Table 13). Average abundance of all taxa detected in Ekman grab samples from Eden Landing were summarized (Tables 15–18). *Artemia* and Corixids were the most common species noted in sweep samples and were absent from ponds with salinity lower than 44 ppt (Table 19).

Ravenswood.--With exception of Pond R1 (sampled June 2003), all Ravenswood ponds were dry in 2003 and were subsequently sampled March 2004. In general, salinity was highest in Ravenswood compared to the other South Bay complexes, with 6 of the 5 ponds between 265 and 327 ppt, and only 1 Ravenswood pond, R1, below 100 ppt (Table 20, Figure 23). Consequently, taxa richness was lowest in the Ravenswood's system compared to Alviso and Eden Landing (Table 5). Ravenswood ponds were dominated with *Artemia* which generally increase in numbers in the higher salinity ponds (Table 20). The Insecta Corixidae was present in highest numbers in Pond R1 and decrease considerably in the remaining ponds (Table 21). In general *Ephydra* was higher in all ponds than Diptera (Table 22). No Gastropoda or Bivalvia were detected in the Ravenswood ponds. Crustacea species detected in benthic samples were *Artemia* and Gammaridae (Table 23). Except for Pond R1, *Artemia* was present in high numbers in all sweep samples in Ravenswood ponds. Corixidae was most abundant in Pond R1 (Table 24). Other taxa present in sweep samples included Diptera, *Ephydra*, and Muscidae (Table 25).

Ponds in the 53 pond set that had salinities similar to Alviso Ponds A9 – A15 (sampled multiple seasons) characteristically had similar invertebrate assemblages and relative abundances. The late spring – early summer seasons, when the 53 ponds were sampled, was usually associated with higher abundances of most taxa (Table 26, Figure 24).

Fishes

A total of 10,258 fish represented by 19 species and 16 families was caught during 2004 (Table 27). Of the 19 species, 13 were caught in ponds and 16 in sloughs. Although we failed to capture bat rays (*Myliobatis californica*), several individuals were observed swimming within the Alviso ponds. Overall, the highest numbers of fish were captured with bag seines, followed by gill nets, then by minnow traps (Table 28). Fish abundance was highest in June and lowest in November. Gill nets, bag seines, and minnow traps targeted different portions of fish communities in the ponds and sloughs (Table 27). In the Alviso and Eden Landing ponds, topsmelt accounted for most of the gillnet catch (>81%). Seining captured mostly rainwater killifish (72.4%) in the Alviso ponds. By comparison, seining in the Eden Landing ponds yielded mostly yellowfin goby (40%) and topsmelt (28.8%). Although minnow traps yielded few fish, most captured individuals consisted of rainwater killifish or yellowfin goby.

Generally, water quality conditions varied significantly among ponds (Table 29). Water temperature and dissolved oxygen fluctuated seasonally, with higher temperatures and lower dissolved oxygen concentrations occurring during June and September (Table 30). Overall, mean temperatures in Alviso were higher than in Eden Landing, and Alviso and Eden Landing sloughs. Mean pH values in Alviso differed significantly from values measured in Eden Landing (Table 29). Overall, however, pH values did not exhibit much temporal variation over the four sampling periods.

Objective 3a. Continue monthly monitoring of water quality concurrent with bird surveys to document baseline levels and to track changes.

Avian Diversity

Alviso.--Avian use of salt ponds varied by foraging guild, pond, and season (Tables 31-41). Alviso salt ponds constituted 57% of total pond area, but supported 92% of gulls and terns and 90% of dabbling ducks counted on all ponds between November 2003 and June 2005. Alviso ponds also supported 73% of diving ducks, 72% of eared grebes, 66% of herons, and 63% of fish eaters and phalaropes.

Alviso ponds can be separated into geographical groupings of ponds in close proximity to one another that also share a circulation pattern and tend to share similar water quality characteristics. Ponds A1, A2W, A2E, AB1, AB2, A3N, and A3W together comprised 26% of all birds counted (Table 31, Figure 25), and supported similar foraging guilds. Ponds A1 and A2W, for example, both supported primarily ducks and fish eaters. Sixteen percent of all dabbling ducks counted in Alviso were counted on ponds A2W and A1, while these two ponds together supported 31% of the diving ducks and 20% of the fish eaters. Ponds A2E, AB1, AB2, A3N, and A3W supported 35% of herons, 29% of fish eaters and divers, and 25% of dabbling ducks. Seasonally, diving ducks comprise the largest proportion of birds on these ponds during winter months, when bird numbers on this system peak, and are replaced by gulls and terns during the summer (Table 31, Figure 26). Foraging rates were relatively consistent among ponds (Figure 27). Nineteen to forty-one percent of dabbling ducks were foraging when they were counted, whereas 3.5-7% of diving ducks were foraging. Eared grebes had high foraging rates (21-66%), as did herons (37-81%) and small shorebirds (40-86%). The foraging rate for fish eaters was 19-47%, and for gulls and terns was typically less than 10%.

Thirty-eight percent of all birds counted in Alviso were found on ponds A5-A8, and nearly half of these were counted on pond A5 alone (Table 31, Figure 28). Alviso pond A5, the largest pond and one of the most variable in water depth, supported the largest number of birds overall, including 53% of Alviso's small shorebirds, 39% of phalaropes, 36% of medium shorebirds, 26% of herons, and 18% of dabbling ducks. Pond A7, which is adjacent to pond A5 but much smaller, supported 38% of Alviso's phalaropes. California gulls comprised the majority of birds counted at pond A6, which has supported a breeding colony that has accounted for 24% of all gulls and terns counted on the Alviso system (many gulls counted elsewhere may have also belonged to this colony). Seasonally, gulls and small shorebirds make up the largest proportion of birds on this system during the summer months, when bird numbers on this system peak, while dabbling ducks made up a larger proportion of the much smaller total during the winter (Figure 29). Fifteen to 58% of dabbling ducks were foraging at the time they were counted, while the foraging rate for diving ducks was 4-36%. Although pond A6 supported a large number of breeding gulls, nearly none were observed foraging on A6 and foraging rates in this system were less than 15%. However, 28-63% of eared grebes and 82-96% of phalaropes were observed feeding, and 28-78% of small shorebirds and 26-49% of herons were feeding (Figure 30).

Ponds A9-A17 were the most variable in water quality parameters (particularly salinity, Figure 66a) and also in bird guild distribution, with the lowest salinity ponds (A9-A10) supporting the largest number of birds. These nine ponds together supported 24% of the total bird counts on Alviso ponds (Figure 31); by foraging guild, these ponds supported 33% of dabbling ducks (23% on pond A9), 29% of diving ducks (26% on A9-A10), 72% of eared grebes (60% on A13-A17), 36% of fish eaters (24% on A9-A10), and 23% of herons (15% on A9-A10). The ponds supported 29% of gulls and terns, which were evenly distributed across ponds, and less than 15% of shorebirds. This pond system showed clear seasonal trends (Figure 32). Overall numbers peaked during the winter months, when eared grebes, dabbling and diving ducks generally comprised well over 50% of the count. Gulls were present year-round, but comprised the largest proportion of the total count during the summer months when few ducks were present (Table 32, Figure 32). Foraging rates were consistent in these ponds, and generally higher than other ponds (Figure 33). Dabbling ducks were foraging 6-78% of the time and diving ducks foraged 3-39% of the time. Eared grebes had consistently high foraging rates from 38 to 72%, and phalaropes were feeding nearly 100% of the time.

The "island ponds," A19-A21, along with A22 and A23, were the most saline and often have the lowest water levels in Alviso. Thirteen percent of all birds counted in Alviso were counted at these ponds (Figure 34), but this was primarily due to very large numbers of gulls. Gulls were the primary bird guild seen at these ponds, which lie in close proximity to a landfill. More gulls (35% of all gulls counted in Alviso despite the large breeding colony at A6) have been found on this system than on any other Alviso ponds (Table 32). Fourteen percent of Alviso's eared grebes have also been counted on this system, along with 8% of medium shorebirds and 4% of small shorebirds. Seasonally, numbers were highest during the winter months (Tables 33-34), but gulls generally make up the largest proportion of birds regardless of season (Table 32, Figure 35). Foraging rates on this pond system were highly variable and in most cases were based on few birds (Figure 36). Foraging rates for gulls was less than 5% except on pond A20 (23%), suggesting that gulls use these ponds primarily for roosting and not for feeding. Gulls were frequently observed flying to and from the nearby landfill, which may provide a significant proportion of their diet.

Eden Landing.--Although Alviso supported the majority of dabbling and diving ducks, Eden Landing was shallower overall and supported the highest proportion of shorebirds - 52% of medium shorebirds and 44% of small shorebirds counted between November 2003 and June 2005, despite comprising only 31% of total pond area. Eden Landing also supported 35% of fish eaters, 32% of herons, 27% of eared grebes, 24% of divers, 12% of phalaropes, 10% of dabblers, and 7% of gulls and terns.

Ponds 1C-6C were shallow ponds of varying water level and supported 16% of all birds counted in Eden Landing (Figure 37). Despite the relatively low numbers of birds counted overall, these ponds were relatively important for some groups, especially dabbling ducks. Thirty-eight percent of Eden Landing's dabbling ducks (29% at B3C and B4C), 28% of gulls and terns, 24% of medium shorebirds, 16% of small shorebirds, 10% of herons and phalaropes, 6% of diving ducks, and less than 5% of eared grebes and fish eaters were counted at these ponds. Small and medium shorebirds comprised the largest proportion of birds counted at these ponds, with the highest numbers on ponds B3C and B4C (Table 35, Figure 37). Seasonally, numbers peak during winter and during spring migration periods, but small and medium shorebirds consistently comprise the majority of birds seen on this system (Figure 38). Pond foraging rates were variable but high relative to other ponds (Figure 39), with dabblers foraging 24-76% of the time and small shorebirds foraging 44-86% of the time. Foraging rates for medium shorebirds ranged from 20-70%.

Although ponds B1-B7 accounted for only about 15% of total Eden Landing bird numbers (Figure 40), the majority of diving ducks and fish eating birds at Eden Landing were found in deeper ponds with more consistent water levels. These ponds supported 86% of fish eaters, 59% of diving ducks (45% in B1-B2), 55% of herons, 37% of gulls and terns, 26% of eared grebes, 20% of dabbling ducks, and less than 5% of shorebirds counted in the Eden Landing complex. Diving ducks and fish eaters comprised the largest proportion of the count overall (Table 35, Figure 40) and during winter months (Tables 37-38, Figure 41), but fish eaters, shorebirds, and gulls and terns comprised a larger proportion of the total count when bird numbers were low in summer and as they increased in the fall. Fourteen to 64% of dabbling ducks counted were foraging, compared to 6-25% of diving ducks and 14-29% of fish eaters (Figure 42).

B6A, B6B, B8, B8A, and B9 are north of Old Alameda Creek and were generally very shallow, seasonally inundated, and highly saline. These ponds accounted for a high proportion of Eden Landing's total bird count (37%, Figure 43), primarily due to their attractiveness to saline specialists and shorebirds. These ponds supported 77% of Eden Landing's phalaropes and 60% of its eared grebes. Both species preferred waters in the salinity range that supported *Artemia* spp., and pond B9 had the highest counts of *Artemia* spp. in pelagic sweep samples (Table 19), more than any other pond. Although some southern ponds had high counts of *Artemia* spp. and *Ephydra* spp., (Tables 13, 19), invertebrates were sampled on only one occasion, and pond conditions favorable to these species in some shallower ponds may be more ephemeral than in the B6A-B9 system. Some ponds in the B1C-B6C and B1-B7 systems increased in salinity seasonally, but B6A-B9 were higher in salinity year-round and probably also provided *Ephydra* spp. and *Artemia* spp. habitat for a greater portion of the year. Pond B9 also had the highest counts of *Ephydra* spp. in benthic samples (Table 13), which provided food for many shorebird species. In addition to grebes and phalaropes, 48% of small and 29% of medium shorebirds in the complex were counted in these ponds, along with 20% of gulls and terns, 10% of diving ducks, 7% of dabbling ducks, and 2% of fish-eating birds. Pond numbers were highest during winter and spring migration, with shorebirds comprising the majority of the birds counted (Tables 37-38, Figure 44). Eared grebes and diving ducks were also counted during the winter and occurred primarily on pond B9 (Table 36, Figure 43), where they foraged at a rate of 39-86% (grebes) and 52-80% (diving ducks) around the deeper west end of the pond and along the deep borrow ditches around the perimeter. Sixty-six to nearly 100% of observed phalaropes were foraging when they were counted (Figure 45).

The northern ponds, B10-B14, supported 32% of Eden Landing birds. These were primarily small and medium shorebirds (Table 36, Figure 46), and, seasonally, diving ducks and terns (Tables 37-38, Figure 47). Although 35% (29% in B10-B11) of dabbling ducks and 25% of diving ducks in Eden Landing were counted on these ponds, ponds B10-B14 supported 41% of medium and 34% of small shorebirds in the Eden Landing complex. Recent water level changes in pond B10, which was temporarily and periodically opened to tidal action beginning in June 2004, have encouraged this trend as shorebirds have been attracted to exposed mud during low tide. In pond B10, 59.4% of small shorebirds counted in the pond were actively foraging (Figure 48).

Ravenswood.--Ravenswood comprised only about 11% of the total area of salt ponds included in these bird surveys. However, 31% of small shorebirds counted on all ponds between November 2003 and June 2005 were counted in Ravenswood. Ravenswood also supported 26% of phalaropes and 12% of medium shorebirds – counts of all other foraging guilds made up less than 5% of the total salt pond count. Ravenswood ponds were among the shallowest of the salt ponds and were only shallowly inundated during winter months. Accordingly, small shorebirds made up the majority of counts during most months (Tables 40-41, Figure 49). Numbers were higher during winter and peaked around spring migration during April with most birds counted on pond R1 (lowest salinity) and RSF2 (Table 39, Figure 50), where 34-56% of small shorebirds were observed foraging (Figure 51).

Multivariate Analyses

Multiple linear regressions for birds counted during spring migration (April) explained 13.2-54.3% of the variation in species richness (Adj R^2 = 0.132 – 0.543; Table 42), and all regression models were significant ($P < 0.05$). The winter (Adj R^2 = 0.050 – 0.385; Table 43) and the fall (September: Adj R^2 = 0.111 – 0.320; Table 44) relationships were somewhat weaker, but trends were similar. For total birds in April, stepwise regression selected 4 independent variables driving bird numbers: pond size, mean depth, maximum depth, and salinity, but pond size (P = 0.12) and salinity (P = 0.09) were not significant. All four variables were significant in the winter model, but in the fall, mean depth, temperature, and pond size were significant. Pond size was expected to be significant wherever more birds congregated on a larger area, because analyses were performed on transformed count values rather than density. Because pond management decisions are made on a pond-by-pond basis, size was considered as a characteristic of each pond rather than a confounding factor. However, analyzing for total birds was problematic because lumping bird species with opposing selection criteria may confound the analysis. Accordingly, the analysis was performed separately on each foraging guild.

Because dabbling ducks were counted at peak numbers in the salt ponds during the winter months, the winter analysis should provide the most appropriate information about pond selection for this guild. Dabbling ducks were associated with mean pond depth, maximum pond depth, salinity, and pond size. Shallow water and aquatic vegetation (not present in highly saline ponds) provided optimal foraging conditions for this guild.

Diving ducks, also present in highest numbers during the winter, were also associated with mean pond depth, salinity, and pond size. Additionally, they were significantly associated with pH, not just during the winter, but also during April ($P < 0.001$) but not significantly in September ($P = 0.056$). Pond depth was important for diving ducks because they need deeper pond water to dive for benthic invertebrates. Salinity was a factor because prey species may be sensitive to salinity (Bivalves such as *Macoma balthica*, for example, were present only in lower salinity ponds; Tables 9, 17, 26), and pH may have a similar limiting effect on prey species.

Eared grebes were present primarily in the winter and were associated with minimum pond depth, variability in pond depth, pond size, and salinity. Because eared grebes dive for food, primarily *Artemia* spp., while foraging in salt ponds, depth and salinity were important variables for pond selection.

Fish eaters were associated with pond size (although not in April) and with salinity during the winter and in the spring, but not in the fall. Pond salinity cycles seasonally and reaches its peak in fall, so September is a time when pond salinity differences were most pronounced. Fish were not tolerant of salinities greater than 80 ppt, so birds that eat fish were strongly associated with ponds of lower salinity and perhaps higher dissolved oxygen. Because herons and Forster's terns also feed on fish, they showed similar associations with salinity. Herons are sit-and-wait predators that stand in shallow water or along banks and wait for their prey, so they were associated with water depth as well. Terns were associated with salinity and herons with salinity and variability in water depth during the spring. During the winter, terns were only associated with temperature, but counts were low during winter months and we lacked sufficient data to determine trends. Herons were associated with depth and pond size but not salinity in the winter, but in the fall, they were associated with both depth and salinity.

Small shorebirds need very shallow water to forage and were consistently associated with mean pond depth. Medium shorebirds were associated with mean pond depth except in September, when they were associated with temperature and pond size. Phalaropes were associated with pond size, pH, and salinity in the fall.

During the spring, the ratio of canonical to unconstrained eigenvalues was 0.38, suggesting that the analysis explained 38% of the explainable variance in the data (Figure 52). The length of the arrows showed the relative importance of the environmental variables to species composition, and the perpendicular distance of the guild points from the arrows revealed the strength and direction of that variable's influence on that foraging guild. In April, salinity and pond depth were the most important factors overall, with eared grebes related to increased salinity and shorebirds related to decreased pond depth. In September, the analysis explained 44% of the explainable variance in the data (Figure 53). Pond size and temperature were relatively more important in the fall compared with the spring, perhaps because smaller ponds were warming up and drying more quickly. Eared grebes and phalaropes were associated with increased salinity and depth, while diving ducks were associated with decreased salinity and increased depth. Shorebirds were again associated with lower depth, and herons and fish eaters with lower salinity. During the winter months, the analysis explained 35% of the variance in the data (Figure 54). Pond size was relatively less important in the winter. Shorebirds were associated with lower pond depth, herons and fish eaters with lower salinity, and grebes with higher salinity.

Pond Water Quality

Pond water quality graphs are presented in geographic groupings, with nearby ponds often sharing water quality patterns when they are on the same circulatory pathway (Figures 56-95). Temperature in the ponds follows a seasonal signal with highest temperatures in the summer. Between-pond temperature differences were typically less than 5ºC, except during the fall when the differences can exceed 6ºC. Salinity in the ponds is influenced primarily by rainfall during the wet winter season, and evaporation and water transfers during the dry season. Highest salinities are typically seen in the late summer and fall, especially for the higher salinity ponds. The low salinity ponds appear to be heavily influenced by water transfers during the year. Trends in turbidity, D.O. and pH between ponds and seasons are much less obvious. The between-pond differences appear to be greater during the summer dry season. Between-pond differences are influenced by a number of physical factors including pond depth, wind speed, fetch, solution density and amount of water influx (rainfall or water transfers), so these differences are not surprising.

Objective 3b. Complete Self-Monitoring Program (SMP) sampling and reports to document compliance with discharge requirements during the initial desalination.

USGS completed data collection of the water quality parameters for the SMP. Results from 2004 water quality monitoring activities can be found in annual self-monitoring reports (USFWS 2005 and CDFG 2005). Data from 2005 are posted at the project webpage (http://www.southbayrestoration.org), where the reports are available for download.

Objective 4. Assess the hydrology and present morphology of the South Bay sloughs by analyzing existing data augmented with collection of new data.

Sediment budget of the South Bay

Siegel and Bachand (2002) identified sediment supply as a key constraint to salt pond restoration. In order to evaluate sediment sources, sinks, and deposition, a sediment budget for South Bay was developed using a sediment transport box model. Opening the salt ponds to tidal action will create multiple new sediment sinks in South Bay and will affect SSC and net sedimentation in the Bay. The same sediment transport box model was used to simulate the affect of adding breached ponds to the system to learn how it could change the sediment budget (Figure 95). These simulations allowed PWA to perform a landscape-scale geomorphic assessment of restoration alternatives. We used the model runs to analyze the potential effects of changing SSC on the potential for phytoplankton blooms. In general, the decrease in South Bay

SSC (roughly 10% decrease) that results from opening additional South Bay area to tidal action will increase the likelihood that South Bay could experience a phytoplankton bloom in any given year. However, the effect of the increased likeliness of a bloom is less than the inter-annual variability in water column clearing rates caused by inter-annual variability in benthic grazing rates. These results were presented at the American Society of Limnology and Oceanography meeting in February 2004 (Shellenbarger *et al.* 2004) and will be formalized in a written report with a draft due 30 Sept. 2005.

Conductivity and temperature data at Channel Marker 17

Conductivity and temperature data were collected continuously every 15 minutes at Channel Marker 17 in South Bay during the winters of water years 2004 and 2005 (Figure 96). The instruments successfully collected data during wet-weather periods. Cleaned and processed data were provided to the State Coastal Conservancy and Phillip Williams & Associates (at the request of the SCC) after each data collection effort.

Reconfigure SPOOM for the Alviso pond system

Management of water movement through the existing pond system will be a primary concern for managing the short-term future to maintain resource values, and for long-term restoration alternatives. Minimizing the expense of pumping and examining scenarios for water flows would be greatly enhanced through use of model simulations. The salt pond box model (SPOOM) was developed to track water and salinity budgets for the Napa-Sonoma salt pond complex (Lionberger *et al.* 2004). The SPOOM model can be used to predict how water transfers will affect the salinity and depths in the ponds. Both salinity and depth are critical parameters for habitat modification and restoration. SPOOM is being reconfigured to simulate ponds in the Alviso pond complex. The SPOOM model can be used as a valuable management tool by the FWS for predicting how to control the pond systems to maintain existing habitat and prevent an accumulation of salt. The model will be provided to USFWS during the summer 2005.

Sediment Synthesis

The purpose of the synthesis answered six questions regarding the sediment management issue and restoration of the South Bay salt ponds (report completed 2005):

- What is the importance of the issue as it relates to the Project Objectives?
- What do we know about this issue as it relates to the Project?
- What is the level of certainty of our knowledge?
- What predictive tools exist for gaining an understanding of this issue and what tools are needed to reduce uncertainty to an acceptable level?
- What are potential restoration targets and performance measures, linked to the Objectives, for evaluating the progress of the restoration project and what management measures might be used to reduce negative impacts?

- What key questions essential to the success of the restoration need to be addressed through further studies, monitoring, or research?

The report has undergone review of the Science Team and will be published in a future outlet.

Coyote Creek Seasonal Suspended-sediment Loads

Daily seasonal suspended-sediment load was collected at an existing flow gaging station on Coyote Creek and the site was maintained by the USGS Marina Field Office. Data were successfully collected during wet-weather periods of water years 2004 and 2005. The addition of a sediment station at the Coyote Creek flow station provided more accurate assessments of the sediment inflow to South Bay and boundary condition data for numerical models of sediment dynamics in South Bay. The three largest sources of freshwater to South Bay (Friebel *et al.* 2002) (Alameda Creek, Coyote Creek, and Guadalupe River) were measured for both water discharge and sediment load.

South Bay Hydrologic Summary and Data Gaps

The purpose of collecting existing hydrologic data was to identify data gaps and to compile existing data for future reference. Identified data gaps, such as suspended-sediment load from Coyote Creek were targeted for future data collection activities. At the request of the Coastal Conservancy, the list was passed on to Amy Stewart at Phillip Williams and Associates in the spring of 2004. A data summary was provided to the State Coastal Conservancy in July 2004 by PWA. PWA's Data Summary Report can be found at http://www.southbayrestoration.org/pdf_files/Final_SBSP_Data_Summary.pdf.

Vegetation Colonization in the Salt Ponds

Collectively over the three sites (Corkscrew Marsh, Bird Island and Palo Alto Baylands), salt marsh vegetation ranged in elevation from 0.98 to 2.94 meters above MLLW (Table 45). *Spartina foliosa* and *Salicornia virginica* were the most frequently observed plant species. *Atriplex patula, Deschampsia cespitosa* and *Limonium californicum* were each only recorded at one of the three sites. Funded with state matching funds as a separate project by USGS, results for this study will be available as Orlando *et al.* (*in prep*).

Objective 5. Characterize invertebrate and fish communities in the slough systems and compare with South Bay pond communities.

Sediments

Slough sediment samples in sloughs were generally lower in salinity and organic carbon content (Table 46). Slough sediments were mainly silty clay loam, having higher sand and silt content than pond sediments (Figure 97).

Benthic macroinvertebrates

We completed a summary of the available existing invertebrate surveys from South Bay mud flats (Thompson and Shouse 2004, Appendix B), which was made available in June 2004 as background for examining the ecological linkage of the shallow-water habitats in restoration planning studies at a landscape level.

Eight sloughs were sampled for invertebrates in April 2004. Samples were dominated with *Heteromastus*, *Streblospio* and Tubeficoides. *Gemma gemma* was abundant in Mt. Eden Creek (162.6 per Ekman) and Alameda Creek (29 per Ekman) and *Macoma balthica* was present in all sloughs with largest numbers found in the Alameda Control Channel (25 per Ekman; Table 47). Insecta was present in only 3 sloughs with greatest taxa richness in Mt. Eden Creek (4 species; Table 48). Chironomidae was present in Mt. Eden Creek and Alameda control Channel (Table 48). Corixidae and Diptera were detected in Mt. Eden Creek and Alameda Creek. (Table 48). *Cumacea* was present in all sloughs and was the most abundant Crustacean detected in slough samples (Table 49). Average abundance of Annelida taxa and other taxa are summarized (Tables 50-51, Figure 99). In general, benthic Ekman grabs in Sloughs contained lower invertebrate populations than pond samples. Mt. Eden Creek had highest taxa richness (24) and Mud Slough lowest (11) (Table 52). The pattern of invertebrate assemblages in slough samples is similar to that found by Thompson and Shouse (2004) in south bay mud flat samples. Thompson and Shouse (2004) demonstrated that there could be high amount of variability in these species depending on year.

Fishes

Sixteen fish species were captured in sloughs. Overall, the highest numbers of fish were captured with bag seines, followed by gill nets, then by minnow traps (Table 28). Fish abundance was highest in June and lowest in November. Due to federal permitting restrictions, fish were not sampled in sloughs during March.

Gill nets, bag seines, and minnow traps targeted different portions of fish communities in the ponds and sloughs (Table 27). In the Alviso sloughs, topsmelt accounted for most of the gillnet catch (>81%). By comparison, gill net catches in the Eden Landing sloughs were not dominated by a single species; instead, three species--topsmelt (31.4%), northern anchovy (27.5%), and leopard shark (24.2%)--collectively dominated the gill net catch. Seining was not used in sloughs. By comparison, seining in the Eden Landing ponds yielded mostly yellowfin goby (40%) and topsmelt (28.8%). Although minnow traps yielded few fish in both ponds and sloughs, most captured individuals consisted of rainwater killifish or yellowfin goby.

Generally, water quality conditions varied significantly among ponds and sloughs (Table 29). Water temperature and dissolved oxygen fluctuated seasonally in both ponds and sloughs, with higher temperatures and lower dissolved oxygen concentrations occurring during June and September (Table 30). Overall, mean temperatures in the Alviso sloughs were higher than in the Eden Landing ponds and the Alviso and Eden Landing sloughs. In addition, mean concentrations of dissolved oxygen were significantly higher in the Eden Landing sloughs (6.77 mg/l) than in other waters. Mean pH values in the Alviso ponds and sloughs differed significantly from values measured in the Eden Landing ponds and sloughs (Table 29). Overall, however, pH values did not exhibit much temporal variation over the four sampling periods. Mean salinities varied between ponds and sloughs (Table 29), with higher concentrations typically occurring in ponds (salinities in the Eden Landing ponds exceeded 90 ppt in March; Table 30).

Objective 6. Assist in development of a land surface elevation map for the South Bay region and map South Bay open bay and slough bathymetry.

LIDAR

More than 250 million returns were collected resulting in a data density greater than one point per square meter over the extent of the LIDAR data (Figure 99). The detail captured by the LIDAR survey is remarkable. For example, a shaded-relief map of the Coyote Creek region (Figure 100) shows many small-scale features not detectable in other elevation data sets. Foxgrover and Jaffe (2005) present additional LIDAR images from the survey.

To make this enormous data set manageable for various end users, all of the deliverables (except hill-shaded images) were partitioned into both 1 x 1 km and 2 x 2 km tiles with 25-meters of overlap between adjacent tiles (Table 53). The bare earth and full feature (all return) point data were made available as ASCII comma delimited text files. TerraPoint also generated a bare earth grid of last returns at 1 m resolution, in ASCII format. The gridded bare earth data was also made available at 1 m and 25 m resolution in an ArcInfo ASCII format for easy import into GIS coverages. Contours generated at a 50 cm nominal contour interval were created in AutoCAD (DWG) format. One-meter resolution hill-shaded images of both the bare earth and full feature data sets were produced in GeoTIFF format. In addition to the elevation data, digital video imagery was collected at 2 frames per second during all flight missions. The geo-referenced video files were in AVI format with accompanying *.GPS files designed for viewing with Trident 3D Vision software. The San Francisco Estuary Institute was given the responsibility for distributing this data (contact: Eric Zhang, ericz@sfei.org, 510-746-7361).

<u>LIDAR Accuracy.--</u>LIDAR accuracy is a function of errors in position and orientation of the laser and the characteristics of the surface being illuminated. Uncertainty in the orientation of the laser is the primary factory influencing horizontal accuracy. Errors in differential GPS solutions and uncertainty in elevations of the ground surface on steep terrain also degrade horizontal accuracy. Absolute positional (horizontal) accuracy at the 2σ level is 20 to 60 cm on all but extremely hilly terrain (Table 54).

Uncertainty in orientation of the laser and differences in elevation of the illuminated surface, which was a distorted circle with a diameter of approximately 0.75 m, are the primary factors determining vertical accuracy. Ground elevations of steep slopes, such as the sides of levees, are less accurate than elevations on flat surfaces (Table 54). The vertical accuracy of this system on low sloping, hard surfaces is 10 to 15 cm at the 95% (2σ) confidence level.

<u>LIDAR ground-truthing.--</u>Over 650 ground-truth measurements were taken in seven areas to evaluate LIDAR performance (Figure 3). Ground-truth locations were selected to include the variety of surface types within the study area and included tidal flats, levees, and marshes. Ground-truthing included static GPS measurements throughout the study area and kinematic GPS surveys on paved roads. Elevations of the static and kinematic GPS ground-truthing points have accuracy relative to the GPS control network of 2 cm in three dimensions, at the 95% confidence interval. A total of 165 static ground-truth points were collected in a variety of

terrain to evaluate how well LIDAR was estimating bare earth elevations in differing vegetations, slopes, and on soft surfaces (tidal flats). Along with each GPS measurement, notes were collected on the description of the terrain, and if present, the type, density, and height of vegetation.

For static ground-truth points, the average difference between the LIDAR and ground-truth elevations was 3.6 cm and 95% (2σ) of the LIDAR elevations were within 28 cm of ground-truth elevations (see appendix). However, accuracy varied with surface types (Table 55). LIDAR estimates of the bare earth surface in areas of pickleweed (*Salicornia virginica*) marsh were good with a 2σ error of 18 cm while in the bulrush (*Scirpus californicus* or *Scirpus maritimus*), LIDAR performed poorly with a 2σ error of 192 cm. Based upon our limited number of bulrush ground-truth locations, we believe the high error is the result of the very dense vegetation that was impenetrable by the LIDAR. Gently sloping areas such as those sampled containing pickleweed, tidal flats, or the center of the levees performed relatively well, while the edges of the levees did not. The higher error of measurements at either the top edges of the levees or at the base of the levee banks is a result of the size of the laser footprint and the steep slope of the levees. The laser footprint is approximately 0.75 m in diameter and with typical levee slopes of 10 to 20 degrees; the LIDAR is unable to resolve the steep slopes with the same accuracy of gently sloping terrain.

In addition to the 165 static ground-truth points, 593 check points were collected using a kinematic surveying method in which the GPS is mounted to an automobile and set to collect data every second. The kinematic ground-truth points were collected along two separate stretches of paved roads totaling 10 km in length and compared to the bare earth LIDAR surface to evaluate absolute accuracy. For the entire set of these points, the average difference between LIDAR and ground-truth elevations was -1.9 cm and 95% of the LIDAR elevations were within 13.2 cm of ground-truth elevations.

<u>Limitations of the 2004 LIDAR survey.--</u>The 2004 South San Francisco Bay LIDAR survey collected elevation data from a variety of surfaces including bare earth, vegetation, structures, and water. The primary limitation to using the data set is the uncertainty in the type of surface the return is from. The three most common problems are: (1) discriminating tidal flats from water returns, (2) discriminating bare earth from vegetation, and (3) discriminating dry ponds from water.

The problem of discriminating tidal flats from water was addressed using the intensity and pattern of LIDAR returns. When LIDAR is collected over water or very dark surfaces, rather than receiving the typical full-swath return, the laser beam is only reflected back to the receiver in a in a very narrow range close to nadir. This reflection pattern results in a limited swath return approximately 30-50 m wide as opposed to the anticipated full swath return of 245 m over a solid surface. Without the full swath return, data from adjacent flight lines do not overlap, resulting in striped pattern of narrow bands of data alternating with bands of no data (Figure 6).

Unfortunately, there is not a simple automated way of identifying these over-water returns and manually delineating them as such can be quite laborious. This data set was collected over a time span of three weeks and due to the complex nature of tides in South Bay, it is impossible to determine a single elevation under which all returns would be classified as over-water returns. Although geo-referenced video was collected at the time of the flights, it has proven difficult to distinguish tidally influenced areas of shallow water from the mudflats, which in the video both appear brown. Therefore, the video, does not independently serve as a reliable source for identifying over-water returns.

The technique that was most reliable for discriminating water and tidal flat was using a combination of high-resolution satellite imagery, exaggerated hill shaded images of the LIDAR, and LIDAR return intensity to manually delineate and remove over-water returns. The IKONOS imagery proved useful in determining areas of standing water that remained relatively constant from the time the imagery was collected and throughout the collection of the LIDAR. Areas such as levied ponds could be delineated using the IKONOS but the imagery could not be used to identify continually changing tidal inundation levels such as those in the tidal flats. To determine the bay-ward extent of the tide or to identify small puddles of water within the tidal flats, LIDAR intensity in conjunction with exaggerated hill-shades of the full feature return data set is best suited for distinguished these false returns from valid surface elevation returns. Areas of water tend to give a strong LIDAR return directly at nadir relative to surrounding tidal flats and marsh (Figure 6). Although a subjective technique, the results appear to be promising.

Logistical constraints.--In winter and spring, some sampling was rescheduled because rainfall caused muddy levees, preventing or restricting access to many ponds. Bathymetric sampling on ponds was further complicated because recent rains were often needed to ensure sufficient depth for sampling. Fish sampling was complicated in many ponds by early ISP activities, which resulted in fluctuating water levels. LIDAR flights were delayed due to problems with airport airspace restrictions.

SUMMARY AND RECOMMENDATIONS

Data collected during the first two years of the SBSP Restoration Project provide baseline information on project area elevation and bathymetry, historic plant species elevation, sedimentation processes, sediment chemistry and character, water quality, nutrients, primary productivity, benthic and pelagic macroinvertebrates, fishes, and birds. These data provide a scientific foundation upon which habitat response to management actions can be evaluated that has already proven useful at this early stage of the project; continued monitoring will provide necessary feedback as restoration continues.

Initial Stewardship Plan (ISP) actions were initiated in July 2004 when five project ponds were opened to circulation with Bay waters (followed by four additional ponds in April 2005). Our monthly monitoring of pond water quality and bird use enabled us to document that winter bird use was substantially higher in the salt pond complexes following pond circulation (for salinity reduction) than in the previous two winters, and that the primary increase in bird numbers was found on ponds that had been affected by the action (Figure 101). Additionally, we identified shorebirds and dabbling ducks as the primary affected foraging guilds (Figure 102) and documented that changing water levels were the likely cause. Although some birds responded quickly to pond changes, these early conditions will not continue indefinitely, and improved understanding of habitat needs will be key to maintaining target populations.

Newark and Mowry salt pond complexes remain in salt production; it is expected that they will supplement much of the lost salt pond habitat during restoration processes to maintain bird abundances in the South Bay. However, these ponds have been little studied, and it is unknown whether they can support large numbers of migratory shorebirds. Supplemental surveys of these salt ponds by San Francisco Bird Observatory in 2005-2006, coordinated with USGS project pond surveys, will provide valuable information on how all five major salt pond systems in the South Bay interact with respect to bird use and distribution.

South Bay mud flats are an important foraging resource for shorebirds, which use the salt ponds primarily during low tide when mud flats are not available. The salt pond beds are now lower than the floor of the adjacent baylands because of groundwater pumping and subsidence. As a result, a large amount of sediment will be required for restoration of salt ponds to tidal marsh (Siegel and Bachand 2002). Sediment may come from adding dredge material, capturing downstream sediments from nearby creeks, and from redistribution in the South Bay that may result in erosion of South Bay mud flats. In addition, invasive *Spartina alterniflora* may spread into the mud flats and vegetate farther onto the intertidal shoals, thereby decreasing available habitat for waterbirds (Stralberg *et al.* 2004). Monitoring of mud flat use by shorebirds will document the importance of mud flat habitat to shorebirds and provide guidance for management action.

The SBSP Restoration Project may extend for 50 years, but the most valuable scientific investment will be in early phases of the project since it will influence more of the future decisions. Consistent project monitoring is a key component of adaptive management and has been called "the environmental counterpart to financial accounting and reporting" (Lee 1993), a tool that can either support management actions or provide the information needed to guide them back in the right direction. Although not all datagaps can be identified and addressed prior to implementing management action (Trulio *et al.* 2005), filling these key datagaps early in the project provides a scientific basis on which to move forward.

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TABLES AND FIGURES

Table 1a. Minimum, maximum, mean, and standard deviation of Alviso pond elevations (NAVD88, feet), derived from 25-m bathymetric grids. Field data collected August 2003-March 2004. See pond metadata files for specifics.

System	Pond	Minimum NAVD (ft)	Maximum NAVD (ft)	Mean NAVD (ft)	StDev NAVD (ft)
Alviso	A1	-2.34	3.21	0.88	0.34
	A10	-6.11	4.26	1.32	1.74
	A11	-6.20	4.00	0.04	1.40
	A12	-11.61	3.55	-1.00	2.16
	A13	-9.14	3.41	0.13	1.73
	A14	-5.86	3.69	1.55	1.61
	A15	-9.88	4.71	0.97	2.72
	A16	-13.30	4.64	0.94	2.96
	A17	-11.72	4.48	2.41	2.40
	A19	-3.03	5.32	3.42	1.70
	A20	-3.77	5.32	3.29	1.90
	A21	-2.90	5.39	4.15	1.37
	A22	-	-	-	-
	A23	-	-	-	-
	A2E	-5.06	1.00	-0.44	0.84
	A2W	-0.44	2.72	0.37	0.40
	A3N	-7.29	1.29	-0.23	1.73
	A3W	-7.88	2.14	0.48	1.31
	A5	-	-	-	-
	A6	-	-	-	-
	A7	-	-	-	-
	A8	-11.48	1.27	-1.48	1.58
	A9	-5.12	3.99	2.97	0.69
	AB1	-2.88	3.69	1.92	0.83
	AB2	-1.30	3.58	1.90	0.52

- not sampled (pond too shallow)

Table 1b. Minimum, maximum, mean, and standard deviation of Eden Landing pond elevations (NAVD88, feet), derived from 25-m bathymetric grids. Field data collected August 2003-March 2004. See pond metadata files for specifics.

System	Pond	Minimum NAVD (ft)	Maximum NAVD (ft)	Mean NAVD (ft)	StDev NAVD (ft)
Eden Landing	B1	-6.46	6.20	4.75	0.68
	B10	1.95	6.86	4.84	0.46
	B11	4.45	7.48	6.08	0.39
	B12	-	-	-	-
	B13	-	-	-	-
	B14	3.36	6.67	5.86	0.46
	B1C	4.64	5.49	5.08	0.18
	B2	3.75	6.51	4.74	0.30
	B2C	4.67	5.61	5.30	0.17
	B3C	-	-	-	-
	B4	4.70	6.95	5.44	0.31
	B4C	-	-	-	-
	B5	2.43	6.87	5.11	0.48
	B5C	3.52	5.46	4.83	0.28
	B6	1.31	7.35	5.09	0.74
	B6A	-	-	-	-
	B6B	-	-	-	-
	B6C	0.64	6.47	5.29	0.70
	B7	2.66	5.99	4.68	0.47
	B8	-	-	-	-
	B8A	-	-	-	-
	B9	1.41	6.61	5.36	0.54

- not sampled (pond too shallow)

Table 2a. Basic sediment chemistry and structure of Alviso salt ponds; provided is average value (n = 4) for each pond, San Francisco Bay, CA.

ALVISO	Na[1/] meq/L[2/]	Na ppt	OM %	C-Org %	Sand %	Silt %	Clay %	Soil Type
Pond								
A1	340.00	7.8	4.02	2.33	20	39	41	Clay
A5	2951.68	67.9	6.43	3.73	58	22	20	Sandy Loam
A6	-	-	-	-	-	-	-	-
A7	2490.00	57.3	6.16	3.57	28	47	26	Loam
A8	2405.00	55.3	5.18	3.01	30	47	23	Loam
A9	885.50	20.4	2.97	1.72	18	41	42	Silty Clay
A10	783.33	18.0	4.57	2.65	11	42	48	Silty Clay
A11	2680.00	61.7	5.53	3.21	29	55	17	Silt Loam
A12	2376.67	54.7	4.40	2.55	30	46	24	Loam
A13	2890.00	66.5	7.29	4.23	39	45	17	Loam
A14	3503.33	80.6	5.33	3.09	56	27	17	Sandy Loam
A15	4133.47	95.1	6.40	3.71	36	40	23	Loam
A16	3710.00	85.4	6.82	3.95	38	42	20	Loam
A17	4727.03	108.8	7.69	4.46	44	24	32	Clay Loam
A19	4597.23	105.8	4.06	2.35	46	34	20	Loam
A20	3350.40	77.1	2.35	1.36	57	34	9	Sand
A21	3055.03	70.3	2.30	1.33	60	32	9	Sand
A22	2342.87	53.9	1.99	1.15	60	29	11	Sand
A23	4486.15	103.2	2.26	1.31	46	36	19	Loam
A2E	1065.00	24.5	5.78	3.35	25	36	39	Clay Loam
A2W	1359.73	31.3	3.74	2.17	41	27	32	Clay Loam
A3N	1133.33	26.1	4.48	2.60	24	40	36	Clay Loam
A3W	2177.57	50.1	4.88	2.83	62	20	19	Sandy Loam
AB1	1032.00	23.8	3.09	1.79	19	40	41	Silty Clay
AB2	1432.50	33.0	3.59	2.08	39	32	29	Clay Loam

1/ Na determined from soluble paste extract. See methods.
2/ Milliequivalents per liter.

Table 2b. Basic sediment chemistry and structure of Eden Landing and Ravenswood salt ponds; provided is average value (n = 4) for each pond, San Francisco Bay, CA.

EDEN LANDING	Na[1/] meq/L[2/]	Na ppt	OM %	C-Org %	Sand %	Silt %	Clay %	Soil Type
Pond								
B1C	2323.33	53.5	5.28	3.06	42	38	20	Loam
B2C	2570.00	59.1	4.37	2.53	36	38	26	Loam
B4C	2093.33	48.2	3.83	2.22	27	43	30	Clay Loam
B5C	2390.00	55.0	4.58	2.65	58	27	15	Sandy Loam
B6C	2752.50	63.3	3.98	2.31	61	22	17	Sandy Loam
B1	1035.15	23.8	3.72	2.16	19	49	32	Silty Clay Loam
B2	1490.00	34.3	4.92	2.86	20	43	37	Silty Clay Loam
B4	1975.50	45.5	7.40	4.30	36	37	26	Loam
B5	2545.67	58.6	4.33	2.51	31	46	23	Loam
B6	3603.45	82.9	3.96	2.29	32	53	16	Silty Loam
B7	1813.70	41.7	4.90	2.84	26	44	30	Clay Loam
B8	4363.47	100.4	4.25	2.46	47	33	20	Loam
B9	1243.50	28.6	1.87	1.08	80	13	7	Loamy Sand
B10	667.50	15.4	4.21	2.44	16	53	31	Silty Clay Loam
B11	1572.50	36.2	4.98	2.89	32	35	34	Clay Loam
B12	2080.00	47.9	5.32	3.09	24	51	26	Silty Loam
B13	3210.23	73.9	3.37	1.96	39	27	34	Clay Loam
B14	2554.80	58.8	2.62	1.52	42	41	17	Loam
B6A	4386.67	101.0	6.57	3.81	38	45	17	Loam
B6B	1357.50	31.2	4.13	2.39	37	44	20	Loam
B8A	3027.15	69.7	3.81	2.21	56	32	13	Sandy Loam
RAVENSWOOD								
R1	3615.00	83.2	1.53	0.92	57	26	17	Sandy Loam
R2	3430.00	78.9	2.22	1.28	56	29	15	Sandy Loam
R3	1933.33	44.5	5.05	2.93	36	52	12	Silty Loam
R4	3176.67	73.1	1.74	1.01	67	19	14	Sandy Loam
R5	2753.33	63.4	2.27	1.32	58	33	9	Sandy Loam
RS5	2450.00	56.4	2.21	1.28	54	36	9	Sandy Loam
RSF2	2922.50	67.3	3.35	1.87	56	27	18	Sandy Loam

[1/] Na determined from soluble paste extract. See methods.
[2/] Milliequivalents per liter.

Table 3. Chlorophyll values for 53 salt ponds, San Francisco Bay, CA.

Pond Number	**Chl a mg/m^3**	**Pond Number**	**Chl a mg/m^3**
ALVISO		**EDEN LANDING**	
A1	67	B1C	0
A2W	114	B2C	5
AB1	27	B3C	15
A2E	90	B4C	3
AB2	111	B5C	0
A3N	60	B6C	0
A3W	157	B1	27
A5	32	B2	11
A6	380	B4	11
A7	20	B5	0
A8	67	B6	0
A9	1.7	B6A	27
A10	15	B6B	187
A11	74.3	B7	36
A12	296	B8A	1
A13	-	B8	6
A14	359	B9	47
A15	203	B10	89
A16	331	B11	41
A17	240	B12	0
A19	329	B13	-
A20	192	B14	0
A21	117	**RAVENSWOOD**	
A22	0	R1	65
A23	0	R2	33
		R3	0
		R4	0
		R5	0
		RS5	0
		RSF2	-

- not sampled.

Table 4a. Water nutrient levels at Alviso salt ponds, San Francisco Bay, CA.

	NH_4-N mg/L	NO_3-N mg/L	P (Soluble) mg/L	P (Total) mg/L	Turbidity NTU	SO_4-S mg/L
A1	1.53	0.08	0.78	0.7	38.7	530
A2W	0.75	0.06	0.72	0.8	201.0	687
AB1	0.05	<0.05	1.18	1.9	270.0	687
A2E	0.76	0.05	0.81	0.9	144.0	706
AB2	0.25	<0.05	1.12	1.4	108.0	698
A3N	1.15	<0.05	1.14	1.2	109.0	974
A3W	0.50	<0.05	1.06	1.7	151.0	964
A5	0.29	0.07	0.29	0.7	61.3	1205
A6	5.74	0.11	1.06	1.1	18.2	4867
A7	0.57	<0.05	0.10	0.3	65.8	1602
A8	0.17	0.09	0.55	0.9	259.0	1919
A9	0.17	<0.05	0.94	0.8	9.6	931
A10	0.70	<0.05	0.71	0.6	59.6	927
A11	0.12	0.07	0.81	1.0	160.0	1969
A12	0.11	0.07	0.88	1.2	124.0	2045
A13	-	-	-	-	-	-
A14	0.13	0.07	0.78	1.1	144.0	2311
A15	0.11	0.06	0.87	1.3	121.0	2214
A16	0.11	0.06	0.64	0.9	107.0	2440
A17	0.10	<0.05	0.47	1.2	127.0	2610
A19	0.31	<0.05	0.88	1.4	199.0	3980
A20	0.38	0.10	0.91	1.4	190.0	4190
A21	6.02	0.12	0.76	1.3	131.0	4700
A22	1.73	0.34	0.65	1.3	34.7	7780
A23	1.07	0.27	0.57	2.0	129.0	8870

- not sampled

Table 4b. Water nutrient levels at Ravenswood salt ponds, San Francisco Bay, CA.

	NH_4-N mg/L	NO_3-N mg/L	P (Soluble) mg/L	P (Total) mg/L	Turbidity NTU	SO_4-S mg/L
R1	1.03	<0.05	0.08	0.6	133.0	2150
R2	1.93	0.26	0.94	1.2	44.9	8160
R3	0.37	0.35	0.65	1.1	26.3	9640
R4	0.45	0.33	1.46	1.7	27.4	8350
R5	0.48	0.35	1.33	1.5	51.0	8650
RS5	1.08	0.15	1.29	1.6	42.6	9970
RSF2	-	-	-	-	-	-

- not sampled

Table 4c. Water nutrient levels at Eden Landing salt ponds, San Francisco Bay, CA.

	NH4-N mg/L	NO3-N mg/L	P (Soluble) mg/L	P (Total) mg/L	Turbidity NTU	SO_4-S mg/L
B1C	1.04	0.06	0.22	0.3	18.6	1480
B2C	1.53	0.08	0.30	0.5	54.9	3490
B3C	2.10	0.15	0.23	0.6	78.0	3170
B4C	0.76	0.11	0.44	0.4	24.3	3720
B5C	1.29	0.14	0.36	0.6	37.2	3370
B5C	0.68	0.24	0.33	1.9	40.0	3390
B6C	0.76	0.17	0.32	0.3	32.6	3410
B6A	2.20	0.32	0.78	1.6	587.0	4280
B6B	8.11	<0.05	3.29	7.0	330.0	16600
B8A	1.48	0.19	0.45	0.4	20.5	3900
B1	0.33	0.23	0.27	0.4	90.2	830
B4	0.89	<0.05	0.50	0.7	50.4	1150
B6	1.01	0.14	0.38	0.5	16.0	3680
B7	0.76	<0.05	0.37	0.9	81.6	1220
B8	2.21	0.18	0.36	0.7	25.8	4250
B9	0.37	0.12	0.25	0.2	30.4	2600
B10	0.24	<0.05	0.26	0.2	6.5	800
B11	0.12	0.05	0.09	0.1	52.6	1800
B12	2.97	0.21	0.54	0.9	48.6	4900
B13	-	-	-	-	-	-
B14	5.50	0.30	3.52	4.9	117.0	18100

- not sampled

Table 5. Invertebrate taxa richness and salinity, in Alviso, Eden Landing, and Ravenswood salt ponds, San Francisco Bay, CA.

Pond	Salinity (ppt)	Annelida	Bivalvia	Crustacea	Insecta	Other	**Total**
A2W	27.1	9	1	7	0	7	**24**
A1	28.2	5	1	9	1	4	**20**
A2E	29.1	5	0	5	0	8	**18**
AB2	30.1	5	0	5	0	4	**14**
A9	32.2	11	3	7	0	6	**27**
AB1	32.2	7	1	6	0	3	**17**
A3W	33.0	5	0	1	0	7	**13**
A10	36.2	9	4	7	0	5	**25**
A3N	39.4	4	0	8	1	5	**18**
B1	41.0	8	1	11	1	6	**27**
B10	41.2	5	0	8	3	5	**21**
B2	42.0	9	1	9	1	6	**26**
B4	43.1	8	0	6	1	4	**19**
B1C	43.9	1	0	1	2	2	**6**
B7	51.9	3	0	4	0	2	**9**
A5	56.1	2	0	1	4	0	**7**
B11	66.7	4	0	3	2	2	**11**
B5	69.8	0	0	1	4	0	**5**
A7	70.6	1	0	1	5	1	**8**
B5C	72.6	0	0	1	3	0	**4**
A11	73.1	2	0	2	4	0	**8**
B6C	73.8	0	0	1	4	0	**5**
A12	75.2	4	0	2	2	0	**8**
B6	75.2	0	0	2	4	0	**6**
B12	76.5	0	0	1	3	0	**4**
A13	77.2	3	0	2	2	1	**8**
B13	80.5	0	0	1	3	0	**4**
A14	82.7	0	0	1	4	1	**6**
B6B	84.1	0	0	1	5	1	**7**
A15	84.3	0	0	1	2	0	**3**
A8	86.9	0	0	1	2	0	**3**
B4C	87.8	0	0	1	5	0	**6**
B14	88.9	0	0	1	3	0	**4**
R1	91.6	4	0	2	5	0	**11**
B6A	93.7	0	0	1	5	1	**7**
A16	97.6	0	0	1	4	0	**5**
B9	98.2	0	0	1	2	0	**3**
B3C	100.6	1	0	1	3	0	**5**
A17	106.3	0	0	1	4	0	**5**
B2C	115.0	1	0	1	4	0	**6**
B8	115.7	0	0	1	4	0	**5**
B8A	175.0	0	0	1	4	2	**7**
A23	179.0	0	0	1	1	0	**2**
A19	187.6	0	0	1	2	0	**3**
A20	194.4	0	0	1	1	0	**2**
A21	203.8	1	0	1	2	0	**4**
A22	220.0	0	0	1	5	1	**7**
A6	252.4	0	0	1	4	0	**5**
R2	264.8	0	0	1	5	1	**7**
RSF2	292.0	0	0	1	5	0	**6**
R3	308.4	0	0	1	6	0	**7**
R4	311.4	0	0	1	4	1	**6**
R5	311.8	0	0	1	4	1	**6**
RS5	326.6	0	0	1	3	0	**4**

Table 6. Annelids in Alviso salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Capitella*	*Cirratulus*	*Eteone*	*Heteromastus*	*Nereis*	Polychate	*Polydora*	Polynoidae	*Pseudopolydora*	Spionidae	*Streblospio*	Tubificoides
A1	62.75	0.00	0.00	0.00	0.00	0.00	348.33	0.00	0.08	0.00	82.33	128.67
A5	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.33	0.00	0.00
A6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
A8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A9	63.83	0.83	0.83	0.92	0.00	3.25	34.42	3.00	0.92	0.33	9.75	29.17
A10	3.75	40.33	0.75	0.08	0.00	8.00	43.42	0.08	0.25	0.00	0.00	5.50
A11	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	2.42
A12	0.17	0.00	0.00	0.00	0.00	0.00	198.42	0.00	1.17	0.17	0.00	0.00
A13	0.00	0.00	0.00	0.00	0.00	0.00	9.17	0.00	1.50	0.00	0.08	0.00
A14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
A22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2E	198.75	0.00	0.42	0.00	0.00	0.00	212.50	0.00	0.00	0.00	0.25	18.75
A2W	0.25	0.08	0.58	0.00	0.75	0.00	39.25	0.00	0.17	0.08	51.67	75.50
A3N	225.08	0.00	0.00	0.00	0.00	0.00	82.25	0.00	0.00	0.00	122.67	4.42
A3W	78.83	0.00	0.08	0.00	0.00	0.00	242.17	0.00	0.00	0.00	0.08	3.75
AB1	123.00	0.00	1.08	0.08	0.67	0.00	177.25	0.00	0.00	0.00	5.50	21.75
AB2	58.67	0.00	0.08	0.00	0.00	0.00	220.50	0.00	0.00	0.00	9.42	13.33

Table 7. Common Species in Alviso salt ponds, average per benthic grab (N = 12) and salinity, San Francisco Bay, CA.

Pond	Salinity (ppt)	*Capitella*	*Polydora*	*Streblospio*	Tubificoides	*Ampelisca*	*Artemia*	*Corophium*	Corixidae	Diptera	*Ephydra*
A2W	27.1	0.25	39.25	51.67	75.50	122.50	0.17	56.58	0.00	0.00	0.00
A1	28.2	62.75	348.33	82.33	128.67	1.92	0.00	380.75	0.00	0.25	0.00
A2E	29.1	198.75	212.50	0.25	18.75	0.00	0.17	1275.00	0.00	0.00	0.00
AB2	30.1	58.67	220.50	9.42	13.33	0.50	0.00	156.67	0.00	0.00	0.00
A9	32.2	63.83	34.42	9.75	29.17	247.92	0.00	87.67	0.00	0.00	0.00
AB1	32.2	123.00	177.25	5.50	21.75	160.83	0.00	112.42	0.00	0.00	0.00
A3W	33.0	78.83	242.17	0.08	3.75	0.00	0.00	591.42	0.00	0.00	0.00
A10	36.2	3.75	43.42	0.00	5.50	0.00	0.00	332.33	0.00	0.00	0.00
A3N	39.4	225.08	82.25	122.67	4.42	17.58	0.08	1.17	0.00	0.08	0.00
A5	56.1	0.00	16.67	0.00	0.00	0.00	0.00	0.00	6.25	0.33	0.08
A7	70.6	0.00	1.00	0.00	0.00	0.00	0.00	0.00	3.50	1.25	1.17
A11	73.1	0.00	0.67	0.00	2.42	0.00	25.25	0.08	0.17	0.17	0.00
A12	75.2	0.17	198.42	0.00	0.00	0.00	14.17	0.00	0.25	0.00	0.00
A13	77.2	0.00	9.17	0.08	0.00	0.00	14.75	0.00	0.42	0.00	0.00
A14	82.7	0.00	0.00	0.00	0.00	0.00	4.83	0.00	0.08	0.00	0.92
A15	84.3	0.00	0.00	0.00	0.00	0.00	5.17	0.00	0.00	0.25	0.00
A8	86.9	0.00	0.00	0.00	0.00	0.00	6.25	0.00	2.58	0.17	0.00
A16	97.6	0.00	0.00	0.00	0.00	0.00	4.75	0.00	0.00	0.08	0.08
A17	106.3	0.00	0.00	0.00	0.00	0.00	2.08	0.00	0.00	0.17	1.25
A23	179.0	0.00	0.00	0.00	0.00	0.00	88.17	0.00	0.00	1.25	0.00
A19	187.6	0.00	0.00	0.00	0.00	0.00	14.92	0.00	0.00	0.08	12.25
A20	194.4	0.00	0.00	0.00	0.00	0.00	82.92	0.00	0.00	0.00	0.83
A21	203.8	0.00	0.00	0.08	0.00	0.00	39.58	0.00	0.00	0.58	0.92
A22	220.0	0.00	0.00	0.00	0.00	0.00	100.08	0.00	1.42	28.00	39.50
A6	252.4	0.00	0.00	0.00	0.00	0.00	82.67	0.00	0.00	0.83	4.42

Table 8. Insecta in Alviso salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	Chironomidae	Coleoptera	Corixidae	Diptera	*Ephydra*	Hydrellia	Hydrophilidae	Muscidae
A1	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
A5	0.00	0.00	6.25	0.33	0.08	0.00	0.25	0.00
A6	0.00	0.00	0.00	0.83	4.42	0.33	0.17	0.00
A7	0.08	0.00	3.50	1.25	1.17	0.00	2.50	0.00
A8	0.00	0.00	2.58	0.17	0.00	0.00	0.00	0.00
A9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A11	0.00	0.00	0.17	0.17	0.00	0.00	0.17	0.08
A12	0.00	0.00	0.25	0.00	0.00	0.00	0.25	0.00
A13	0.00	0.00	0.42	0.00	0.00	0.00	2.08	0.00
A14	0.00	0.00	0.08	0.00	0.92	0.00	3.25	0.00
A15	0.00	0.00	0.00	0.25	0.00	0.00	2.50	0.00
A16	0.00	0.00	0.00	0.08	0.08	0.00	1.09	0.00
A17	0.00	0.00	0.00	0.17	1.25	0.00	2.91	0.00
A19	0.00	0.00	0.00	0.08	12.25	0.00	0.00	0.00
A20	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00
A21	0.00	0.00	0.00	0.58	0.92	0.00	0.00	0.00
A22	0.00	0.08	1.42	28.00	39.50	0.00	0.00	0.50
A23	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00
A2E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A3N	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
A3W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9. Gastropoda and Bivalvia in Alviso salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Assiminea californica*	Muricidae	*Opisthobranchia*	*Tryonia*	Pyramidellidae	*Gemma gemma*	*Macoma balthica*	*M. senhousia*	*Mya arenaria*	Mytilidae
A1	6.17	0.00	0.42	0.00	0.00	0.08	0.00	0.00	0.00	0.00
A5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A9	0.17	0.08	0.83	0.00	0.00	0.17	0.17	0.00	0.00	0.08
A10	0.00	0.00	0.08	0.00	0.00	21.00	0.00	0.42	5.42	2.92
A11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2E	0.42	0.00	0.17	41.58	0.00	0.00	0.00	0.00	0.00	0.00
A2W	0.17	0.00	0.00	0.00	0.42	28.08	0.00	0.00	0.00	0.00
A3N	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A3W	0.75	0.00	0.08	5.50	0.00	0.00	0.00	0.00	0.00	0.00
AB1	0.00	0.00	0.00	7.67	0.00	0.00	0.25	0.00	0.00	0.00
AB2	0.00	0.00	0.00	17.08	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Crustacea in Alviso salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Ampelisca*	Ampithoidae	*Artemia*	*Cirripedia*	Copepoda	*Corophium*	Cumacea	*Ericthonius*	Gammaridae	*Melita Californica*	*Mysis*	Ostracoda	*Palaemon macrodactylus*	*Paranthura elegans*	Sphaeromatidae
A1	1.92	0.00	0.00	0.00	0.67	380.75	0.33	0.08	10.25	0.83	4.08	0.08	0.00	0.00	0.00
A5	0.00	0.00	0.00	0.00	2.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A6	0.00	0.00	82.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A7	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A8	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A9	247.92	0.08	0.00	0.00	0.17	87.67	8.67	19.75	0.00	0.00	0.00	0.42	0.00	0.00	0.00
A10	0.00	3.75	0.00	0.00	0.33	332.33	0.00	13.42	0.00	0.00	0.08	0.00	0.08	0.50	0.00
A11	0.00	0.00	25.25	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A12	0.00	0.00	14.17	25.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A13	0.00	0.00	14.75	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A14	0.00	0.00	4.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	5.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A16	0.00	0.00	4.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A17	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	0.00	0.00	14.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A20	0.00	0.00	82.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	0.00	0.00	39.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A22	0.00	0.00	100.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A23	0.00	0.00	88.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2E	0.00	1.25	0.17	0.00	0.00	1275.00	0.00	1.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00
A2W	122.50	0.00	0.17	0.00	0.00	56.58	4.67	5.33	0.00	0.00	0.92	0.00	0.00	0.00	0.08
A3N	17.58	4.17	0.08	0.00	0.17	1.17	8.67	34.75	0.00	0.00	0.08	0.00	0.00	0.00	0.00
A3W	0.00	0.00	0.00	0.00	0.00	591.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB1	160.83	0.17	0.00	0.00	0.00	112.42	0.42	2.83	0.17	0.00	0.00	0.00	0.00	0.00	0.00
AB2	0.50	1.25	0.00	0.00	0.00	156.67	0.92	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00

Table 11. Other species in Alviso salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Turbellaria*	Lineidae	Nematoda	Spider	Anthozoa	*Diadumene*	*Edwardsia*	Hydrozoa	Hydroid Colony
A1	0.00	0.00	6.50	0.00	0.00	0.00	5.50	0.00	0.00
A5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A7	0.00	0.00	1.83	0.00	0.00	0.00	0.00	0.00	0.00
A8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A9	0.00	0.00	17.42	0.00	0.00	0.00	0.00	0.17	0.58
A10	3.83	0.25	4.58	0.00	0.00	0.67	0.00	0.00	0.00
A11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A13	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
A14	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
A15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A22	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00
A23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2E	0.08	0.00	1.17	0.00	0.08	0.00	0.67	0.00	0.00
A2W	0.25	0.42	3.08	0.00	0.00	0.33	0.00	0.00	0.25
A3N	0.00	29.58	0.33	0.00	0.00	0.08	0.17	0.00	0.00
A3W	1.00	0.00	0.33	0.00	0.00	0.17	0.17	0.00	0.00
AB1	0.00	0.00	2.75	0.00	0.00	0.00	1.25	0.00	0.00
AB2	0.75	0.00	0.00	0.00	0.00	0.00	2.50	0.08	0.00

Table 12. Taxa in sweep samples in Alviso salt ponds, average per sweep (N = 12) and salinity, San Francisco Bay, CA.

Pond	Salinity	*Artemia*	Ampithoe	Corixidae	*Corophium*	Diptera	*Ephydra*	Gammaridae	Hydrophilidae	*Mysis*
A2W	27.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A1	28.2	0.00	0.00	0.00	1.0	0.00	0.00	3.0	0.00	22.0
A2E	29.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB2	30.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A9	32.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB1	32.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A3W	33.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A10	36.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A3N	39.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5	56.1	0.00	0.00	47.0	0.00	0.00	0.00	0.00	0.00	0.00
A7	70.6	0.7	0.00	161.0	0.00	0.00	0.00	0.00	0.00	0.00
A11	73.1	3707.5	0.00	3.5	0.00	0.00	0.00	0.00	0.00	0.00
A12	75.2	2141.0	0.00	11.0	0.00	0.00	0.00	0.00	0.00	0.00
A13	77.2	1467.0	0.00	3.5	0.00	0.00	0.00	0.00	0.00	0.00
A14	82.7	1656.3	0.00	1.0	0.00	0.5	0.00	0.00	0.00	0.00
A15	84.3	656.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A8	86.9	1254.3	0.00	200.0	0.00	0.00	0.00	0.00	0.00	0.00
A16	97.6	2688.0	0.00	0.7	0.00	0.00	0.00	0.00	0.00	0.00
A17	106.3	919.0	0.00	4.3	0.00	0.00	1.0	0.00	3.3	0.00
A23	179.0	1808.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A19	187.6	2317.3	0.00	0.00	0.00	0.00	1.3	0.00	0.00	0.00
A20	194.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A21	203.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A22	220.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A6	252.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 13. Common species in Eden Landing salt ponds, average per benthic grab (N = 12) and salinity, San Francisco Bay, CA.

Pond	Salinity (ppt)	*Capitella*	*Polydora*	*Streblospio*	Tubificoides	*Ampelisca*	*Artemia*	*Corophium*	Corixidae	Diptera	*Ephydra*
B1	41.0	0.67	0.75	32.17	71.58	100.42	0.00	237.67	0.00	0.08	0.00
B10	41.2	64.75	28.42	138.50	43.92	39.42	0.00	132.92	0.08	0.42	0.67
B2	42.0	1.58	3.75	24.42	291.75	17.00	0.00	390.67	0.00	0.00	0.00
B4	43.1	132.25	75.33	121.08	8.83	0.00	0.00	272.50	0.00	0.08	0.00
B1C	43.9	0.00	0.00	0.00	0.08	0.00	91.75	0.00	0.00	0.08	0.25
B7	51.9	35.08	62.67	117.92	0.00	0.00	0.08	271.33	0.00	0.00	0.00
B11	66.7	14.00	186.92	1.00	101.08	0.00	0.00	1.08	1.50	0.00	0.08
B5	69.8	0.00	0.00	0.00	0.00	0.00	30.33	0.00	0.58	0.08	3.33
B5C	72.6	0.00	0.00	0.00	0.00	0.00	76.92	0.00	0.25	0.00	1.17
B6C	73.9	0.00	0.00	0.00	0.00	0.00	5.09	0.00	0.27	0.55	8.27
B6	75.2	0.00	0.00	0.00	0.00	0.00	115.58	0.08	0.58	0.08	14.17
B12	76.5	0.00	0.00	0.00	0.00	0.00	93.50	0.00	0.08	0.17	9.92
B13	80.5	0.00	0.00	0.00	0.00	0.00	137.92	0.00	0.00	0.75	46.00
B6B	84.1	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.08	0.58	2.17
B4C	87.8	0.00	0.00	0.00	0.00	0.00	47.33	0.00	1.17	0.17	0.58
B14	88.9	0.00	0.00	0.00	0.00	0.00	27.50	0.00	0.00	1.00	45.33
B6A	93.7	0.00	0.00	0.00	0.00	0.00	6.58	0.00	0.17	1.42	2.00
B9	98.2	0.00	0.00	0.00	0.00	0.00	54.17	0.00	0.00	0.00	74.25
B3C	100.6	0.00	0.42	0.00	0.00	0.00	38.33	0.00	0.92	0.00	0.17
B2C	115.0	0.00	1.67	0.00	0.00	0.00	28.75	0.00	2.92	0.00	0.33

Table 14. Annelids in Eden Landing salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Capitella*	*Cirratulus*	*Eteone*	*Heteromastus*	Polychate	*Polydora*	*Pseudopolydora*	*Streblospio*	Tubificoides
B1	0.67	0.08	0.00	12.25	215.33	0.75	0.42	32.17	71.58
B2	1.58	0.08	1.08	196.58	210.50	3.75	0.17	24.42	291.75
B4	132.25	0.00	0.08	5.00	0.67	75.33	0.08	121.08	8.83
B5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B7	35.08	0.00	0.00	0.00	0.00	62.67	0.00	117.92	0.00
B8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B10	64.75	0.00	0.33	0.00	0.00	28.42	0.00	138.50	43.92
B11	14.00	0.00	0.00	0.00	0.00	186.92	0.00	1.00	101.08
B12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B1C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
B2C	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00
B3C	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00
B4C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B5C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B8A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 15. Crustacea in Eden Landing salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Ampelisca*	Ampithoidae	*Artemia*	*Cirripedia*	Copepoda	*Corophium*	Cumacea	*Ericthonius*	Gammaridae	*Hemigrapsus oregonensis*	*Mysis*	Ostracoda	*Palaemon macrodactylus*
B1	100.42	0.00	0.00	0.17	2.00	237.67	17.42	5.00	0.00	0.08	0.67	77.58	0.08
B2	17.00	0.00	0.00	0.00	6.67	390.67	6.92	13.50	0.33	0.00	3.83	57.50	0.00
B4	0.00	0.00	0.00	0.00	6.75	272.50	0.17	2.08	0.00	0.00	0.08	18.67	0.00
B5	0.00	0.00	30.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6	0.00	0.00	115.58	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B7	0.00	0.00	0.08	0.00	2.75	271.33	0.00	0.00	0.00	0.00	0.00	1.17	0.00
B8	0.00	0.00	28.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B9	0.00	0.00	54.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B10	39.42	0.17	0.00	0.00	11.00	132.92	10.08	13.42	0.08	0.00	0.00	3.58	0.00
B11	0.00	0.00	0.00	0.00	0.08	1.08	0.00	0.08	0.00	0.00	0.00	0.00	0.00
B12	0.00	0.00	93.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B13	0.00	0.00	137.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B14	0.00	0.00	27.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B1C	0.00	0.00	91.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B2C	0.00	0.00	28.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B3C	0.00	0.00	38.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B4C	0.00	0.00	47.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B5C	0.00	0.00	76.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6C	0.00	0.00	5.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6A	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6B	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B8A	0.00	0.00	73.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 16. Insecta in Eden Landing salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	Coleoptera	Corixidae	Diptera	*Ephydra*	Hydrophilidae	Muscidae
B1	0.00	0.00	0.08	0.00	0.00	0.00
B2	0.08	0.00	0.00	0.00	0.00	0.00
B4	0.00	0.00	0.08	0.00	0.00	0.00
B5	0.00	0.58	0.08	3.33	0.75	0.00
B6	0.00	0.58	0.08	14.17	10.25	0.00
B7	0.00	0.00	0.00	0.00	0.00	0.00
B8	0.00	0.92	0.25	17.33	0.83	0.00
B9	0.00	0.00	0.00	74.25	0.33	0.00
B10	0.00	0.08	0.42	0.67	0.00	0.00
B11	0.00	1.50	0.00	0.08	0.00	0.00
B12	0.00	0.08	0.17	9.92	0.00	0.00
B13	0.00	0.00	0.75	46.00	0.08	0.00
B14	0.00	0.00	1.00	45.33	0.17	0.00
B1C	0.00	0.00	0.08	0.25	0.00	0.00
B2C	0.00	2.92	0.00	0.33	2.91	0.00
B3C	0.00	0.92	0.00	0.17	1.17	0.00
B4C	0.00	1.17	0.17	0.58	0.42	0.00
B5C	0.00	0.25	0.00	1.17	0.50	0.00
B6C	0.00	0.27	0.55	8.27	3.82	0.00
B6A	0.08	0.17	1.42	2.00	0.00	1.08
B6B	0.00	0.08	0.58	2.17	0.00	0.58
B8A	0.00	1.08	0.42	202.92	0.25	0.00

Table 17. Gastropoda and Bivalvia in Eden Landing salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Assiminea californica*	*Tryonia imitator*	Opisthobranchia	*Gemma gemma*
B1	0.00	6.58	0.00	20.50
B2	0.00	3.75	0.08	0.33
B4	0.00	0.00	0.92	0.00
B5	0.00	0.00	0.00	0.00
B6	0.00	0.00	0.00	0.00
B7	0.00	0.00	0.08	0.00
B8	0.00	0.00	0.00	0.00
B9	0.00	0.00	0.00	0.00
B10	0.00	0.00	0.00	0.00
B11	0.00	0.00	0.00	0.00
B12	0.00	0.00	0.00	0.00
B13	0.00	0.00	0.00	0.00
B14	0.00	0.00	0.00	0.00
B1C	0.17	0.00	0.00	0.00
B2C	0.00	0.00	0.00	0.00
B3C	0.00	0.00	0.00	0.00
B4C	0.00	0.00	0.00	0.00
B5C	0.00	0.00	0.00	0.00
B6C	0.00	0.00	0.00	0.00
B6A	0.00	0.00	0.00	0.00
B6B	0.00	0.00	0.00	0.00
B8A	0.00	0.00	0.00	0.00

Table 18. Other species in Eden Landing salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	Lineidae	Nematoda	Spider	Anthozoa	Diadumene	*Edwardsia*	Hydrozoa
B1	0.33	28.92	0.00	0.00	0.25	1.92	1.25
B2	0.00	52.08	0.00	0.33	0.50	20.83	4.25
B4	0.00	73.50	0.00	0.67	0.00	26.33	0.92
B5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B7	0.00	363.08	0.00	0.00	0.00	0.00	0.00
B8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B10	0.08	16.58	0.08	0.00	0.00	0.75	1.58
B11	0.00	0.08	0.00	0.00	0.00	0.08	0.00
B12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B1C	0.00	0.08	0.00	0.00	0.00	0.00	0.00
B2C	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B3C	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B4C	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B5C	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6C	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6A	0.00	0.00	0.08	0.00	0.00	0.00	0.00
B6B	0.00	0.00	0.33	0.00	0.00	0.00	0.00
B8A	0.00	0.00	0.08	0.00	0.00	0.08	0.00

Table 19. Taxa in sweep samples in Eden Landing salt ponds, average per sweep (N = 12), San Francisco Bay, CA.

Pond	Salinity (ppt)	*Artemia*	Corixidae	Chironomidae	Diptera	*Ephydra*	Hydrophilidae	Hydrozoa	*Mysis*	Muscidae
B1	41.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B10	41.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B2	42.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B4	43.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B1C	43.9	3046.0	1.0	0.7	0.3	0.3	0.00	0.00	0.3	0.00
B7	51.9	6180.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B11	66.7	1.0	20.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B5	69.8	970.0	20.3	0.00	0.00	0.3	0.00	0.00	0.00	0.00
B5C	72.6	11928.0	174.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6C	73.8	1568.0	7.0	0.00	0.00	1.0	0.00	0.00	0.00	0.00
B6	75.2	5620.0	6.5	0.00	0.00	3.7	3.3	0.00	0.00	0.00
B12	76.5	4497.7	0.00	0.00	0.3	0.00	0.00	0.00	0.00	0.00
B13	80.5	2125.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B6B	84.1	424.0	2.3	0.00	0.00	0.5	0.00	0.00	0.00	0.00
B4C	87.8	11247.7	788.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B14	88.9	913.7	0.00	0.00	1.0	11.3	0.00	0.00	0.00	0.00
B6A	93.7	29.3	2.0	0.00	3.0	1.0	0.00	1.0	0.00	1.0
B9	98.2	23120.0	0.00	0.00	0.00	4.0	0.00	0.00	0.00	0.00
B3C	100.6	21744.0	199.0	0.00	0.00	0.00	0.3	0.00	0.00	0.00
B2C	115.0	842.0	678.0	0.00	0.00	0.00	0.7	0.00	0.00	0.00
B8	115.7	3234.7	0.00	0.00	0.00	1.7	0.3	0.00	0.00	0.00
B8A	175.0	4521.8	7.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 20. Common species in Ravenswood salt ponds, average per benthic grab (N = 12) and salinity, San Francisco Bay, CA.

Pond	Salinity (ppt)	*Polydora*	*Artemia*	Corixidae	Diptera	*Ephydra*
R1	91.6	80.08	0.42	39.67	3.33	10.25
R2	264.8	0.00	45.75	0.08	1.17	1.33
RSF2	292.0	0.00	103.50	0.08	4.33	0.75
R3	308.4	0.00	91.67	0.50	0.92	21.42
R4	311.4	0.00	73.33	0.25	1.92	25.33
R5	311.8	0.00	101.33	0.17	4.67	8.33
RS5	326.6	0.00	25.83	0.00	2.00	4.17

Table 21. Annelids in Ravenswood salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Heteromastus*	*Nereis*	*Polydora*	*Pseudopolydora*
R1	0.42	0.08	80.08	0.17
R2	0.00	0.00	0.00	0.00
R3	0.00	0.00	0.00	0.00
R4	0.00	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00
RS5	0.00	0.00	0.00	0.00
RSF2	0.00	0.00	0.00	0.00

Table 22. Insecta in Ravenswood salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	Coleoptera	Corixidae	Diptera	*Ephydra*	Hydrophilidae	Muscidae
R1	0.00	39.67	3.33	10.25	0.17	0.08
R2	0.00	0.08	1.17	1.33	0.00	5.34
R3	0.25	0.50	0.92	21.42	0.00	1.25
R4	0.00	0.25	1.92	25.33	0.00	0.33
R5	0.00	0.17	4.67	8.33	0.00	0.50
RS5	0.00	0.00	2.00	4.17	0.00	2.00
RSF2	0.00	0.08	4.33	0.75	0.08	0.50

Table 23. Crustacea in Ravenswood salt ponds, average per benthic grab (N = 12), San Francisco Bay, CA.

Pond	*Artemia*	Gammaridae
R1	0.42	0.08
R2	45.75	0.00
R3	91.67	0.00
R4	73.33	0.00
R5	101.33	0.00
RS5	25.83	0.00
RSF2	103.50	0.00

Table 24. Common species in Ravenswood salt ponds, average per sweep (N = 12) and salinity, San Francisco Bay, CA.

Pond	Salinity (ppt)	*Artemia*	Corixidae
R1	91.6	0.00	79.00
R2	264.8	651.25	0.75
R3	308.4	519.50	0.00
R4	311.4	7994.50	0.25
R5	311.8	821.00	0.00
RS5	326.6	279.00	0.50
RSF2	292.0	5581.50	4.50

Table 25. Taxa in sweep samples in Ravenswood salt ponds, average per sweep (N = 12), San Francisco Bay, CA.

Pond	*Artemia*	Corixidae	Diptera	*Ephydra*	Muscidae
R1	0.00	79.00	0.00	0.30	0.00
R2	651.30	0.75	4.00	2.10	8.00
R3	519.50	0.00	0.80	0.8	0.00
R4	7994.50	0.25	0.00	0.00	0.00
R5	821.00	0.00	0.00	0.00	0.00
RS5	279.00	0.5	1.00	0.50	0.00
RSF2	5581.50	4.5	0.80	0.80	0.00

Table 26. Average taxa group per benthic grab (N = 12) from an ongoing seasonal USGS Place-based study of 6 Alviso salt ponds initiated in 2002, San Francisco Bay, CA.

		Salinity	Annelida	Bivalvia	Crustacea	Insecta	Other
Pond 9	Jan-02	32.5	37.93	3.47	165.67	0.00	10.60
	Jul-02	25.8	163.53	9.27	1037.93	0.80	26.33
	Oct-02	30.7	287.87	1.73	483.60	0.00	7.13
	Mar-03	32.2	147.25	0.42	365.08	0.00	19.58
	Jun-03	-	387.92	1.69	780.31	0.08	81.23
Pond 10	Jan-02	35.0	144.73	0.00	71.20	0.00	1.07
	Jul-02	27.5	227.60	0.67	374.60	0.00	3.33
	Oct-02	38.2	201.87	1.93	628.73	0.07	2.67
	Mar-03	36.2	102.17	29.75	350.50	0.00	9.42
	Jun-03	-	355.83	13.83	1515.92	0.00	61.58
Pond 11	Jan-02	61.4	7.00	0.00	6.27	0.79	0.00
	Jul-02	42.1	146.27	0.00	23.20	13.20	0.13
	Oct-02	62.2	0.20	0.00	0.33	0.20	0.00
	Mar-03	73.1	3.08	0.00	25.33	0.75	0.00
	Jun-03	-	0.50	0.00	12.67	0.83	0.00
Pond 12	Jan-02	55.6	270.07	0.00	14.73	0.80	7.13
	Jul-02	57.2	14.73	0.00	2.47	0.13	0.13
	Oct-02	67.8	22.33	0.00	17.13	0.00	0.13
	Mar-03	75.2	199.92	0.00	39.42	0.50	0.00
Pond 14	Jan-02	71.9	0.00	0.00	7.93	1.33	0.00
	Jul-02	104.0	0.00	0.00	10.00	1.07	0.00
	Oct-02	132.2	0.00	0.00	3.93	0.27	0.13
	Mar-03	82.7	0.00	0.00	4.83	5.17	0.08
	Jun-03	-	0.00	0.00	36.75	1.08	0.00
	Oct-03	-	0.00	0.00	1.13	13.53	0.00
Pond 16	Jan-02	67.6	0.00	0.00	0.93	16.53	0.00
	Jul-02	93.5	0.00	0.00	16.67	2.87	0.00
	Oct-02	114.3	0.00	0.00	6.13	3.20	0.00
	Mar-03	97.6	0.00	0.00	4.75	1.42	0.00
	Jun-03	-	0.00	0.00	44.75	7.25	0.00

- not sampled

Table 27. Species composition of fish captured by using gill nets, bag seines, and minnow traps during 2004. Values are number of individuals or percent.

Family	Species		Gill net								Bag seine[2]				Minnow trap							
	Scientific Name	Common name[1]	Ponds				Sloughs				Ponds				Ponds				Sloughs			
			Alviso		Baumberg		Alviso		Baumberg		Alviso		Baumberg		Alviso		Baumberg		Alviso		Baumberg	
			N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Clupeidae	*Alosa sapidissima*	American shad (I)	0	0.0	0	0.0	8	0.7	18	3.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Clupeidae	*Dorosoma petenense*	Threadfin shad (I)	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	*Cyprinus carpio*	Common carp (I)	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Tridentiger trigonocephalus*	Chameleon goby (I)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	14	0.8	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Acanthogobius flavimanus*	Yellowfin goby (I)	21	1.8	4	3.2	15	1.2	7	1.3	61	1.2	682	40.0	1	0.4	0	0.0	4	57.1	3	4.6
Fundulidae	*Lucania parva*	Rainwater killifish (I)	0	0.0	0	0.0	0	0.0	0	0.0	3743	72.4	207	12.2	217	90.4	6	85.7	2	28.6	62	95.4
Moronidae	*Morone saxatilis*	Striped bass (I)	1	0.1	0	0.0	9	0.7	32	5.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Syngnathidae	*Syngnathus leptorhynchus*	Bay pipefish (N)	0	0.0	1	0.8	0	0.0	0	0.0	4	0.1	25	1.5	0	0.0	0	0.0	0	0.0	0	0.0
Myliobatidae	*Myliobatis californica*	Bat ray (N)	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	*Gillichthys mirabilis*	Longjaw mudsucker (N)	5	0.4	1	0.8	0	0.0	0	0.0	517	10.0	210	12.3	16	6.7	0	0.0	1	14.3	0	0.0
Triakidae	*Triakis semifasciata*	Leopard shark (N)	13	1.1	1	0.8	3	0.2	132	24.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmeridae	*Spirinchus thaleichthys*	Longfin smelt (N)	0	0.0	0	0.0	2	0.2	4	0.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Engraulididae	*Engraulis mordax*	Northern anchovy (N)	32	2.7	9	7.1	168	14.0	150	27.5	2	0.0	16	0.9	0	0.0	0	0.0	0	0.0	0	0.0
Atherinidae	*Atherinops affinis*	Topsmelt (N)	1110	93.0	103	81.7	991	82.5	171	31.4	345	6.7	491	28.8	6	2.5	1	14.3	0	0.0	0	0.0
Catostomidae	*Catostomus occidentalis*	Sacramento sucker (N)	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Embioticidae	*Cymatogaster aggregata*	Shiner surfperch (N)	3	0.3	0	0.0	0	0.0	8	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Table 27. Continued.

Family	Species: Scientific Name	Species: Common name[1]	Gill net: Ponds: Alviso N	%	Baumberg N	%	Gill net: Sloughs: Alviso N	%	Baumberg N	%	Bag seine[2]: Ponds: Alviso N	%	Baumberg N	%	Minnow trap: Ponds: Alviso N	%	Baumberg N	%	Minnow trap: Sloughs: Alviso N	%	Baumberg N	%
Cottidae	*Leptocottus armatus*	Staghorn sculpin (N)	8	0.7	3	2.4	2	0.2	18	3.3	270	5.2	28	1.6	0	0.0	0	0.0	0	0.0	0	0.0
Pleuronectidae	*Platichthys stellatus*	Starry flounder (N)	0	0.0	4	3.2	0	0.0	4	0.7	0	0.0	2	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback (N)	0	0.0	0	0.0	0	0.0	0	0.0	6	0.1	5	0.3	0	0.0	0	0.0	0	0.0	0	0.0
Gobiidae	NA	Unidentified gobies (ND)	0	0.0	0	0.0	0	0.0	0	0.0	58	1.1	18	1.1	0	0.0	0	0.0	0	0.0	0	0.0
Undetermined	NA	Unidentified larvae (ND)	0	0.0	0	0.0	0	0.0	0	0.0	164	3.2	5	0.3	0	0.0	0	0.0	0	0.0	0	0.0
		TOTAL	1193	100	126	100	1201	100	545	100	5171	100	1703	100	240	100	7	100	7	100	65	100

[1]Codes: I, introduced; N, native; ND, not determined; NA, not applicable.
[2] Seining not conducted in sloughs.

Table 28. Fish abundance in selected salt ponds or sloughs during March, June, September, and November 2004. Values are catch-per-unit-effort (number of sets or hauls in parentheses).

Site	**Gill net (No. fish/2 hr of fishing)**				**Minnow trap (No. fish/1 hr of fishing)**				**Bag seine (No. fish/haul)**			
	Mar	**Jun**	**Sep**	**Nov**	**Mar**	**Jun**	**Sep**	**Nov**	**Mar**	**Jun**	**Sep**	**Nov**
Pond A10	1.63 (8)	2.25 (8)	0.25 (8)	1.88 (8)	--- (0)	--- (0)	--- (0)	0.55 (20)	16.45 (20)	70.05 (20)	20.25 (16)	1.25 (4)
Pond A11	4.38 (8)	24.25 (8)	0.25 (8)	0.00 (8)	--- (0)	1.35 (20)	--- (0)	0.25 (20)	3.25 (20)	--- (0)	6.31 (16)	--- (0)
Pond A12	7.38 (8)	7.50 (8)	22.25 (8)	1.25 (8)	--- (0)	--- (0)	--- (0)	0.40 (20)	7.20 (15)	--- (0)	4.00 (16)	1.33 (3)
Pond A2E	0.00 (8)	0.75 (8)	2.50 (8)	0.13 (8)	--- (0)	--- (0)	--- (0)	0.40 (20)	1.40 (20)	3.56 (20)	46.19 (16)	3.50 (4)
Pond A2W	2.38 (8)	49.75 (8)	7.75 (8)	0.00 (8)	--- (0)	--- (0)	--- (0)	8.90 (20)	14.85 (20)	10.44 (20)	10.63 (16)	1.00 (4)
Pond A9	7.00 (8)	1.25 (8)	4.38 (8)	0.00 (8)	--- (0)	--- (0)	--- (0)	0.20 (20)	11.90 (20)	29.13 (20)	28.13 (16)	4.00 (3)
Pond B1	0.63 (8)	0.13 (8)	0.50 (8)	0.25 (8)	--- (0)	--- (0)	--- (0)	0.05 (20)	4.35 (20)	7.25 (20)	8.17 (12)	4.25 (4)
Pond B2	0.50 (8)	0.50 (8)	--- (0)	0.00 (8)	--- (0)	--- (0)	0.00 (20)	0.00 (20)	7.30 (20)	5.56 (20)	0.50 (8)	0.75 (4)
Pond B4	0.63 (8)	0.13 (8)	--- (0)	--	--- (0)	--- (0)	--- (0)	--- (0)	15.55 (20)	3.38 (20)	--- (0)	--- (0)
Pond B5	0.00 (6)	2.13 (8)	2.38 (8)	0.17 (8)	--- (0)	--- (0)	--- (0)	0.00 (15)	0.00 (15)	4.50 (20)	1.44 (16)	1.00 (3)
Pond B6C	0.00 (6)	0.00 (8)	0.38 (8)	0.00 (8)	--- (0)	--- (0)	--- (0)	0.05 (20)	0.00 (15)	7.06 (20)	0.50 (16)	0.25 (4)
Pond B7	0.75 (8)	0.63 (8)	6.13 (8)	0.00 (8)	--- (0)	--- (0)	--- (0)	0.25 (20)	10.30 (20)	14.31 (20)	7.50 (16)	1.50 (2)
Coyote Hills Slough	--- (0)	2.88 (8)	18.25 (8)	0.25 (8)	--- (0)	0.05 (20)	0.00 (15)	0.00 (20)	--- (0)	--- (0)	--- (0)	--- (0)
Alviso Slough	--- (0)	5.25 (8)	18.75 (8)	1.25 (8)	--- (0)	0.10 (20)	0.07 (15)	0.10 (20)	--- (0)	--- (0)	--- (0)	--- (0)
Coyote Creek	--- (0)	24.13 (8)	4.50 (8)	3.13 (8)	--- (0)	0.05 (20)	0.00 (10)	0.10 (20)	--- (0)	--- (0)	--- (0)	--- (0)
Old Alameda Flood Control Channel	--- (0)	3.00 (8)	12.00 (8)	0.00 (8)	--- (0)	0.00 (20)	3.05 (20)	0.00 (20)	--- (0)	--- (0)	--- (0)	--- (0)
Stevens Creek	--- (0)	121.25 (8)	2.25 (8)	1.38 (8)	--- (0)	0.10 (20)	0.00 (20)	0.00 (10)	--- (0)	--- (0)	--- (0)	--- (0)

Table 29. Summary of water temperature (Temp), dissolved oxygen (DO), pH, and salinity (Sal) measured concurrent with fish surveys on four occasions (March, June, September, and November) during 2004. Values are arithmetic means.[a] Alviso ponds consist of A2E, A2W, A9, A10, A11 and A12; Alviso sloughs consist of Alviso Slough, Coyote Creek, and Stevens Creek; Baumberg ponds consist of B1, B2, B4, B5, B6C, and B7; and Baumberg sloughs consist of Coyote Hills Slough and Old Alameda Creek Flood Control Channel.

Locality or ANOVA	**Temp (°C)**	**DO (mg/l)**	**pH**	**Sal (ppt)**
Alviso ponds	17.65 B	6.03 B	8.56 A	34.57 B
Alviso sloughs	19.55 A	6.03 B	7.9 B	16.52 D
Baumberg ponds	16.75 B	5.76 B	8.58 A	47.06 A
Baumberg sloughs	17.32 B	6.77 A	7.91 B	23.27 C
F-value[b]	10.15*	7.26*	242.38*	228.43*

[a]Within each column, means followed by the same capital letter are not significantly different (P>0.05).
[b]Code: $P \leq 0.0001$.

Table 30. Summary of water temperature (Temp), Dissolved oxygen (DO) concentration, pH, and Salinity (Sal) measured concurrent with fish surveys from March to November 2004. Values are arithmetic means (No. observations in parentheses), minima, and maxima.

Locality	Parameter	March			June			September			November		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Alviso ponds	Temp	17.1 (44)	12.0	21.5	20.1 (75)	16.8	25	21.08 (64)	17	27	11.66 (63)	7.23	14.46
	DO	7.0 (44)	1.9	13.4	4.51 (75)	0.14	8.9	4.5 (64)	1.4	8.6	8.21 (63)	2.41	16.53
	pH	8.64 (44)	7.80	9.39	8.7 (75)	7.95	9.7	8.5 (64)	8	9	8.41 (63)	7.81	9.07
	Sal	39.2 (44)	21.0	64.7	35.5 (75)	0.2	63	34.42 (64)	17	51	29.91 (63)	21.4	40.7
Baumberg ponds	Temp	15.2 (30)	13.0	20.7	20.3 (73)	17.15	25	19.44 (51)	14	25	8.25 (41)	6.49	11.17
	DO	6.5 (30)	4.5	10.4	5.11 (72)	0.68	9.1	4.16 (51)	0.6	8.3	8.33 (41)	4.09	12.24
	pH	8.48 (30)	8.00	8.92	8.5 (72)	6.69	8.8	8.84 (51)	7.8	11	8.48 (47)	7.89	9.09
	Sal	54.4 (28)	38.0	91.1	44.2 (73)	25.1	64	46.95 (51)	17	61	47.18 (45)	28.3	88.4
Alviso sloughs	Temp	--- (0)	---	---	23 (42)	18.64	30	21.09 (42)	19	24	15.11 (47)	14.6	15.91
	DO	--- (0)	---	---	5.96 (42)	2.61	7.3	5.63 (42)	3.9	8	6.45 (47)	4.72	7.67
	pH	--- (0)	---	---	7.95 (42)	7.76	8.3	8.03 (42)	7.4	8.4	7.73 (47)	7.35	8.08
	Sal	--- (0)	---	---	12.7 (42)	0.7	22	17.25 (42)	0.8	27	19.3 (47)	1.8	25.1
Baumberg sloughs	Temp	--- (0)	---	---	19.6 (72)	15.72	23	21.64 (67)	19	25	11.23 (75)	8.79	17.23
	DO	--- (0)	---	---	6.07 (72)	4.69	7.9	5.07 (67)	2.4	7.5	8.97 (75)	5.42	11.73
	pH	--- (0)	---	---	7.87 (72)	7.64	8.1	7.74 (67)	7.5	7.9	8.09 (75)	7.43	8.41
	Sal	--- (0)	---	---	21.4 (72)	3.4	29	22.49 (67)	2.5	33	25.81 (75)	10.1	29.4

Table 31. Counts of waterbird species of the major foraging guilds, Alviso salt ponds A1-A8, San Francisco Bay, CA. Sample dates October 2002 - June 2005.

		Pond										
Species		**A1**	**A2E**	**A2W**	**A3N**	**A3W**	**AB1**	**AB2**	**A5**	**A6**	**A7**	**A8**
Dabblers												
American coot	*Fulica americana*	7085	8803	3745	746	3053	6190	7520	264	0	4	0
American wigeon	*Anas americana*	926	5865	19373	1181	2139	1248	2280	3684	0	216	0
blue winged teal	*Anas discors*	3	0	0	0	0	0	1	2	0	0	0
cinnamon teal	*Anas cyanoptera*	13	7	0	0	0	4	12	1	0	8	0
Eurasian wigeon	*Anas penelope*	2	7	28	0	1	0	7	4	0	0	0
gadwall	*Anas strepera*	600	1345	1790	48	729	300	621	1717	2	493	46
green-winged teal	*Anas crecca*	1	319	3	0	2	590	110	525	0	15	0
long-tailed duck	*Clangula hyemalis*	0	0	0	1	0	0	0	0	0	0	0
mallard	*Anas platyrhynchos*	336	106	317	93	113	581	140	443	4	172	46
northern pintail	*Anas acuta*	227	380	125	181	355	297	199	2343	0	559	6
northern shoveler	*Anas clypeata*	6568	4465	2410	116	5347	4729	6108	39938	0	16038	1979
Divers												
bufflehead	*Bucephala albeola*	388	174	1308	122	247	129	12	620	209	1359	847
canvasback	*Aythya valisineria*	106	55	445	19	16	1407	170	16	0	1	1
common goldeneye	*Bucephala clangula*	41	18	83	1	39	3	13	216	12	48	4
common loon	*Gavia immer*	0	0	0	0	0	0	0	1	0	0	0
redhead	*Aythya americana*	24	36	99	0	1	0	27	2	0	0	0
ruddy duck	*Oxyura jamaicensis*	41727	24594	38960	6412	27422	14112	18669	25762	0	4842	503
scaup (lesser, greater)	*Aythya affinis, A. marila*	5331	10797	34866	1156	4738	716	3461	1913	687	983	489
surf scoter	*Melanitta perspicillata*	134	0	4	2	0	0	1	0	0	0	0
white-winged scoter	*Melanitta fusca*	4	0	0	0	0	0	0	0	0	0	0
Eared Grebe												
eared grebe	*Podiceps nigricollis*	409	342	1148	45	1515	41	69	1454	1	575	4544
Fish Eaters												
American white pelican	*Pelecanus erythrorhynchos*	1658	536	737	203	777	802	2116	1176	4	1308	15
brown pelican	*Pelecanus occidentalis*	16	28	38	6	149	3	9	92	0	97	0
Clark's grebe	*Aechmophorus clarkii*	9	12	33	1	182	1	0	24	0	0	0
common merganser	*Mergus merganser*	1	0	0	0	10	2	0	1	0	0	0
double-crested cormorant	*Phalacrocorax auritis*	761	566	2505	202	3888	181	172	1335	0	198	18
Forster's tern	*Sterna forsteri*	1868	1015	1161	80	599	667	839	1769	0	480	859
horned grebe	*Podiceps auritus*	6	1	1	0	1	0	0	2	0	0	0
pied-billed grebe	*Podilymbus podiceps*	392	453	1286	113	1176	173	67	214	0	122	4

Table 31 Continued.

Species		A1	A2E	A2W	A3N	A3W	AB1	AB2	A5	A6	A7	A8
red-breasted merganser	*Mergus serrator*	0	24	0	4	62	5	3	170	0	47	4
western grebe	*Aechmophorus occidentalis*	37	36	147	8	433	9	2	141	1	8	0
Goose												
Canada goose	*Branta Canadensis*	316	48	203	50	88	36	57	341	36	43	62
greater white-fronted goose	*Anser albifrons*	0	0	0	0	0	0	0	1	0	0	0
Gull Tern												
black skimmer	*Rynchops niger*	161	0	9	0	0	8	9	1	0	0	111
Bonaparte's gull	*Larus philadephia*	198	30	1	0	255	88	0	286	0	86	1901
California gull	*Larus californicus*	7350	63	665	268	1196	128	6579	5369	127078	3945	3716
Caspian tern	*Sterna caspia*	10	22	2	4	4	7	21	13	0	360	4
Franklin’s gull	*Larus pipixcan*	0	0	0	0	0	0	0	1	0	0	0
gull spp.	*Larus* spp.	568	13	127	61	618	73	14	2007	60	442	4080
glaucous-winged gull	*Larus glaucescens*	1	3	0	0	0	2	0	0	0	0	0
herring gull	*Larus argentatus*	117	162	464	651	852	152	255	2931	382	1144	4759
least tern	*Sterna antillarum*	0	15	0	0	2	3	6	42	0	0	0
mew gull	*Larus canus*	0	0	0	0	0	0	0	42	0	2	0
ring-billed gull	*Larus delawarensis*	244	70	181	23	550	92	217	4677	41	696	3853
Thayer's gull	*Larus thayeri*	0	0	0	2	0	0	0	0	0	2	0
western gull	*Larus occidentalis*	30	23	117	42	115	17	5	440	17	179	1054
Heron												
black-crowned night heron	*Nycticorax nycticorax*	14	8	11	2	8	7	4	62	0	11	7
great blue heron	*Ardea herodias*	23	24	34	26	38	37	29	103	3	58	14
great egret	*Casmerodius albus*	81	69	115	143	204	243	84	675	4	208	10
snowy egret	*Egretta thula*	306	189	226	342	567	554	320	1283	1	206	18
Land												
belted kingfisher	*Ceryle alcyon*	1	1	7	0	0	1	0	3	0	0	0
common raven	*Corvus corax*	2	1	4	0	8	1	0	10	11	12	4
Medium Shorebird												
American avocet	*Recurvirostra americana*	5711	182	701	1050	415	2277	5930	9989	437	7166	5590
black-bellied plover	*Pluvialis squatarola*	19	23	1	7	0	18	78	14671	18	190	8
black turnstone	*Arenaria melanocephala*	0	0	0	0	0	0	0	0	2	1	0
black-necked stilt	*Himantopus mexicanus*	148	35	96	54	32	88	371	4172	18	3192	2265
greater yellowlegs	*Tringa melanoleuca*	18	12	3	16	33	10	75	94	0	24	62

Table 31 Continued.

Species		**A1**	**A2E**	**A2W**	**A3N**	**A3W**	**AB1**	**AB2**	**A5**	**A6**	**A7**	**A8**
killdeer	*Charadrius vociferous*	2	0	0	1	5	0	23	15	1	0	17
long-billed curlew	*Numenius americanus*	4	0	0	161	0	114	46	1864	11	1352	2
lesser yellowlegs	*Tringa flavipes*	4	0	3	13	0	0	8	18	0	4	24
marbled godwit	*Limosa fedoa*	1200	0	26	0	0	798	385	6111	13	2826	2
red knot	*Calidris canutus*	0	0	0	0	0	0	0	18	0	0	0
ruddy turnstone	*Arenaria interpres*	1	0	0	0	0	0	1	0	0	0	0
whimbrel	*Numenius phaeopus*	0	0	0	0	0	0	0	0	2	1	0
willet	*Catoptrophorus semipalmatus*	303	3	2650	36	10	262	216	4211	198	1038	98
yellowlegs spp.	*Tringa* spp.	0	0	0	0	0	0	1	0	0	0	0
Phalaropes												
red-necked phalarope	*Phalaropus lobatus*	0	0	1	0	0	0	0	7053	8	4633	2132
Wilson's phalarope	*Phalaropus tricolor*	0	0	0	0	0	0	0	109	0	2293	128
Small Shorebird												
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	1377	3	51	11	2	966	828	7104	0	5242	20
dunlin	*Calidris alpina*	1101	0	39	11	0	219	289	34950	3228	4172	7475
least sandpiper	*Calidris minutilla*	1177	134	277	1291	310	411	1145	8610	2653	1632	1409
sanderling	*Calidris alba*	0	0	0	0	0	0	4	59	2	42	21
semipalmated plover	*Charadrius semipalmatus*	1	0	0	115	2	66	38	464	14	214	300
semipalmated sandpiper	*Calidris pusilla*	0	0	0	0	0	0	0	0	0	0	1
snowy plover	*Charadrius alexandrinus*	0	0	0	0	0	0	0	1	0	0	11
western sandpiper	*Calidris mauri*	2600	24	37	1605	236	1233	3016	125591	22202	32942	28710
least or western sandpiper	*Calidris* spp.	18	14	32	50	9	0	2	150	0	31	0
Totals		91779	61155	116696	16775	58555	40101	62684	327372	157360	101962	77233

Table 32. Counts of waterbird species of the major foraging guilds, Alviso salt ponds A9-A23, San Francisco Bay, CA. Sample dates October 2002 - June 2005.

		Pond													
Species		**A9**	**A10**	**A11**	**A12**	**A13**	**A14**	**A15**	**A16**	**A17**	**A19**	**A20**	**A21**	**A22**	**A23**
Dabblers															
American coot	*Fulica americana*	2340	435	10	4	2	0	0	0	0	0	0	0	1	0
American wigeon	*Anas americana*	35743	4725	1	0	8	0	0	0	0	10	0	0	0	0
blue-winged teal	*Anas discors*	4	0	0	0	0	0	0	0	0	0	0	0	0	0
cinnamon teal	*Anas cyanoptera*	25	0	0	0	0	0	0	0	0	1	0	0	0	0
Eurasian wigeon	*Anas penelope*	1	3	0	0	0	0	0	0	0	0	0	0	0	0
gadwall	*Anas strepera*	4257	202	43	15	10	4	26	46	53	1	0	0	13	2
green-winged teal	*Anas crecca*	1521	6	0	0	0	0	1	0	0	0	0	0	0	0
mallard	*Anas platyrhynchos*	264	75	11	9	2	0	26	23	30	1	0	0	16	4
northern pintail	*Anas acuta*	8458	176	9	0	12	3	0	0	2	0	0	0	15	0
northern shoveler	*Anas clypeata*	20259	900	350	12	168	1262	2317	1458	578	107	60	1	0	0
Divers															
bufflehead	*Bucephala albeola*	3778	2366	356	55	16	30	17	9	4	0	0	12	7	0
canvasback	*Aythya valisineria*	4619	2510	42	0	1	0	0	0	46	0	0	0	0	0
common goldeneye	*Bucephala clangula*	50	191	2	20	0	0	0	3	0	0	10	19	70	0
redhead	*Aythya americana*	87	1084	0	0	0	0	0	0	0	0	0	0	0	0
ruddy duck	*Oxyura jamaicensis*	31259	29793	4907	205	250	140	286	188	22	0	1	23	0	0
scaup (lesser, greater)	*Aythya affinis, A. marila*	8100	15031	2473	424	2	208	24	10	21	0	0	2	0	0
surf scoter	*Melanitta perspicillata*	0	27	8	124	0	0	0	0	9	0	0	0	0	0
white-winged scoter	*Melanitta fusca*	0	1	3	0	0	0	0	0	0	0	0	0	0	0
Eared Grebe															
eared grebe	*Podiceps nigricollis*	387	1062	3653	2409	6115	7114	13294	10652	3613	5067	1761	2455	0	446
Fish Eaters															
American white pelican	*Pelecanus erythrorhynchos*	2881	1065	157	76	31	394	0	55	150	0	0	0	0	0
brown pelican	*Pelecanus occidentalis*	60	142	55	20	0	43	0	0	0	0	0	0	0	0
Clark's grebe	*Aechmophorus clarkii*	28	92	21	21	26	0	3	3	1	0	0	0	0	0
common merganser	*Mergus merganser*	1	9	0	0	0	4	0	0	0	0	0	0	0	0

Table 32 Continued.

Species		A9	A10	A11	A12	A13	A14	A15	A16	A17	A19	A20	A21	A22	A23
double-crested cormorant	*Phalacrocorax auritis*	2685	2629	513	792	311	230	3	32	178	0	1	0	0	0
Forster's tern	*Sterna forsteri*	432	136	165	184	64	98	5	910	34	1	6	15	6	0
horned grebe	*Podiceps auritus*	0	7	0	0	1	17	16	37	8	0	0	0	0	0
hooded merganser	*Lophodytes cucullatus*	0	4	0	0	0	0	0	0	0	0	0	0	0	0
pied-billed grebe	*Podilymbus podiceps*	444	834	10	11	0	1	4	38	5	0	2	1	0	0
red-breasted merganser	*Mergus serrator*	269	256	10	135	8	0	0	0	0	0	0	0	0	0
western grebe	*Aechmophorus occidentalis*	61	527	213	46	71	3	5	0	0	0	0	0	0	0
Goose															
Canada goose	*Branta canadensis*	33	20	8	8	0	11	4	22	60	53	79	23	587	146
Gull Tern															
black skimmer	*Rynchops niger*	0	0	0	0	0	0	0	20	0	0	0	0	0	0
Bonaparte's gull	*Larus philadephia*	78	18	51	135	109	334	1925	115	0	6	2	0	0	0
California gull	*Larus californicus*	10950	6914	4193	4022	4208	4305	2347	755	5668	6792	474	2418	6187	16893
Caspian tern	*Sterna caspia*	5	9	0	2	1	0	0	3	0	0	0	0	0	0
Franklin’s gull	*Larus pipixcan*	0	0	0	0	0	0	0	1	0	0	0	0	0	0
gull spp.	*Larus* spp.	1728	730	1935	1478	1439	1617	227	669	1459	41305	383	1906	4434	15174
glaucous-winged gull	*Larus glaucescens*	0	0	0	0	0	1	1	0	161	0	0	0	1	4
herring gull	*Larus argentatus*	3036	3915	5372	1759	5334	9037	2374	10713	6167	1127	410	2324	12420	46159
mew gull	*Larus canus*	0	0	0	0	0	0	0	2	0	0	0	0	0	0
ring-billed gull	*Larus delawarensis*	561	534	665	1938	659	191	907	2116	1088	1531	429	1598	7027	13703
Thayer's gull	*Larus thayeri*	0	0	0	0	0	0	1	2	7	0	0	7	0	9
western gull	*Larus occidentalis*	60	115	201	360	113	9	14	521	3428	0	11	440	175	3358
Heron															
black-crowned night heron	*Nycticorax nycticorax*	1	2	1	0	0	0	0	3	1	0	0	0	0	0
great blue heron	*Ardea herodias*	27	10	5	6	3	0	0	3	1	0	1	0	0	0
great egret	*Casmerodius albus*	317	47	37	72	15	6	5	10	1	3	1	0	6	3
little blue heron	*Egretta caerulea*	0	1	0	0	0	0	0	0	0	0	0	0	0	0
snowy egret	*Egretta thula*	609	200	73	161	42	15	8	3	12	0	0	1	2	0

Table 32 Continued.

Species		A9	A10	A11	A12	A13	A14	A15	A16	A17	A19	A20	A21	A22	A23
Land															
common raven	*Corvus corax*	11	10	15	2	18	7	6	0	12	0	0	6	5	1
Medium Shorebird															
American avocet	*Recurvirostra americana*	2273	8	29	139	392	1958	57	2011	439	61	29	2108	1975	38
black-bellied plover	*Pluvialis squatarola*	915	50	9	5	21	106	69	3	0	0	0	69	15	0
black-necked stilt	*Himantopus mexicanus*	80	5	27	84	50	125	5	507	84	271	3	2365	915	81
greater yellowlegs	*Tringa melanoleuca*	5	1	1	6	0	1	0	4	0	1	0	11	116	1
killdeer	*Charadrius vociferous*	0	0	0	1	1	0	2	26	0	0	0	0	4	0
long-billed curlew	*Numenius americanus*	127	2	3	0	0	902	662	0	10	3	0	11	0	0
lesser yellowlegs	*Tringa flavipes*	1	0	0	0	0	1	0	6	0	0	0	1	13	0
marbled godwit	*Limosa fedoa*	1824	18	27	0	0	437	81	1	4	15	0	135	0	0
whimbrel	*Numenius phaeopus*	0	0	0	0	0	1	0	0	0	0	0	0	0	0
willet	*Catoptrophorus semipalmatus*	622	26	19	10	14	595	223	112	5	8	5	598	506	2
Phalaropes															
red-necked phalarope	*Phalaropus lobatus*	0	4	25	221	86	46	19	651	0	0	0	0	0	0
Wilson's phalarope	*Phalaropus tricolor*	0	0	0	13	2	2	0	753	0	0	0	4	0	0
Small Shorebird															
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	2028	0	45	0	0	516	0	2	0	0	0	0	0	0
Dunlin	*Calidris alpina*	2259	0	0	8	6	142	17	25	0	47	20	570	1202	87
least sandpiper	*Calidris minutilla*	355	125	5	3	243	554	487	628	164	260	12	870	2316	591
Sanderling	*Calidris alba*	2	0	0	0	0	0	1	2	0	0	0	0	1	0
semipalmated plover	*Charadrius semipalmatus*	3	0	0	0	0	4	0	0	0	0	0	0	42	0
semipalmated sandpiper	*Calidris pusilla*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
snowy plover	*Charadrius alexandrinus*	0	0	0	0	0	0	0	0	0	0	0	0	72	0

Table 32 Continued.

Species		**A9**	**A10**	**A11**	**A12**	**A13**	**A14**	**A15**	**A16**	**A17**	**A19**	**A20**	**A21**	**A22**	**A23**
western sandpiper	*Calidris mauri*	3230	204	27	6	145	4590	77	195	3	5	20	1021	3584	2758
least or western sandpiper	*Calidris* spp.	200	8	0	4	10	0	9	0	0	0	0	0	66	6
Totals		159353	77267	25785	15014	20009	35064	25555	33349	23528	56679	3720	19016	41802	99466

Table 33. Monthly counts of waterbird species of the major foraging guilds October 2002-December 2003, Alviso salt ponds, San Francisco Bay, CA.

	2002			2003										
Species	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dabblers															
American coot	368	1188	500	2453	2658	1948	378	0	1	0	13	15	326	310	3239
American wigeon	0	623	231	3149	4248	4422	2	2	0	0	0	68	284	3336	7557
blue-winged teal	0	0	0	1	0	0	0	0	0	0	1	0	0	5	0
cinnamon teal	0	0	4	0	0	0	0	1	0	0	0	2	0	5	0
Eurasian wigeon	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3
gadwall	23	12	0	88	198	148	144	112	53	33	432	113	52	146	1018
green-winged teal	2	44	0	0	0	0	0	0	0	0	0	3	2	18	1127
mallard	89	52	10	4	41	51	78	114	43	80	363	213	40	125	22
northern pintail	729	236	53	19	422	159	21	13	0	0	0	785	1027	2203	1275
northern shoveler	5974	4882	2246	885	1144	1549	38	1	2	0	59	11471	6468	7390	5173
Divers															
bufflehead	0	519	132	227	1094	595	0	1	0	0	1	1	0	227	813
canvasback	11	690	1536	345	819	659	464	1	0	0	0	0	0	1	899
common goldeneye	0	13	9	10	9	3	3	0	0	0	0	0	0	13	133
redhead	0	120	0	87	16	0	0	0	0	0	1	0	0	0	10
ruddy duck	7520	9062	7513	12280	17069	10802	5840	241	125	112	93	1004	5460	6763	13730
scaup (lesser, greater)	34	1433	424	2756	5767	2711	992	849	14	5	3	11	60	725	3773
surf scoter	0	0	0	0	2	43	0	0	0	0	0	0	0	0	0
Eared Grebe															
eared grebe	986	4564	3609	1642	3524	5351	3798	965	20	1	134	663	934	1677	3930
Fish Eaters															
American white pelican	794	408	71	27	20	19	34	200	521	953	1404	869	1246	836	102
brown pelican	19	15	16	20	0	0	0	0	3	0	101	84	68	9	2
Clark's grebe	1	13	0	6	0	28	9	15	5	5	3	6	2	7	7
common merganser	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
double-crested cormorant	426	695	53	48	20	39	210	176	219	223	852	998	1963	786	447
Forster's tern	100	41	22	12	7	144	300	513	901	814	824	495	310	7	22
horned grebe	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
hooded merganser	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
pied-billed grebe	98	230	27	29	8	6	0	1	6	34	192	217	460	339	260
red-breasted merganser	0	18	12	4	50	27	0	1	0	0	0	0	0	30	87

Table 33 Continued.

Species	2002 Oct	2002 Nov	2002 Dec	2003 Jan	2003 Feb	2003 Mar	2003 Apr	2003 May	2003 June	2003 July	2003 Aug	2003 Sept	2003 Oct	2003 Nov	2003 Dec
western grebe	8	88	60	98	180	181	87	39	9	1	1	3	32	61	79
Goose															
Canada goose	6	25	0	59	101	84	51	73	18	16	0	0	0	0	17
greater white-fronted goose	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gull Tern															
black skimmer	0	8	0	2	0	6	1	2	6	5	14	18	21	0	0
Bonaparte's gull	0	442	476	200	0	29	159	0	0	0	19	9	2	299	729
California gull	2488	1	1	0	419	5557	9092	12643	12532	12821	18913	4651	6234	1702	4611
Caspian tern	1	0	0	0	0	0	11	11	60	32	58	4	0	1	0
gull spp.	3291	38417	1978	530	14092	4297	2095	594	1931	683	4	0	130	44	83
glaucous-winged gull	0	0	0	0	118	0	0	0	0	0	0	0	1	0	6
herring gull	1	3615	6407	5001	1430	2819	5	0	0	0	0	0	9	2660	7943
least tern	0	0	0	0	0	0	0	0	0	0	51	0	0	0	0
ring-billed gull	495	177	6845	1164	28	629	0	1	0	5	68	33	211	218	938
Thayer's gull	0	0	0	0	7	1	0	0	0	0	0	0	2	2	0
western gull	329	2252	0	1	1	5	34	0	0	3	243	171	154	36	6
Heron															
black-crowned night heron	2	2	0	1	0	0	1	2	7	8	27	6	5	2	3
great blue heron	7	10	4	5	8	3	0	3	9	14	27	35	37	16	23
great egret	25	57	21	14	15	35	22	19	17	58	249	76	290	150	92
snowy egret	212	75	39	13	18	37	22	44	104	78	522	206	480	283	271
Land															
belted kingfisher	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0
common raven	0	2	2	3	0	0	6	0	1	2	2	0	0	0	2
Medium Shorebird															
American avocet	1357	1481	604	100	360	2272	572	624	1056	2034	1929	2368	2044	2016	1275
black-bellied plover	5	12	0	0	1711	256	335	2	40	9	77	504	1276	3026	742
black turnstone	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
black-necked stilt	694	113	162	472	112	64	18	43	151	1181	2297	1719	741	761	352
greater yellowlegs	16	10	1	0	5	45	0	2	0	0	43	28	110	7	7
killdeer	4	0	0	0	1	0	6	0	4	11	3	16	4	1	0
long-billed curlew	0	87	0	40	25	353	0	0	24	513	7	241	541	1208	4
lesser yellowlegs	0	0	5	0	2	0	1	0	0	0	0	2	11	17	2
marbled godwit	13	587	15	20	36	14	1	0	102	200	155	459	1710	1195	703

Table 33 Continued.

Species	2002 Oct	2002 Nov	2002 Dec	2003 Jan	2003 Feb	2003 Mar	2003 Apr	2003 May	2003 June	2003 July	2003 Aug	2003 Sept	2003 Oct	2003 Nov	2003 Dec
red knot	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
ruddy turnstone	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
whimbrel	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
willet	116	203	63	129	73	697	353	37	0	325	367	658	608	2574	140
yellowlegs spp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Phalaropes															
red-necked phalarope	0	0	0	4	1	0	0	185	0	0	10701	2934	4	35	0
Wilson's phalarope	0	0	0	0	0	0	0	21	4	746	2419	36	69	0	0
Small Shorebird															
dowitcher (long, short-billed)	522	46	28	10	1	6	249	1	0	227	1606	1181	1311	1024	1614
dunlin	0	74	17	8	1089	2854	4975	1416	0	0	1	10	62	17	2311
least sandpiper	78	291	169	41	1367	3044	231	0	0	317	317	1107	1385	518	180
sanderling	0	0	0	0	16	7	0	0	0	0	0	1	1	2	1
semipalmated plover	1	0	0	0	3	8	0	0	0	0	64	20	137	0	0
semipalmated sandpiper	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
snowy plover	0	4	0	0	0	0	2	6	0	23	17	0	0	4	0
western sandpiper	39	29	7	41	1428	5314	8956	6568	0	8727	10779	8183	11402	9222	2781
least or western sandpiper	216	0	0	18	121	54	200	0	0	0	0	0	0	0	0
Totals	27103	72975	33375	32072	59884	57378	39815	25544	17988	30299	55458	41699	47728	52059	68544

Table 34. Monthly counts of waterbird species of the major foraging guilds January 2004-June 2005, Alviso salt ponds, San Francisco Bay, CA.

	2004											2005					
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Dabblers																		
American coot	2771	3006	2483	116	2	0	5	7	115	920	2975	4689	3115	3548	2436	611	4	2
American wigeon	9351	8862	3328	100	0	3	0	0	196	306	1675	8093	10090	7089	3708	674	0	2
Blue-winged teal	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
cinnamon teal	15	0	14	0	0	0	0	0	0	4	0	8	1	0	11	1	0	5
Eurasian wigeon	3	5	0	0	0	0	0	0	0	2	3	4	11	11	8	1	0	0
gadwall	1440	686	111	84	103	95	0	28	358	292	625	715	1780	2412	502	258	100	202
green-winged teal	294	0	5	0	0	0	0	0	0	24	31	1132	93	274	41	3	0	0
long-tailed duck	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
mallard	27	30	45	83	84	71	7	89	244	6	49	34	12	44	112	106	218	226
northern pintail	611	1413	88	8	3	0	1	3	75	163	257	1971	1228	525	30	15	12	2
northern shoveler	2610	2442	818	195	0	0	0	2154	3619	9360	11083	13315	8614	9136	3163	1378	1	0
Divers																		
bufflehead	1297	1342	494	25	6	7	5	4	4	14	1091	1780	1262	890	234	0	0	0
canvasback	407	370	513	12	0	0	0	0	0	57	580	613	648	666	163	0	0	0
common goldeneye	87	78	116	0	0	0	0	0	0	0	8	124	104	59	74	0	0	0
common loon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
redhead	471	473	8	0	0	0	0	0	0	0	0	32	52	70	20	0	0	0
ruddy duck	13525	16114	11614	4349	102	105	105	107	765	10002	22315	23448	26026	23701	14506	5122	431	126
scaup (lesser, greater)	8024	14100	4781	727	22	14	7	0	19	295	3140	7850	10593	9896	9056	3147	180	24
surf scoter	10	75	1	0	0	0	0	0	0	0	0	0	3	4	20	111	40	0
white-winged scoter	3	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0

Table 34 Continued.

Species	2004 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2005 Jan	Feb	Mar	Apr	May	Jun
Eared Grebe																		
eared grebe	3780	2487	1675	2494	83	16	9	28	195	1177	6235	4498	5800	3409	2109	2266	109	3
Fish Eaters																		
American white pelican	55	12	10	48	291	461	1352	942	1306	816	620	212	12	23	16	74	100	287
brown pelican	0	0	0	0	0	1	27	86	225	62	11	0	0	0	0	0	0	9
Clark's grebe	37	22	13	29	1	4	0	2	5	0	25	43	29	22	57	52	7	2
common merganser	0	11	1	4	0	0	0	0	0	9	0	0	0	0	0	0	0	0
double-crested cormorant	381	98	93	108	403	349	607	538	1307	1761	2026	317	231	86	324	309	374	733
Forster's tern	55	4	0	105	737	567	1258	767	144	206	145	84	62	17	14	469	959	1288
horned grebe	0	1	0	0	1	0	0	0	0	75	13	0	0	1	4	0	0	0
pied-billed grebe	317	116	29	13	3	2	63	98	274	617	897	577	275	101	45	7	3	6
red-breasted merganser	53	63	37	0	1	0	0	0	0	0	221	116	106	100	54	17	0	0
western grebe	58	112	92	61	1	0	1	0	0	52	119	50	58	90	69	41	9	8
Goose																		
Canada goose	156	205	112	83	1	9	95	8	1	32	1	8	437	294	191	94	138	19
Gull Tern																		
black skimmer	0	0	0	0	26	6	14	14	37	20	25	26	10	20	19	4	15	0
Bonaparte's gull	251	25	26	774	0	2	0	0	0	10	685	848	99	0	6	515	0	13
California gull	79	973	6313	12614	18497	11060	5998	3903	3736	3399	3692	914	931	9008	9682	17838	19227	12954
Caspian tern	0	0	0	9	34	17	34	65	19	0	0	0	0	0	0	2	46	63
Franklin’s gull	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
gull spp.	2545	2842	400	80	3	1	3079	740	31	33	23	1322	644	2633	0	0	2	0

Table 34 Continued						2004									2005			
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
glaucous-winged gull	3	1	43	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
herring gull	7582	6502	5778	67	0	0	0	104	0	2048	6903	18581	28036	13794	2410	321	0	0
least tern	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
mew gull	0	0	0	2	0	0	0	0	0	0	1	1	42	0	0	0	0	0
ring-billed gull	240	2857	260	9	3	145	0	82	2978	4590	6171	5283	2809	6213	214	200	312	413
Thayer's gull	1	0	1	0	0	0	0	0	0	9	5	0	0	2	0	0	0	0
western gull	30	39	7	9	19	0	0	1665	1452	894	1903	421	868	76	44	95	7	80
Heron																		
black-crowned night heron	1	0	6	5	17	7	3	3	4	5	1	2	0	3	3	4	4	8
great blue heron	8	5	5	4	6	14	11	21	22	25	25	24	16	22	6	5	2	23
great egret	22	22	33	19	39	39	60	99	108	159	145	116	60	68	82	20	51	77
little blue heron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
snowy egret	107	53	43	55	131	95	237	306	325	331	261	177	67	61	81	114	79	211
Land																		
belted kingfisher	0	0	0	0	0	0	0	0	1	1	0	1	1	3	2	0	0	0
common raven	0	13	6	1	1	1	0	10	10	3	12	8	8	37	7	2	1	6
Medium Shorebird																		
American avocet	1444	306	599	633	889	590	612	662	1699	1860	4513	3592	2756	4407	2343	1299	1309	1360
black-bellied plover	399	64	0	9	0	28	0	5	246	43	1574	2539	2263	1084	0	46	0	0
black turnstone	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
black-necked stilt	731	187	3	49	304	137	102	714	411	495	776	370	435	1143	8	106	72	150
greater yellowlegs	9	0	1	9	0	0	12	20	23	16	43	10	15	9	36	16	1	0

Table 34 Continued.

Species	2004 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2005 Jan	Feb	Mar	Apr	May	Jun
killdeer	1	4	0	0	1	1	3	4	6	8	0	0	1	1	2	6	3	7
long-billed curlew	223	159	93	0	0	0	56	137	262	253	380	6	191	442	5	0	0	24
lesser yellowlegs	4	0	0	0	0	8	0	1	0	4	0	7	6	6	19	0	1	0
marbled godwit	1977	64	40	6	120	0	133	154	280	171	1366	692	1386	1807	1	478	8	10
whimbrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
willet	115	469	319	40	10	1	424	171	988	341	653	467	608	253	288	176	1	103
Phalaropes																		
red-necked phalarope	0	0	0	0	48	0	657	300	0	0	0	0	0	0	0	9	0	1
Wilson's phalarope	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Small Shorebird																		
dowitcher (long, short-billed)	263	0	85	23	1	0	301	286	302	285	2958	3488	350	902	2	1001	121	1
Dunlin	290	29	267	148	0	0	0	84	64	2422	13105	7248	5681	3748	3332	6528	87	0
least sandpiper	666	113	148	201	0	0	59	568	2414	1947	2990	2308	2455	1294	1129	318	6	1
sanderling	2	0	1	0	0	0	0	0	3	0	4	34	13	45	4	0	0	0
semipalmated plover	0	3	0	0	0	0	45	2	109	112	13	390	301	0	0	13	42	0
semipalmated sandpiper	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
snowy plover	0	0	0	0	0	0	8	0	0	0	0	0	0	0	2	5	8	5
western sandpiper	1349	97	4352	388	0	0	22569	4619	8007	6121	17224	10763	26500	17751	11450	28747	495	153
Totals	64181	66954	45312	23798	21995	13856	37960	19618	32389	51867	119597	129351	147198	127301	68150	72624	24590	18617

Table 35. Total counts of waterbird species of the major foraging guilds, Eden Landing salt ponds B1C- B7, San Francisco Bay, CA. Sample dates October 2002 through June 2005.

		Pond											
Species		**B1C**	**B2C**	**B3C**	**B4C**	**B5C**	**B6C**	**B1**	**B2**	**B4**	**B5**	**B6**	**B7**
Dabblers													
American coot	*Fulica americana*	3	0	279	0	12	1	0	11	8	0	0	0
American wigeon	*Anas americana*	4	2	403	4	15	0	4	199	392	0	0	202
cinnamon teal	*Anas cyanoptera*	0	0	3	0	0	0	0	0	0	0	0	0
Eurasian wigeon	*Anas penelope*	0	0	0	0	0	0	0	0	2	0	0	0
gadwall	*Anas strepera*	31	18	78	52	16	18	7	26	242	22	59	116
green-winged teal	*Anas crecca*	125	10	121	0	0	0	0	0	5	0	0	1
mallard	*Anas platyrhynchos*	119	89	296	74	68	50	23	83	173	25	48	35
northern pintail	*Anas acuta*	32	43	153	68	67	42	12	39	124	54	27	15
northern shoveler	*Anas clypeata*	1252	136	4420	2693	416	213	67	1040	214	520	1038	1250
Divers													
bufflehead	*Bucephala albeola*	89	13	304	89	175	132	309	388	174	189	262	198
canvasback	*Aythya valisineria*	0	3	0	0	0	0	266	6	0	0	0	0
common goldeneye	*Bucephala clangula*	40	9	103	16	53	10	308	200	95	72	17	33
redhead	*Aythya americana*	0	0	0	0	0	0	0	0	0	0	0	2
ring-necked duck	*Aythya collaris*	0	0	0	0	0	0	0	1	0	0	0	0
ruddy duck	*Oxyura jamaicensis*	1534	16	312	825	1799	246	16196	32619	6500	779	886	4993
scaup (lesser, greater)	*Aythya affinis, A. marila*	430	3	522	237	211	94	3812	2727	1427	221	169	2918
surf scoter	*Melanitta perspicillata*	0	0	0	0	0	0	25	3	0	0	0	0
Eared Grebe													
eared grebe	*Podiceps nigricollis*	3	0	522	37	4	673	430	916	329	2644	2479	155
Fish Eaters													
American white pelican	*Pelecanus erythrorhynchos*	165	0	123	176	40	11	905	534	1048	42	37	307
brown pelican	*Pelecanus occidentalis*	0	0	0	0	0	0	231	349	52	6	0	4
Clark's grebe	*Aechmophorus clarkii*	0	0	0	0	0	1	41	204	11	0	0	8
common merganser	*Mergus merganser*	0	0	0	0	0	0	2	15	2	6	0	0
double-crested cormorant	*Phalacrocorax auritis*	0	0	3	16	6	39	4132	6257	865	363	586	1593
Forster's tern	*Sterna forsteri*	77	1	15	354	3	34	878	1714	625	705	500	1484
horned grebe	*Podiceps auritus*	0	0	0	0	0	0	0	0	0	1	0	0
hooded merganser	*Lophodytes cucullatus*	0	0	0	0	0	0	0	2	0	0	0	0
pied-billed grebe	*Podilymbus podiceps*	0	0	1	2	0	1	106	108	96	16	47	116
red-breasted merganser	*Mergus serrator*	0	0	0	0	0	1	183	150	31	75	25	60

Table 35 Continued.

Species		B1C	B2C	B3C	B4C	B5C	B6C	B1	B2	B4	B5	B6	B7
western grebe	*Aechmophorus occidentalis*	0	0	5	2	1	3	241	506	54	16	6	58
Goose													
Canada goose	*Branta canadensis*	68	58	728	110	81	48	28	154	44	36	61	65
snow goose	*Chen caerulescens*	0	0	1	0	0	0	0	0	0	0	0	0
Gull Tern													
Bonaparte's gull	*Larus philadephia*	53	0	401	192	315	8	103	554	1253	251	422	168
California gull	*Larus californicus*	23	307	1159	4176	465	1898	431	739	160	2095	4098	573
Caspian tern	*Sterna caspia*	0	0	0	21	0	0	57	15	4	0	3	32
elegant tern	*Sterna elegans*	0	0	0	0	0	0	8	53	0	5	0	5
gull spp.	*Larus* spp.	1	0	181	161	2	0	267	155	60	50	196	22
glaucous-winged gull	*Larus glaucescens*	0	0	3	0	0	0	2	5	2	0	0	0
herring gull	*Larus argentatus*	10	2	110	27	7	1	238	217	39	4	45	33
least tern	*Sterna antillarum*	0	0	0	0	0	0	0	20	3	0	0	0
mew gull	*Larus canus*	0	0	0	0	0	0	13	0	2	0	456	7
ring-billed gull	*Larus delawarensis*	7	0	1070	156	56	3	49	193	16	144	582	96
Thayer's gull	*Larus thayeri*	0	0	0	0	0	6	0	3	3	0	0	2
western gull	*Larus occidentalis*	1	0	4	2	10	0	84	100	119	24	24	146
Heron													
black-crowned night heron	*Nycticorax nycticorax*	3	0	0	3	1	0	7	7	17	10	0	2
great blue heron	*Ardea herodias*	7	0	5	3	2	5	29	48	27	10	27	14
great egret	*Casmerodius albus*	28	3	54	18	9	9	198	213	160	55	105	154
snowy egret	*Egretta thula*	73	1	97	23	13	25	283	331	250	80	88	85
Land													
belted kingfisher	*Ceryle alcyon*	1	0	0	0	0	0	5	0	0	1	1	1
Medium Shorebird													
American avocet	*Recurvirostra americana*	2919	516	4029	1491	626	162	123	65	31	47	1461	27
black-bellied plover	*Pluvialis squatarola*	8	1	2098	13156	151	2	544	1831	767	52	190	1076
black-necked stilt	*Himantopus mexicanus*	1816	1248	3284	1467	234	2	3	2	10	26	502	14
greater yellowlegs	*Tringa melanoleuca*	70	64	74	72	35	13	2	0	24	8	177	5
killdeer	*Charadrius vociferous*	31	10	12	2	4	3	0	0	1	2	1	1
long-billed curlew	*Numenius americanus*	320	0	2	3	0	0	254	0	0	0	93	0
lesser yellowlegs	*Tringa flavipes*	5	10	11	20	4	1	2	1	14	0	21	0

Table 35 Continued.

Species		B1C	B2C	B3C	B4C	B5C	B6C	B1	B2	B4	B5	B6	B7
marbled godwit	*Limosa fedoa*	95	54	446	986	3	8	327	344	0	19	17	0
red knot	*Calidris canutus*	3	0	735	1355	0	0	0	0	0	0	42	0
ruddy turnstone	*Arenaria interpres*	0	0	4	3	0	0	0	0	0	0	0	1
whimbrel	*Numenius phaeopus*	0	1	0	0	0	0	0	2	0	0	0	0
willet	*Catoptrophorus semipalmatus*	731	147	1462	948	65	16	204	889	47	24	151	25
Phalaropes													
red-necked phalarope	*Phalaropus lobatus*	5	3	305	22	1	0	1	0	1	0	0	0
Wilson's phalarope	*Phalaropus tricolor*	1	1	0	0	0	0	0	0	0	0	52	0
Small Shorebird													
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	3544	7	1425	1996	393	2	48	44	0	0	121	19
dunlin	*Calidris alpina*	3646	1055	15938	18830	738	37	7	181	470	80	1265	367
least sandpiper	*Calidris minutilla*	2379	886	3480	1589	1199	242	478	498	389	495	969	361
sanderling	*Calidris alba*	0	0	0	2	0	0	0	0	0	0	1	1
semipalmated plover	*Charadrius semipalmatus*	272	16	470	45	12	0	4	0	3	0	12	3
snowy plover	*Charadrius alexandrinus*	3	0	49	0	0	0	0	0	3	0	0	0
spotted sandpiper	*Actitis macularia*	0	0	0	0	0	0	0	0	0	0	1	0
western sandpiper	*Calidris mauri*	7291	1765	10716	14853	2575	15	1381	44	806	82	3292	644
least or western sandpiper	*Calidris* spp	60	54	140	26	0	4	0	0	2	0	0	3
Totals		27378	6552	56156	66403	9891	4079	33358	54805	17196	9356	20662	17503

Table 36. Total counts of waterbird species of the major foraging guilds, Eden Landing salt ponds B6A, B6B, B8-B14, San Francisco Bay, CA. Sample dates October 2002 through June 2005.

		Pond									
Species		**B6A**	**B6B**	**B8**	**B8A**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**
Dabblers											
American coot	*Fulica americana*	0	0	0	0	0	29	0	15	0	0
American wigeon	*Anas americana*	224	56	0	0	0	1746	813	1	0	0
cinnamon teal	*Anas cyanoptera*	0	0	0	0	0	2	2	0	0	0
Eurasian wigeon	*Anas penelope*	1	0	0	0	0	0	0	0	0	0
gadwall	*Anas strepera*	42	19	19	13	19	286	495	12	7	8
green-winged teal	*Anas crecca*	0	2	0	0	1	67	13	0	0	0
mallard	*Anas platyrhynchos*	256	100	138	84	88	155	261	6	40	15
northern pintail	*Anas acuta*	12	12	9	8	34	480	123	1	31	10
northern shoveler	*Anas clypeata*	85	10	427	177	157	2765	1361	596	1130	105
Divers											
bufflehead	*Bucephala albeola*	142	99	1836	688	5731	812	36	40	99	2299
canvasback	*Aythya valisineria*	0	0	0	0	0	482	0	0	0	0
common goldeneye	*Bucephala clangula*	83	83	207	69	121	51	4	7	4	115
redhead	*Aythya americana*	0	0	0	0	0	5	0	0	0	0
ruddy Duck	*Oxyura jamaicensis*	4	65	430	2	206	14054	1327	116	66	1409
scaup (lesser, greater)	*Aythya affinis, A. marila*	235	164	900	518	715	3485	98	1569	2840	3456
surf scoter	*Melanitta perspicillata*	0	0	0	0	1	0	0	0	0	0
Eared Grebe											
eared grebe	*Podiceps nigricollis*	48	0	3519	50	12182	443	31	279	693	843
Fish Eaters											
American white pelican	*Pelecanus erythrorhynchos*	0	0	8	0	4	846	106	0	0	0
Clark's grebe	*Aechmophorus clarkii*	0	0	2	0	0	4	0	0	0	0
double-crested cormorant	*Phalacrocorax auritis*	3	0	37	2	2	460	12	0	3	1
Forster's tern	*Sterna forsteri*	3	1	223	66	294	932	56	3	32	20
horned grebe	*Podiceps auritus*	0	0	0	0	0	0	0	1	0	0
pied-billed grebe	*Podilymbus podiceps*	0	0	7	0	1	33	2	0	0	0
red-breasted merganser	*Mergus serrator*	0	0	0	0	0	10	0	0	0	0
western grebe	*Aechmophorus occidentalis*	0	0	0	0	2	21	2	2	0	1

Table 36 Continued.

Species		B6A	B6B	B8	B8A	B9	B10	B11	B12	B13	B14
Flamingo											
greater flamingo	*Phoenicopterus ruber*	0	0	0	0	0	1	0	0	0	0
Goose											
Canada goose	*Branta canadensis*	154	274	106	51	28	32	16	2	2	63
snow goose	*Chen caerulescens*	1	0	0	0	0	0	0	0	0	0
Gull Tern											
black skimmer	*Rynchops niger*	1	0	0	3	0	0	0	0	0	0
black tern	*Chlidonias niger*	0	0	3	0	0	0	0	0	0	0
Bonaparte's gull	*Larus philadephia*	391	203	452	855	19	1	0	969	992	1705
California gull	*Larus californicus*	300	1	497	495	2027	626	331	86	177	311
Caspian tern	*Sterna caspia*	0	0	0	4	3	154	1	0	0	0
gull spp.	*Larus* spp.	5	1	325	37	3	94	18	6	37	0
glaucous-winged gull	*Larus glaucescens*	0	0	0	8	0	1	0	0	0	0
herring gull	*Larus argentatus*	107	13	88	356	32	57	11	7	16	11
least tern	*Sterna antillarum*	0	0	0	0	0	30	0	0	0	0
ring-billed gull	*Larus delawarensis*	441	51	133	553	290	86	91	199	30	77
Thayer's gull	*Larus thayeri*	0	0	0	0	0	1	1	0	0	0
western gull	*Larus occidentalis*	0	2	3	11	14	15	0	0	1	0
Heron											
black-crowned night heron	*Nycticorax nycticorax*	1	1	5	0	2	14	3	0	0	1
great blue heron	*Ardea herodias*	6	109	4	10	31	59	14	1	5	19
great egret	*Casmerodius albus*	5	8	82	3	7	166	31	1	3	15
snowy egret	*Egretta thula*	3	3	11	3	5	349	393	1	4	8
Land											
common raven	*Corvus corax*	0	0	0	0	0	0	2	0	0	0
Medium Shorebird											
American avocet	*Recurvirostra americana*	433	524	1577	4718	1576	6201	2778	1933	1030	1502
black-bellied plover	*Pluvialis squatarola*	246	800	2781	3763	8991	1982	528	11512	13744	1195
black turnstone	*Arenaria melanocephala*	0	0	0	0	16	0	0	0	28	45
black-necked stilt	*Himantopus mexicanus*	52	37	1332	717	832	160	367	537	753	1982
greater yellowlegs	*Tringa melanoleuca*	188	60	156	18	17	23	7	191	53	25

Table 36 Continued.

Species		B6A	B6B	B8	B8A	B9	B10	B11	B12	B13	B14
killdeer	*Charadrius vociferous*	8	1	1	0	0	1	2	14	5	2
long-billed curlew	*Numenius americanus*	1	0	26	181	2	376	0	0	0	0
lesser yellowlegs	*Tringa flavipes*	57	11	49	4	4	2	0	3	5	12
marbled godwit	*Limosa fedoa*	10	0	7	2159	290	3999	888	12	1	1
red knot	*Calidris canutus*	0	0	151	66	20	102	82	88	25	1
ruddy turnstone	*Arenaria interpres*	0	1	12	0	131	1	0	0	122	1
willet	*Catoptrophorus semipalmatus*	62	54	479	8553	7872	11539	1180	1037	704	1489
Phalaropes											
red phalarope	*Phalaropus fulicarius*	0	0	0	1	1	0	0	0	0	0
red-necked phalarope	*Phalaropus lobatus*	0	18	389	294	1609	0	15	27	0	2
Wilson's phalarope	*Phalaropus tricolor*	0	0	17	52	271	0	215	2	0	142
Small Shorebird											
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	98	506	47	19	51	4010	3612	1664	1813	571
dunlin	*Calidris alpina*	7139	7749	14919	58297	28442	4975	995	30880	21591	18361
least sandpiper	*Calidris minutilla*	1617	461	2760	5797	988	1488	212	1063	4791	2006
sanderling	*Calidris alba*	2	4	25	12	15	0	0	9	0	0
semipalmated plover	*Charadrius semipalmatus*	180	1087	38	1701	8	95	842	396	88	198
snowy plover	*Charadrius alexandrinus*	15	145	69	55	23	11	9	59	24	10
western sandpiper	*Calidris mauri*	11842	13625	17823	71090	45144	33131	4942	21911	31145	12200
least or western sandpiper	*Calidris* spp.	0	1	1150	0	65	7	25	0	0	3600
Totals		24503	26361	53279	161563	118387	96957	22358	75258	82134	53837

Table 37. Monthly counts of waterbird species of the major foraging guilds October 2002-December 2003, Eden Landing salt ponds, San Francisco Bay, CA.

	2002			2003										
Species	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dabblers															
American coot	3	0	1	27	166	8	0	0	0	0	0	0	4	0	3
American wigeon	62	30	668	582	426	52	0	0	0	0	0	7	7	5	62
cinnamon teal	0	0	0	1	0	0	2	0	0	0	0	0	0	2	0
gadwall	48	0	0	31	70	17	21	45	27	7	8	23	9	12	48
green-winged teal	0	6	57	1	3	10	0	0	0	0	1	0	0	0	0
mallard	2	23	0	26	46	51	41	68	34	59	236	53	82	11	2
northern pintail	11	12	11	23	12	28	10	11	0	0	5	267	116	27	11
northern shoveler	670	883	937	77	107	27	2	1	0	0	27	4150	2002	2335	670
Divers															
bufflehead	40	287	2874	2488	1974	67	4	2	2	0	0	1	43	657	40
canvasback	0	3	317	177	0	0	0	0	1	0	0	0	0	34	0
common goldeneye	45	45	46	162	364	40	0	0	0	0	0	0	37	88	45
redhead	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
ring necked duck	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
ruddy duck	2421	3327	7150	12507	9285	1408	34	23	8	0	0	199	1320	2801	2421
scaup (lesser, greater)	341	900	2403	6668	5173	913	122	36	23	3	6	8	9	11	341
surf scoter	0	1	10	6	7	0	0	0	0	0	0	0	0	0	0
Eared Grebe															
eared grebe	771	604	2161	4068	2757	1640	420	19	9	17	130	457	1082	1468	771
Fish Eaters															
American white pelican	206	92	4	0	0	11	71	2	208	280	201	939	427	13	206
brown pelican	18	23	3	1	0	0	0	0	0	16	61	52	237	0	18
Clark's grebe	3	0	0	25	13	24	6	0	1	8	0	2	27	0	3
common merganzer	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
double-crested cormorant	423	251	26	13	10	15	11	225	334	770	1055	1871	3198	130	423
Forster's tern	127	148	33	1	1	192	366	396	306	156	229	319	816	44	127
horned grebe	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
hooded merganzer	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
pied-billed grebe	42	44	20	3	0	0	0	1	0	3	23	26	61	89	42
red-breasted merganser	0	10	2	3	9	1	1	3	0	0	1	0	35	33	0
western grebe	49	75	57	66	49	20	36	11	9	0	6	11	43	8	49

Table 37 Continued.

Species	2002 Oct	Nov	Dec	2003 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Goose															
Canada goose	26	99	7	202	122	168	91	64	4	17	0	0	4	0	12
Gull Tern															
black tern	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Bonaparte's gull	0	186	640	954	2809	760	552	7	6	0	0	0	0	442	131
California gull	9	8	64	0	273	102	24	36	977	736	5569	7466	2219	381	42
Caspian tern	25	0	0	0	0	0	14	1	28	33	27	1	48	0	0
elegant tern	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
gull spp.	725	225	54	37	10	2	30	17	4	1	1	0	49	163	4
glaucous-winged gull	0	0	1	0	1	0	0	0	0	0	0	0	0	3	0
herring gull	0	23	45	69	45	44	22	0	0	0	0	0	0	13	31
least tern	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0
mew gull	0	0	30	0	20	85	0	0	0	0	0	0	0	0	0
ring-billed gull	54	308	361	75	38	218	59	0	0	0	3	47	24	478	203
Thayer's gull	0	3	0	0	2	0	0	0	0	0	0	0	0	11	0
western gull	16	2	59	4	3	17	8	0	1	2	2	8	7	72	3
Heron															
black-crowned night heron	1	1	1	1	0	0	3	2	2	3	10	2	3	0	2
great blue heron	7	8	6	13	17	10	10	13	17	15	5	7	14	14	16
great egret	113	36	104	21	7	18	9	6	6	14	11	38	29	206	80
snowy egret	149	101	179	31	4	10	17	17	13	63	40	40	113	146	44
Land															
belted kingfisher	1	1	0	0	0	0	0	0	0	0	0	0	1	0	2
Medium Shorebird															
American avocet	480	1431	1322	1884	514	595	505	504	539	608	1044	3183	1908	1266	1328
black-bellied plover	1428	3012	3912	1462	3033	3816	1487	525	7	0	527	2104	401	1692	1323
black turnstone	58	0	3	0	0	19	0	0	0	0	0	0	0	0	0
black-necked stilt	1142	726	1114	550	0	1	57	48	80	128	858	1305	2531	1048	263
greater yellowlegs	3	2	13	2	39	50	0	1	0	4	38	32	32	55	50
killdeer	0	0	2	0	3	0	0	2	3	4	3	0	0	6	0
long-billed curlew	59	1	1	26	1	0	0	0	0	15	1	120	62	122	244
lesser yellowlegs	0	1	0	0	0	1	0	0	0	0	1	2	16	1	19
marbled godwit	3	12	160	8	8	0	573	206	1	16	252	90	26	212	335
red knot	0	0	0	0	0	17	1	269	0	0	0	0	0	12	0
ruddy turnstone	9	71	23	0	1	21	8	8	0	0	3	0	0	11	24

Table 37 Continued.

Species	2002 Oct	2002 Nov	2002 Dec	2003 Jan	2003 Feb	2003 Mar	2003 Apr	2003 May	2003 June	2003 July	2003 Aug	2003 Sept	2003 Oct	2003 Nov	2003 Dec
whimbrel	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0
willet	2048	745	1530	124	1121	1271	1371	362	81	1116	1638	1413	1288	1320	1272
Phalaropes															
red phalarope	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
red-necked phalarope	0	0	0	0	0	0	0	464	12	15	313	611	57	45	0
Wilson's phalarope	0	0	0	0	0	0	44	2	120	501	74	0	0	0	0
Small Shorebird															
dowitcher (long, short-billed)	1416	1474	1052	110	0	33	846	10	0	154	2	2	6	287	3
dunlin	5686	17827	25020	1556	3102	5633	7389	2436	0	0	0	0	1	20530	6960
least sandpiper	331	811	1321	935	198	392	205	0	2	31	888	2638	1400	10964	827
sanderling	0	22	11	8	0	9	0	0	0	0	0	1	0	2	1
semipalmated plover	1	200	3	0	0	0	32	169	0	2	315	15	7	135	4
snowy plover	0	0	0	0	0	0	2	28	24	66	12	20	11	11	0
western sandpiper	147	4635	5662	458	246	2921	2395	3402	2	3710	8874	14330	6710	16514	3409
least or western sandpiper	5137	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	24833	37253	49466	25320	38574	36685	20278	9749	2772	8216	21859	35465	25352	65727	24408

Table 38. Monthly counts of waterbird species of the major foraging guilds January 2004-June 2005, Eden Landing salt ponds, San Francisco Bay, CA.

	2004											2005					
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Dabblers																		
American coot	17	50	67	0	0	0	0	0	0	0	0	0	8	3	2	0	0	2
American wigeon	79	146	197	4	0	0	0	0	0	0	104	73	385	255	880	92	3	0
cinnamon teal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Eurasian wigeon	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
gadwall	3	122	16	24	40	36	26	54	49	0	90	42	116	201	203	100	101	64
green-winged teal	0	0	0	0	0	0	0	0	0	0	5	20	0	39	2	0	0	0
mallard	4	33	98	52	73	43	141	30	3	20	16	14	38	53	301	294	168	102
northern pintail	1	4	17	8	3	2	6	0	0	12	22	217	94	154	222	52	13	3
northern shoveler	2546	423	14	0	0	0	0	0	101	1722	773	1107	489	331	278	12	1	2
Divers																		
bufflehead	1259	452	354	6	0	0	0	0	0	0	139	618	1052	923	788	69	0	0
canvasback	35	20	58	0	0	0	0	0	0	0	0	1	44	35	32	0	0	0
common goldeneye	234	81	16	0	0	0	0	0	0	0	29	132	145	107	98	30	0	1
ruddy duck	3171	3760	6449	626	1	6	1	3	0	4	820	3151	6880	7184	7032	4405	29	2
scaup (lesser, greater)	285	1168	1289	522	14	3	0	0	0	0	34	15	786	1369	1779	2475	304	92
surf scoter	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Eared Grebe																		
eared grebe	2134	2549	1632	1504	3	12	2	2	3	3	31	90	115	379	538	605	10	3
Fish Eaters																		
American white pelican	0	0	0	0	91	177	297	295	474	26	62	3	0	1	0	5	1	2
brown pelican	0	0	0	0	0	0	30	28	48	81	0	0	0	0	0	0	0	0

Table 38 Continued.

Species	Jan 2004	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 2005	Feb	Mar	Apr	May	Jun
Clark's grebe	11	0	5	0	0	0	0	2	0	0	57	4	21	1	29	30	2	0
common merganzer	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
double-crested cormorant	46	21	48	6	99	305	661	588	1105	352	286	150	24	57	25	19	115	279
Forster's tern	0	0	9	23	236	629	464	513	601	595	346	134	29	10	92	269	284	130
horned grebe	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pied-billed grebe	13	7	5	0	0	0	0	3	1	3	23	20	23	17	29	3	0	0
red-breasted merganser	17	0	13	1	1	0	0	0	0	0	66	81	86	119	48	5	0	0
western grebe	29	55	50	24	4	1	0	0	2	2	3	37	28	109	39	35	5	19
Flamingo																		
greater flamingo	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Goose																		
Canada goose	110	128	176	60	23	36	6	4	0	0	20	30	192	150	191	149	72	46
snow goose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Gull Tern																		
black skimmer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Bonaparte's gull	158	10	0	648	0	0	0	1	0	1	38	167	50	6	293	1348	99	1
California gull	49	52	140	114	0	132	99	405	918	196	39	27	0	14	54	40	38	752
Caspian tern	0	0	0	25	0	2	20	5	16	0	0	0	0	0	7	6	3	33
elegant tern	0	0	0	0	0	0	0	0	10	51	0	0	0	0	0	0	0	0
gull spp.	7	2	134	0	54	2	76	0	2	14	8	0	0	0	0	0	0	0
glaucous-winged gull	11	1	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
herring gull	65	63	58	0	0	0	1	0	8	37	66	96	468	129	57	25	47	19
least tern	0	0	0	0	0	0	1	23	0	0	0	0	0	0	0	0	0	0
mew gull	0	0	0	0	0	0	0	0	0	0	49	4	6	117	167	0	0	0
ring-billed gull	73	123	93	9	4	0	24	113	142	126	45	44	485	229	636	93	85	131

Table 38 Continued.

	2004											2005					
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
tern spp.	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
western gull	3	7	9	9	7	0	0	0	49	149	27	15	30	32	5	5	4	5
Heron																		
black-crowned night heron	1	0	0	0	0	6	7	4	2	6	3	0	0	0	0	4	4	9
great blue heron	8	8	21	0	7	8	16	17	13	23	10	15	4	8	24	19	33	29
great egret	17	12	13	1	10	15	52	63	113	202	9	57	8	3	8	16	6	24
snowy egret	9	4	11	5	19	51	238	360	134	154	29	34	8	4	11	19	27	45
Land																		
belted kingfisher	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0
common raven	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Medium Shorebird																		
American avocet	203	1136	954	894	657	330	221	269	698	1597	2581	1626	1141	489	920	947	909	1086
black-bellied plover	1671	2665	2974	1053	183	71	360	472	938	1428	3041	3248	7298	5176	7011	1530	715	855
black turnstone	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
black-necked stilt	613	708	840	25	129	52	378	282	338	447	240	364	78	17	516	193	178	128
greater yellowlegs	45	28	45	257	0	0	10	14	41	38	8	34	18	26	27	311	32	27
killdeer	0	4	9	2	1	4	0	1	7	24	3	1	4	3	5	1	6	3
long-billed curlew	45	45	16	37	1	0	2	17	174	66	72	0	0	101	0	15	5	10
lesser yellowlegs	1	7	1	1	1	0	0	2	5	31	5	18	24	18	11	59	5	6
marbled godwit	158	801	0	194	38	0	55	490	168	1095	1928	706	543	277	16	861	433	1
red knot	0	0	0	16	7	0	96	23	0	0	0	0	0	0	1	299	1875	54
ruddy turnstone	0	59	0	0	2	7	0	0	0	0	1	15	0	3	0	6	1	3

Table 38 Continued.

Species	Jan 2004	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 2005	Feb	Mar	Apr	May	Jun
willet	433	1529	921	1066	42	0	737	1044	1458	1231	2996	2757	947	2202	2391	849	372	3
Phalaropes																		
red-necked phalarope	0	0	0	0	0	0	0	13	9	0	0	0	1	0	0	808	344	0
Wilson's phalarope	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	2	3
Small Shorebird																		
dowitcher (long, short-billed)	6	0	1	436	4	0	765	201	69	358	2879	2566	599	1271	1058	3388	994	0
dunlin	2256	13253	10620	15525	11	0	4	0	30	1949	17765	11995	9188	14402	12423	19421	10972	8
least sandpiper	1118	391	283	433	6	0	305	321	2033	2588	1933	1230	246	749	1178	207	182	2
sanderling	1	1	0	0	0	0	0	0	0	0	0	0	0	6	4	2	3	0
semipalmated plover	1	6	110	7	2	0	7	43	199	2	820	175	652	390	1198	411	531	33
snowy plover	3	6	0	0	7	21	11	33	6	9	39	62	6	6	6	8	47	31
spotted sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
western sandpiper	8624	10586	10494	32752	8	0	7109	7825	11853	10639	12442	18465	25513	19463	26943	20723	9463	0
Totals	25574	40546	38263	56374	1788	1951	12231	13570	21824	25283	50007	49661	57883	56638	67578	60268	28527	4053

Table 39. Total counts of waterbird species of the major foraging guilds, Redwood salt ponds, San Francisco Bay, CA. Sample dates November 2002 through June 2005.

		Pond						
Species		**R1**	**R2**	**R3**	**R4**	**R5**	**RS5**	**RSF2**
Dabblers								
gadwall	*Anas strepera*	9	0	0	0	1	0	9
mallard	*Anas platyrhynchos*	24	5	3	0	6	0	15
northern pintail	*Anas acuta*	5	0	0	0	1	0	0
northern shoveler	*Anas clypeata*	769	71	0	2	17	43	0
Divers								
bufflehead	*Bucephala albeola*	2557	415	0	102	0	0	180
canvasback	*Aythya valisineria*	3	0	0	0	0	0	0
common goldeneye	*Bucephala clangula*	44	484	0	2224	4	16	59
ruddy duck	*Oxyura jamaicensis*	45	71	0	0	0	0	20
scaup (lesser, greater)	*Aythya affinis, A. marila*	2534	3243	0	594	173	71	55
surf scoter	*Melanitta perspicillata*	71	0	0	0	0	0	0
Eared Grebe								
eared grebe	*Podiceps nigricollis*	85	107	11	483	0	0	1
Fish Eaters								
American white pelican	*Pelecanus erythrorhynchos*	134	0	0	0	0	0	0
brown pelican	*Pelecanus occidentalis*	1	0	0	0	0	0	0
double-crested cormorant	*Phalacrocorax auritis*	199	0	0	0	0	0	0
Forster's tern	*Sterna forsteri*	758	0	1	0	0	0	0
Goose								
Canada goose	*Branta canadensis*	13	7	38	13	36	56	4
Gull Tern								
black skimmer	*Rynchops niger*	31	0	0	0	0	0	0
Bonaparte's gull	*Larus philadephia*	831	0	0	27	0	0	0
California gull	*Larus californicus*	1813	28	731	103	121	231	109
Caspian tern	*Sterna caspia*	80	0	0	0	0	0	0
gull spp.	*Larus* spp.	246	0	8	1391	0	56	42
glaucous-winged gull	*Larus glaucescens*	0	0	2	0	0	0	1
herring gull	*Larus argentatus*	499	1	99	131	26	10	69
least tern	*Sterna antillarum*	152	0	0	0	0	0	0

Table 39 Continued.

Species		R1	R2	R3	R4	R5	RS5	RSF2
ring-billed gull	*Larus delawarensis*	1034	0	295	1	2	672	173
Thayer's gull	*Larus thayeri*	1	0	0	0	0	0	0
western gull	*Larus occidentalis*	135	0	0	0	0	0	45
Heron								
black-crowned night heron	*Nycticorax nycticorax*	41	0	0	0	0	0	0
great blue heron	*Ardea herodias*	23	0	1	0	0	0	0
great egret	*Casmerodius albus*	118	0	2	0	1	1	1
snowy egret	*Egretta thula*	134	0	1	0	0	1	0
Land								
common raven	*Corvus corax*	0	0	2	0	0	0	0
Medium Shorebird								
American avocet	*Recurvirostra americana*	4413	323	802	871	417	768	324
black-bellied plover	*Pluvialis squatarola*	947	152	2448	246	4	1	561
black-necked stilt	*Himantopus mexicanus*	4280	475	745	329	677	1176	1052
greater yellowlegs	*Tringa melanoleuca*	21	4	6	1	14	73	18
killdeer	*Charadrius vociferous*	3	6	108	2	41	1	33
long-billed curlew	*Numenius americanus*	660	6	80	48	3	28	61
lesser yellowlegs	*Tringa flavipes*	2	1	2	2	1	4	4
marbled godwit	*Limosa fedoa*	558	10	2	4	0	2	1
ruddy turnstone	*Arenaria interpres*	0	1	0	0	0	0	0
stilt sandpiper	*Calidris himantopus*	1	0	0	0	0	0	0
whimbrel	*Numenius phaeopus*	37	14	0	0	0	0	0
willet	*Catoptrophorus semipalmatus*	7041	364	1831	2715	745	166	3176
Phalaropes								
red-necked phalarope	*Phalaropus lobatus*	6657	65	0	106	2	0	122
Wilson's phalarope	*Phalaropus tricolor*	444	0	0	0	0	31	0
Small Shorebird								
dowitcher (long, short-billed)	*Limnodromus scolopaceus, L. griseus*	1274	24	8	83	57	432	2948
dunlin	*Calidris alpina*	53201	4395	3200	11369	966	3	22838
least sandpiper	*Calidris minutilla*	7448	1415	1218	3141	92	69	4142
sanderling	*Calidris alba*	47	0	0	2	0	0	0
semipalmated plover	*Charadrius semipalmatus*	6721	1217	4824	642	584	0	2791

Table 39 Continued.

Species		R1	R2	R3	R4	R5	RS5	RSF2
semipalmated sandpiper	*Calidris pusilla*	1	0	0	0	0	0	0
snowy plover	*Charadrius alexandrinus*	163	4	6	10	43	0	113
western sandpiper	*Calidris mauri*	110896	15878	32515	42098	3025	106	83861
Totals		217204	28786	49054	66740	7312	4017	122828

Table 40. Total counts of waterbird species of the major foraging guilds, Redwood salt ponds November 2002-December 2003, San Francisco Bay, CA.

Species	2002 Nov	Dec	Jan	Feb	Mar	Apr	May	2003 June	July	Aug	Sept	Oct	Nov	Dec
Dabblers														
gadwall	0	0	0	0	0	4	2	0	0	0	0	0	0	0
mallard	0	0	0	0	0	7	5	0	0	0	8	0	0	0
northern pintail	0	0	0	0	0	3	0	0	0	0	0	0	0	0
northern shoveler	0	0	19	0	0	0	0	0	0	0	0	0	0	0
Divers														
bufflehead	0	4	168	32	139	0	0	0	0	0	0	0	0	0
common goldeneye	0	2	67	1689	260	0	0	0	0	0	0	0	0	0
ruddy duck	0	0	20	20	0	0	0	0	0	0	0	0	0	0
scaup (lesser, greater)	0	0	256	545	498	3	1	0	0	0	0	0	0	0
Eared Grebe														
eared grebe	0	0	64	244	150	13	0	0	0	0	0	0	0	1
Fish Eaters														
American white pelican	0	0	0	0	0	0	64	0	32	25	6	3	0	0
brown pelican	0	0	0	0	0	0	1	0	0	0	0	0	0	0
double-crested cormorant	1	2	6	1	2	7	105	0	45	7	19	3	0	0
Forster's tern	0	0	0	0	0	76	291	19	159	65	2	0	0	0
Goose														
Canada goose	0	10	4	8	29	3	9	0	0	0	0	0	0	12
Gull Tern														
black skimmer	0	0	0	0	0	0	0	2	0	1	0	0	0	0
Bonaparte's gull	0	0	0	0	27	0	0	0	0	0	0	0	0	0
California gull	0	14	0	395	738	0	246	186	3	45	142	67	2	0
Caspian tern	0	0	0	0	0	2	19	3	4	2	17	0	0	0
gull spp.	67	1	0	1421	0	0	164	0	0	1	0	0	0	1
glaucous-winged gull	0	0	0	2	0	0	0	0	0	0	0	0	0	0
herring gull	1	6	14	124	0	0	0	0	0	0	0	0	0	1
least tern	0	0	0	0	0	0	0	0	42	0	0	0	0	0
ring-billed gull	0	175	207	0	45	0	23	0	39	2	0	28	104	70
Thayer's gull	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Table 40 Continued.

Species	2002 Nov	Dec	2003 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
western gull	0	0	23	0	10	0	0	0	2	3	9	0	0	0
Heron														
black-crowned night heron	0	0	0	0	0	0	36	5	0	0	0	0	0	0
great blue heron	2	0	1	2	2	0	5	4	0	0	0	5	1	0
great egret	17	3	1	5	1	1	25	4	25	17	0	17	3	1
snowy egret	5	6	1	0	1	3	61	18	2	10	4	12	7	0
Medium Shorebird														
American avocet	40	12	91	895	406	97	96	45	2	0	0	6	43	0
black-bellied plover	0	0	0	7	0	245	0	0	64	73	0	0	3	117
black-necked stilt	0	0	199	677	698	72	62	17	1	0	0	0	25	0
greater yellowlegs	0	0	1	1	1	6	1	0	0	0	0	0	23	1
killdeer	0	0	0	0	2	6	1	1	0	0	5	6	1	48
long-billed curlew	54	55	1	71	0	0	0	0	45	35	0	0	62	72
lesser yellowlegs	0	0	0	1	0	0	0	0	0	1	0	0	4	0
marbled godwit	15	53	0	2	0	0	0	0	13	64	1	0	1	0
ruddy turnstone	0	0	0	0	0	1	0	0	0	0	0	0	0	0
whimbrel	0	4	0	2	0	0	0	2	0	1	0	0	0	0
willet	575	372	71	690	1036	40	0	0	104	403	0	145	2	0
Phalaropes														
red-necked phalarope	0	0	0	0	0	475	9	0	0	2	5	0	0	0
Wilson's phalarope	0	0	0	0	0	0	0	0	0	8	31	0	0	0
Small Shorebird														
dowitcher (long, short-billed)	0	56	72	243	0	2454	0	0	50	0	0	0	103	0
dunlin	16294	14723	349	7912	3324	14312	0	0	0	1	0	0	1601	1157
least sandpiper	440	1060	120	677	1665	1647	0	0	126	426	378	296	1682	1098
sanderling	0	0	2	47	0	0	0	0	0	0	0	0	0	0
semipalmated plover	654	134	103	3256	588	380	57	79	80	49	329	3	757	1464
semipalmated sandpiper	0	0	0	0	0	0	1	0	0	0	0	0	0	0
snowy plover	11	4	5	7	0	25	58	3	14	5	0	0	18	9
western sandpiper	6704	12176	158	6411	13334	56768	10	3	301	593	3695	239	1347	1603
Totals	24880	28872	2023	25387	22956	76650	1352	391	1153	1839	4651	830	5790	5799

Table 41. Total counts of waterbird species of the major foraging guilds, Redwood salt ponds January 2004-June 2005, San Francisco Bay, CA.

	2004												2005					
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**
Dabblers																		
gadwall	0	0	0	0	0	0	1	0	0	0	0	0	0	6	0	3	1	2
mallard	0	5	0	0	3	1	0	0	0	0	0	0	0	7	10	3	2	2
northern pintail	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
northern shoveler	0	93	6	0	0	0	0	0	0	638	129	17	0	0	0	0	0	0
Divers																		
bufflehead	11	27	21	0	0	0	0	0	0	10	0	70	782	1267	624	99	0	0
canvasback	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
common goldeneye	5	169	34	0	0	0	0	0	0	0	0	4	44	279	276	1	1	0
ruddy duck	0	0	0	0	0	0	0	0	0	0	0	0	0	60	11	25	0	0
scaup (lesser, greater)	0	257	497	0	0	0	0	0	0	0	0	3	2	1111	959	1879	659	0
surf scoter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	15	0
Eared Grebe																		
eared grebe	8	65	18	0	0	0	0	0	0	3	8	0	3	37	23	43	7	0
Fish Eaters																		
American white pelican	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
double-crested cormorant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Forster's tern	0	0	0	32	11	14	56	0	7	0	0	0	0	0	0	10	15	2
Goose																		
Canada goose	7	0	5	16	2	0	0	0	0	0	0	2	8	11	23	7	11	0
Gull Tern																		
black skimmer	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	4	14	7
Bonaparte's gull	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	831	0	0
California gull	0	46	477	0	0	1	0	27	54	246	0	382	1	41	0	8	0	15
Caspian tern	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0	2	24	2
gull spp.	1	18	1	1	0	0	67	0	0	0	0	0	0	0	0	0	0	0

Table 41 Continued.

	2004												2005					
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**
glaucous-winged gull	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
herring gull	35	395	226	0	0	0	0	0	0	23	0	5	3	1	0	0	1	0
least tern	0	0	0	0	0	0	110	0	0	0	0	0	0	0	0	0	0	0
ring-billed gull	44	59	63	0	0	0	0	0	76	245	741	16	12	144	46	32	0	6
western gull	0	0	0	0	0	0	0	0	0	84	0	0	0	45	0	2	0	2
Heron																		
great blue heron	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
great egret	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
snowy egret	0	0	0	1	1	2	0	0	0	0	0	2	0	0	0	0	0	0
Land																		
common raven	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Medium Shorebird																		
American avocet	5	373	378	100	201	136	205	343	523	482	946	495	182	400	517	492	260	147
black-bellied plover	3	0	0	182	27	14	0	196	6	338	16	425	1128	1100	128	241	46	0
black-necked stilt	60	279	463	29	17	27	275	75	664	576	1043	1538	360	1029	276	168	78	26
greater yellowlegs	0	2	6	9	0	0	0	23	16	4	5	2	1	23	2	8	2	0
killdeer	34	12	0	1	0	3	2	3	5	21	28	1	0	7	4	0	1	2
long-billed curlew	0	3	0	0	0	0	49	29	69	5	125	61	27	9	107	4	0	3
lesser yellowlegs	0	1	0	0	0	0	0	0	0	0	1	1	0	3	1	2	1	0
marbled godwit	0	0	0	0	0	0	100	42	21	16	82	161	0	1	4	0	1	0
stilt sandpiper	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
whimbrel	0	0	0	0	0	0	1	0	0	0	10	0	0	0	0	31	0	0
willet	0	879	835	777	0	0	574	114	800	508	775	1812	318	2267	2373	464	104	0
Phalaropes																		
red-necked phalarope	0	0	0	20	1	0	133	2251	1638	2	0	0	0	0	0	226	2190	0
Wilson's phalarope	0	0	0	0	0	0	0	230	185	21	0	0	0	0	0	0	0	0
Small Shorebird																		
dowitcher (long, short-billed)	0	163	0	331	0	0	0	13	0	40	0	132	30	0	67	1072	0	0
dunlin	871	1898	10	5735	0	0	0	0	0	37	120	3069	1728	880	3850	17333	768	0
least sandpiper	30	132	16	169	0	0	18	294	711	966	448	558	349	1033	3039	118	29	0

Table 41 Continued.

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
					2004										**2005**			
semipalmated plover	415	598	208	431	0	0	43	18	34	3311	298	749	197	808	611	1091	34	0
snowy plover	72	3	0	8	6	11	12	3	0	0	0	0	20	1	1	28	6	9
western sandpiper	701	7916	5520	68358	3	0	4968	442	3094	664	4867	16465	1981	6957	27692	33074	2335	0
Totals	2476	13394	8784	76206	273	211	6618	4107	7904	8241	9642	25970	7178	17528	40644	57361	6606	225

Table 42. Results of stepwise multiple regression analyses of April 2002-2005 total birds and foraging guilds with water depth parameters, salinity, dissolved oxygen, water temperature, pH, and pond size. *values are significant ($P < 0.05$).

Dependent variable	Independent variable	Coefficient	p-level	Adj R²
Total			0.005*	0.274
	Pond size (acres)	0.247	0.120	
	Mean depth (ft)	-0.800	0.002*	
	Max depth (ft)	0.662	0.008*	
	Salinity	-0.270	0.089	
Dabbling ducks			0.006*	0.263
	Mean depth (ft)	-0.696	0.006*	
	Pond size (acres)	0.210	0.188	
	Max depth (ft)	1.059	0.010*	
	St dev depth (ft)	-0.643	0.075	
Diving ducks			0.000*	0.543
	Pond size (acres)	0.424	0.002*	
	Min depth (ft)	-0.377	0.003*	
	pH	-0.536	0.000*	
	Salinity	-0.503	0.001*	
	Temperature (ºC)	0.215	0.080	
Eared Grebes			0.002*	0.247
	St dev depth (ft)	0.497	0.001*	
	DO (mg/L)	-0.206	0.157	
Fish-eaters			0.021	0.178
	Salinity	-0.335	0.046*	
	Min depth (ft)	-0.271	0.084	
	Pond size (acres)	0.213	0.202	
Forster's Terns			0.032*	0.132
	Salinity	-0.382	0.021*	
	Temperature (ºC)	0.291	0.073	
Herons			0.005*	0.320
	pH	0.259	0.157	
	Min depth (ft)	-0.112	0.582	
	St dev depth (ft)	0.618	0.010*	
	Salinity	-0.349	0.042*	
	Mean depth (ft)	-0.515	0.089	
	DO (mg/L)	0.197	0.202	

Table 42 Continued

Dependent variable	**Independent variable**	*Coefficient*	**p-level**	**Adj R^2**
Medium-sized Shorebirds			0.021*	0.178
	Mean depth (ft)	-0.786	0.004*	
	Max depth (ft)	0.628	0.020*	
	Temperature (ºC)	-0.318	0.049*	
Small-sized Shorebirds			0.002*	0.331
	pH	0.556	0.000*	
	Mean depth (ft)	-0.623	0.007*	
	St dev depth (ft)	0.387	0.086	
	Temperature (ºC)	0.156	0.294	

Table 43. Results of stepwise multiple regression analyses of winter months (Dec-Feb) 2002-2005 total birds and foraging guilds with water depth parameters, salinity, dissolved oxygen, water temperature, pH, and pond size. *values are significant (*P* < 0.05).

Dependent variable	**Independent variable**	**Coefficient**	**p-level**	**Adj R^2**
Total			0.000*	0.287
	Pond size (acres)	0.295	0.000*	
	Salinity	-0.324	0.000*	
	Mean depth (ft)	-0.505	0.000*	
	Max depth (ft)	0.383	0.000*	
	pH	-0.117	0.090	
	Temperature (ºC)	0.081	0.217	
Dabbling ducks			0.000*	0.217
	Salinity	-0.228	0.005*	
	Mean depth (ft)	-0.631	0.000*	
	Max depth (ft)	0.614	0.001*	
	Pond size (acres)	0.169	0.023*	
	St dev depth (ft)	-0.219	0.233	
	Min depth (ft)	0.109	0.296	
Diving ducks			0.000*	0.385
	Salinity	-0.379	0.000*	
	Pond size (acres)	0.354	0.000*	
	Mean depth (ft)	-0.318	0.000*	
	pH	-0.211	0.003*	
	St dev depth (ft)	0.133	0.139	
	DO (mg/L)	0.104	0.153	
Eared Grebes			0.000*	0.310
	St dev depth (ft)	0.574	0.000*	
	Salinity	0.235	0.001*	
	Pond size (acres)	0.185	0.008*	
	Min depth (ft)	0.155	0.030*	
	Max depth (ft)	-0.234	0.169	
Fish-eaters			0.000*	0.209
	Pond size (acres)	0.365	0.000*	
	Salinity	-0.200	0.012*	
	DO (mg/L)	-0.099	0.229	
	Min depth (ft)	-0.110	0.103	
	pH	-0.114	0.151	
Gulls and Terns			0.000*	0.210
	Max depth (ft)	0.213	0.207	
	Temperature (ºC)	-0.126	0.054	
	Mean depth (ft)	0.140	0.190	
	St dev depth (ft)	0.157	0.290	

Table 43 Continued

Dependent variable	**Independent variable**	*Coefficient*	**p-level**	**Adj R^2**
Forster's Terns			0.006*	0.054
	Temperature (ºC)	-0.179	0.014*	
	pH	-0.129	0.081	
	Min depth (ft)	-0.105	0.167	
	Pond size (acres)	0.090	0.203	
Herons			0.001*	0.077
	Min depth (ft)	-0.242	0.001*	
	Pond size (acres)	0.147	0.040*	
	Temperature (ºC)	-0.087	0.246	
	DO (mg/L)	-0.082	0.281	
Medium-sized Shorebirds			0.001*	0.075
	Mean depth (ft)	-0.399	0.001*	
	Max depth (ft)	0.148	0.198	
	DO (mg/L)	0.131	0.107	
	pH	-0.095	0.254	
Small-sized Shorebirds			0.005*	0.050
	Mean depth (ft)	-0.300	0.011*	
	Temperature (ºC)	0.176	0.015*	
	Max depth (ft)	0.120	0.299	

Table 44. Results of stepwise multiple regression analyses of September 2002-2005 total birds and foraging guilds with water depth parameters, salinity, dissolved oxygen, water temperature, pH, and pond size. *values are significant ($P < 0.05$).

Dependent variable	**Independent variable**	**Coefficient**	**p-level**	**Adj R²**
Total			0.019*	0.146
	Temperature (ºC)	-0.385	0.012*	
	Pond size (acres)	0.338	0.019*	
	Mean depth (ft)	-0.315	0.031*	
	Salinity	0.158	0.313	
Dabbling ducks			0.005*	0.225
	Temperature (ºC)	-0.427	0.005*	
	Pond size (acres)	0.360	0.011*	
	Mean depth (ft)	-0.552	0.008*	
	Max depth (ft)	0.424	0.033*	
	pH	0.234	0.128	
	Salinity	0.195	0.278	
Diving ducks			0.044*	0.111
	Temperature (ºC)	-0.191	0.207	
	St dev depth (ft)	-0.211	0.143	
	pH	-0.308	0.056	
	Salinity	-0.204	0.269	
Eared Grebes			0.002*	0.238
	St dev depth (ft)	0.521	0.000*	
	DO (mg/L)	0.152	0.243	
	pH	0.153	0.256	
	Pond size (acres)	0.136	0.266	
Fish-eaters			0.000*	0.315
	Pond size (acres)	0.490	0.000*	
	St dev depth (ft)	-0.231	0.067	
	Salinity	-0.132	0.300	
Gulls and Terns			0.010*	0.170
	Min depth (ft)	0.218	0.187	
	Salinity	0.178	0.213	
	Mean depth (ft)	0.204	0.205	
	Pond size (acres)	-0.153	0.261	
Herons			0.001*	0.292
	Salinity	-0.318	0.036*	
	Mean depth (ft)	-0.571	0.004*	
	Max depth (ft)	1.011	0.001*	
	St dev depth (ft)	-0.652	0.026*	
	pH	-0.202	0.153	

Table 44 Continued

Dependent variable	**Independent variable**	**Coefficient**	**p-level**	**Adj R^2**
Medium-sized Shorebirds			0.000*	0.320
	Temperature (ºC)	-0.492	0.001*	
	Mean depth (ft)	-0.118	0.639	
	Pond size (acres)	0.343	0.009*	
	Salinity	0.312	0.066	
	Min depth (ft)	-0.339	0.066	
	St dev depth (ft)	-0.274	0.206	
Phalaropes			0.027*	0.131
	Pond size (acres)	0.335	0.017*	
	pH	0.451	0.007*	
	Salinity	0.461	0.014*	
	Temperature (ºC)	-0.221	0.139	
Small-sized Shorebirds			0.001*	0.265
	Mean depth (ft)	-0.302	0.043*	
	Min depth (ft)	-0.306	0.054	
	Temperature (ºC)	-0.334	0.022*	
	DO (mg/L)	0.203	0.121	
	Salinity	0.190	0.214	

Table 45. Total number of observations, observed range in elevation above MLLW, and median elevation for each plant species for each site studied, San Francisco Bay, CA

	Corkscrew Marsh Plant Observations/Total Observations	Corkscrew Marsh Elevation Range (m)	Corkscrew Marsh Median Elevation (m)	Bird Island Plant Observations/Total Observations	Bird Island Elevation Range (m)	Bird Island Median Elevation (m)	Palo Alto Baylands Plant Observations/Total Observations	Palo Alto Baylands Elevation Range (m)	Palo Alto Baylands Median Elevation (m)	All Sites Observations/Total Observations	All Sites Elevation Range (m)	All Sites Median Elevation (m)
Bare Ground	57/266	1.19 to 2.47	2.01	128/268	.98 to 2.28	1.96	21/114	2.48 to 2.64	2.51	206/648	0.98 to 2.64	2.02
Atriplex patula	0/266	NA	NA	0/268	NA	NA	4/114	2.47 to 2.68	2.51	4/648	2.47 to 2.68	2.51
Deschampsia cespitosa	0/266	NA	NA	32/268	1.86 to 2.30	2.08	0/114	NA	NA	32/648	1.86 to 2.30	2.08
Distichlis spicata	124/266	1.76 to 2.45	2.25	82/268	1.82 to 2.52	2.10	23/114	2.44 to 2.68	2.52	229/648	1.76 to 2.68	2.26
Frankenia salina	9/266	2.16 to 2.55	2.31	2/268	2.41 to 2.52	2.46	12/114	2.48 to 2.74	2.52	23/648	2.16 to 2.74	2.51
Grindelia stricta	0/266	NA	NA	2/268	2.41 to 2.52	2.46	8/114	2.45 to 2.94	2.50	10/648	2.41 to 2.94	2.50
Jaumea carnosa	57/266	2.06 to 2.45	2.30	66/268	1.77 to 2.30	2.08	29/114	2.43 to 2.61	2.51	152/648	1.77 to 2.61	2.24
Limonium californicum	0/266	NA	NA	1/268	NA	NA	0/114	NA	NA	1/648	none	2.52
Salicornia virginica	138/266	1.61 to 2.55	2.25	206/268	1.02 to 2.52	2.07	97/114	2.37 to 2.68	2.51	441/648	1.02 to 2.68	2.21
Spartina foliosa	175/266	1.19 to 2.38	2.22	246/268	.98 to 2.28	2.03	73/114	1.45 to 2.68	2.50	494/648	0.98 to 2.68	2.12

[m, meters; NA, not applicable]

Table 46. Basic chemistry and structure of slough sediments; provided is average value (n = 3) per slough, San Francisco Bay, CA.

Slough	Na[1/] meq/L[2/]	Na ppt	OM %	C-Org %	Sand %	Silt %	Clay %	Soil Type
Alviso								
Upper	82.9	1.9	2.29	1.33	8	48	44	Silty Clay
Adjacent	295.8	6.8	2.18	1.27	10	55	35	Silty Clay Loam
Mouth	357.0	8.2	2.11	1.22	18	47	35	Silty Clay Loam
Mallard								
Upper	39.7	0.9	7.00	4.06	19	42	39	Silty Clay Loam
Adjacent	59.2	1.4	2.87	1.67	9	53	38	Silty Clay Loam
Mouth	208.7	4.8	2.68	1.55	13	53	34	Silty Clay Loam
Mud								
Upper	91.0	2.1	2.37	1.37	38	32	30	Clay Loam
Adjacent	199.0	4.6	2.37	1.37	8	49	43	Silty Loam
Mouth	365.7	8.4	2.05	1.19	9	49	42	Silty Loam
Guadalupe								
Upper	23.4	0.5	2.29	1.33	10	46	44	Silty Loam
Adjacent	285.8	6.6	1.89	1.10	20	45	35	Silty Clay Loam
Mouth	327.7	7.5	1.72	1.00	10	67	23	Silty Loam

[1/] Na determined from soluble paste extract. See methods.
[2/] Milliequivalents per liter.

Table 47. Gastropoda and Bivalvia in slough samples, average per benthic grab (N = 9), San Francisco Bay, CA.

	Assiminea californica	*Tryonia imitartor*	*Gemma gemma*	*Macoma balthica*	*Mya arenaria*	*Potamacorbula*
Stevens Creek	3.11	0.22	0.44	4.44	1.56	0.00
Guadalupe Slough	0.44	0.33	0.00	1.78	0.00	0.11
Alviso Slough	0.00	0.11	0.00	1.11	0.11	1.89
Coyote Creek	0.00	0.56	1.33	1.11	0.22	0.22
Mud Slough	0.00	2.78	0.00	0.67	0.00	0.00
Mt. Eden Creek	0.00	3.00	162.58	1.58	1.00	0.00
Alameda Creek	0.00	0.44	29.00	9.33	1.22	0.33
Alameda Flood Control Channel	0.00	0.00	0.78	24.78	0.89	0.00

Table 48. Insecta in slough samples, average per benthic grab (N = 9), San Francisco Bay, CA.

	Chironomidae	Corixidae	Diptera	Muscidae
Stevens Creek	0.00	0.00	0.00	0.00
Guadalupe Slough	0.00	0.00	0.00	0.00
Alviso Slough	0.00	0.00	0.00	0.00
Coyote Creek	0.00	0.00	0.00	0.00
Mud Slough	0.00	0.00	0.00	0.00
Mt. Eden Creek	21.25	14.33	0.17	0.08
Alameda Creek	0.00	0.11	0.22	0.00
Alameda Flood Control Channel	0.11	0.00	0.00	0.00

Table 49. Crustacea in slough samples, average per benthic grab (N = 9), San Francisco Bay, CA.

	Ampelisca	Ampithoidae	Cirripedia	Copepoda	*Corophium*	*Cumacea*	*Ericthonius*	Gammaridae	*Mysis*	Ostracoda	*Pancolus californiensis*
Stevens Creek	0.11	0.00	0.00	0.00	0.22	66.67	1.33	0.00	0.00	0.56	0.00
Guadalupe Slough	0.00	0.00	0.00	0.11	0.00	24.56	0.11	0.00	0.00	0.00	0.00
Alviso Slough	0.00	0.00	0.44		2.22	60.78	4.11	0.00	0.11	0.00	0.00
Coyote Creek	0.00	0.00	0.00	0.33		47.44	0.11	0.00		2.78	0.00
Mud Slough	0.00	0.00	0.00		1.33	41.78	0.00	0.00	0.22		0.00
Mt. Eden Creek	0.00	0.08	0.00	0.08	0.33	3.50	0.00	0.50	0.00	0.33	0.25
Alameda Creek	0.00	0.00	0.00	0.78	0.33	53.33	5.67	0.00	0.00	0.00	0.00
Alameda Flood Control Channel	0.11	0.00	0.00	0.22	0.22	9.33	0.00	0.00	0.11	0.11	0.00

Table 50. Annelids in slough samples, average per benthic grab (N = 9), San Francisco Bay, CA.

	Capitella	*Cirratulus*	*Eteone*	Glycindae	*Heteromastus*	*Nereis*	*Polydora*	*Pseudopolydora*	Sabellidae	Spionidae	*Streblospio*	Tubificoides
Stevens Creek	0.00	0.00	2.56	0.00	5.00	0.89	10.44	0.00	0.00	0.00	16.89	15.22
Guadalupe Slough	0.00	0.00	0.56	0.00	0.22	0.11	0.00	0.00	0.00	0.33	7.33	76.44
Alviso Slough	0.11	0.00	0.11	0.00	0.22	2.67	0.44	0.00	0.00	0.11	14.89	6.78
Coyote Creek	0.22	0.00	1.78	0.00	16.56	0.33	6.00	0.00	0.00	0.00	10.56	11.22
Mud Slough	0.00	0.00	0.00	0.00	0.00	0.22	0.11	0.00	0.11	0.00	3.11	37.00
Mt. Eden Creek	0.00	0.33	0.33	0.00	1.08	0.00	3.25	2.33	0.00	0.00	63.42	12.42
Alameda Creek	0.00	0.11	2.44	0.67	14.78	0.33	0.11	1.00	0.00	0.00	26.11	14.67
Alameda Flood Control Channel	0.22	0.44	3.00	0.00	28.78	0.00	0.67	0.00	0.00	0.00	9.11	35.00

Table 51. Other species in slough samples, average per benthic grab (N = 9), San Francisco Bay, CA.

	Nematoda	*Edwardsia*
Stevens Creek	5.56	0.00
Guadalupe Slough	11.67	0.00
Alviso Slough	0.00	0.00
Coyote Creek	3.89	0.00
Mud Slough	10.78	0.00
Mt. Eden Creek	3.08	7.50
Alameda Creek	5.89	0.11
Alameda Flood Control Channel	8.56	0.00

Table 52. Invertebrate taxa richness in slough samples, San Francisco Bay, CA.

	Annelida	Bivalvia	Crustacea	Insecta	Other	total
Stevens Creek	6	3	5	0	3	**17**
Guadalupe Slough	6	2	3	0	3	**14**
Alviso Slough	8	3	5	0	1	**17**
Coyote Creek	7	4	4	0	2	**17**
Mud Slough	5	1	3	0	2	**11**
Mt. Eden Creek	7	3	7	4	3	**24**
Alameda Creek	9	4	4	2	3	**22**
Alameda Flood Control Channel	7	3	6	1	1	**18**

Table 53. Data available from the 2004 South Bay LIDAR survey. The San Francisco Estuary Institute is responsible for maintaining and distributing this data. Contact Eric Zhang (ericz@sfei.org or 510-746-7361) to obtain the data.

Available Data	**File Format**	**Data Partitions**
Full Feature Points	ASCII text	1 km & 2 km tiles
Bare Earth Points	ASCII text	1 km & 2 km tiles
1 m Bare Earth Grids	ASCII text	1 km & 2 km tiles
1 m Bare Earth Grids	ArcInfo ASCII text	2 km tiles
25 m Bare Earth Grids	ArcInfo ASCII text	2 km tiles
Full Feature Hill-Shaded Image	GeoTIFF	3 large regions
Bare Earth Hill-Shaded Image	GeoTIFF	3 large regions
Contours (50cm interval)	AutoCAD DWG	1 km & 2 km tiles
Digital Video Imagery	AVI	collected at 2 frames per second (sorted by Julian day and flight number)

Table 54**.** Absolute vertical accuracy of LIDAR data.

2σ Error (cm)	**Terrain Description**
± 10 – 15	Hard Surfaces (roads and buildings)
± 15 – 25	Soft/Vegetated Surfaces (flat to rolling terrain)
± 25 – 40	Soft/Vegetated Surfaces (hilly terrain)

Table 55. Differences between LIDAR values and ground-truth elevations classified by surface type.

Location	**Number of Samples**	**Min**	**Max**	**Mean**	**RMSE**	**2σ Difference**
Center of Levee	19	-29	26	-6	13	25
Edges of Levee[1]	49	-81	114	4	31	61
Pickleweed Marsh	42	-7	29	6	9	18
Tidal Flat	14	-18	25	2	11	21
Bulrush Marsh	3	82	121	96	98	192

[1] edges of levee includes both the top outer edges of the levee and base of levee banks

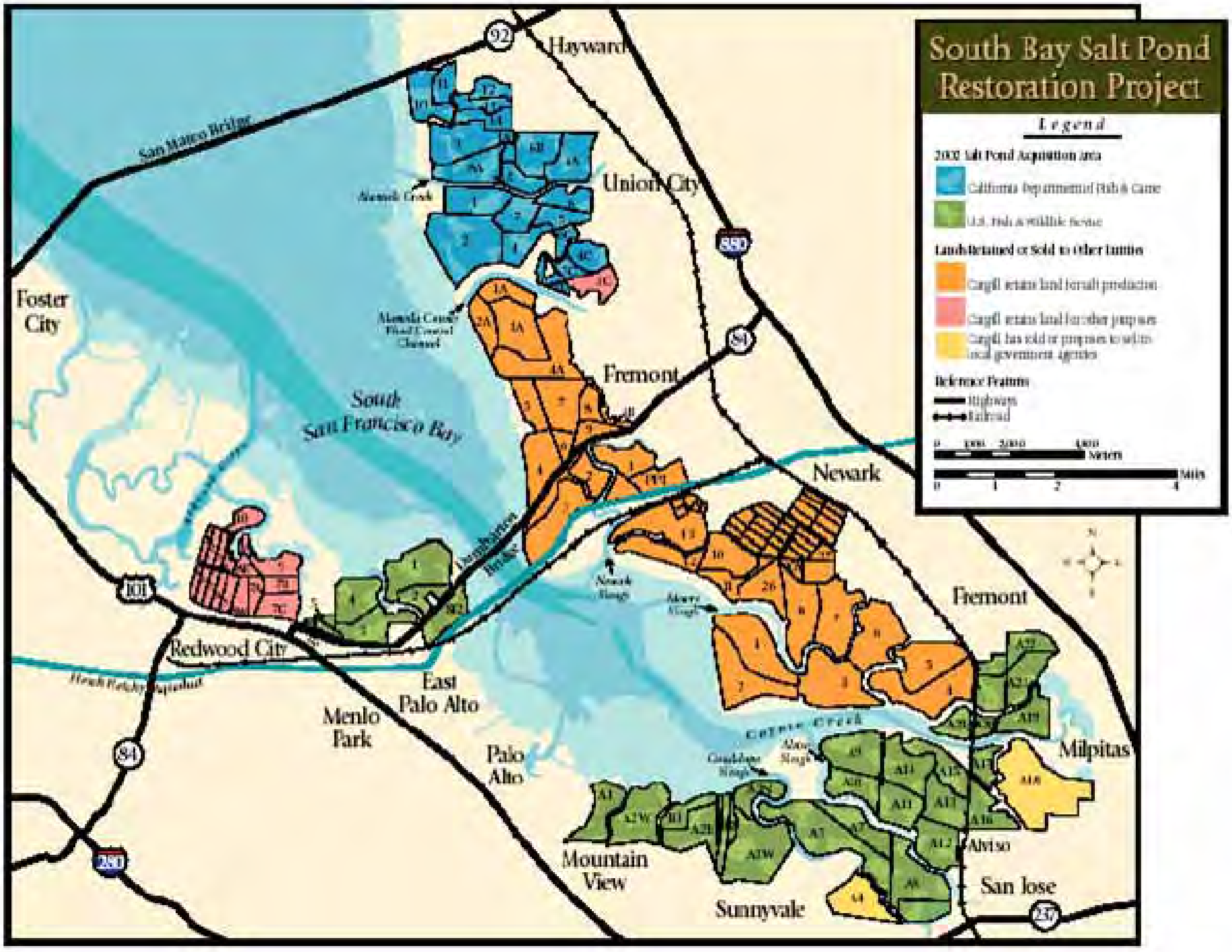


Figure 1. Project area map of salt ponds in South San Francisco Bay, CA. Blue = Eden Landing Complex, green ponds from Mountain View to Milpitas = Alviso Complex, and green ponds in Menlo Park = Ravenswood Complex. Orange and red ponds are retained by Cargill and were not studied here (figure from Trulio and Clark 2005).

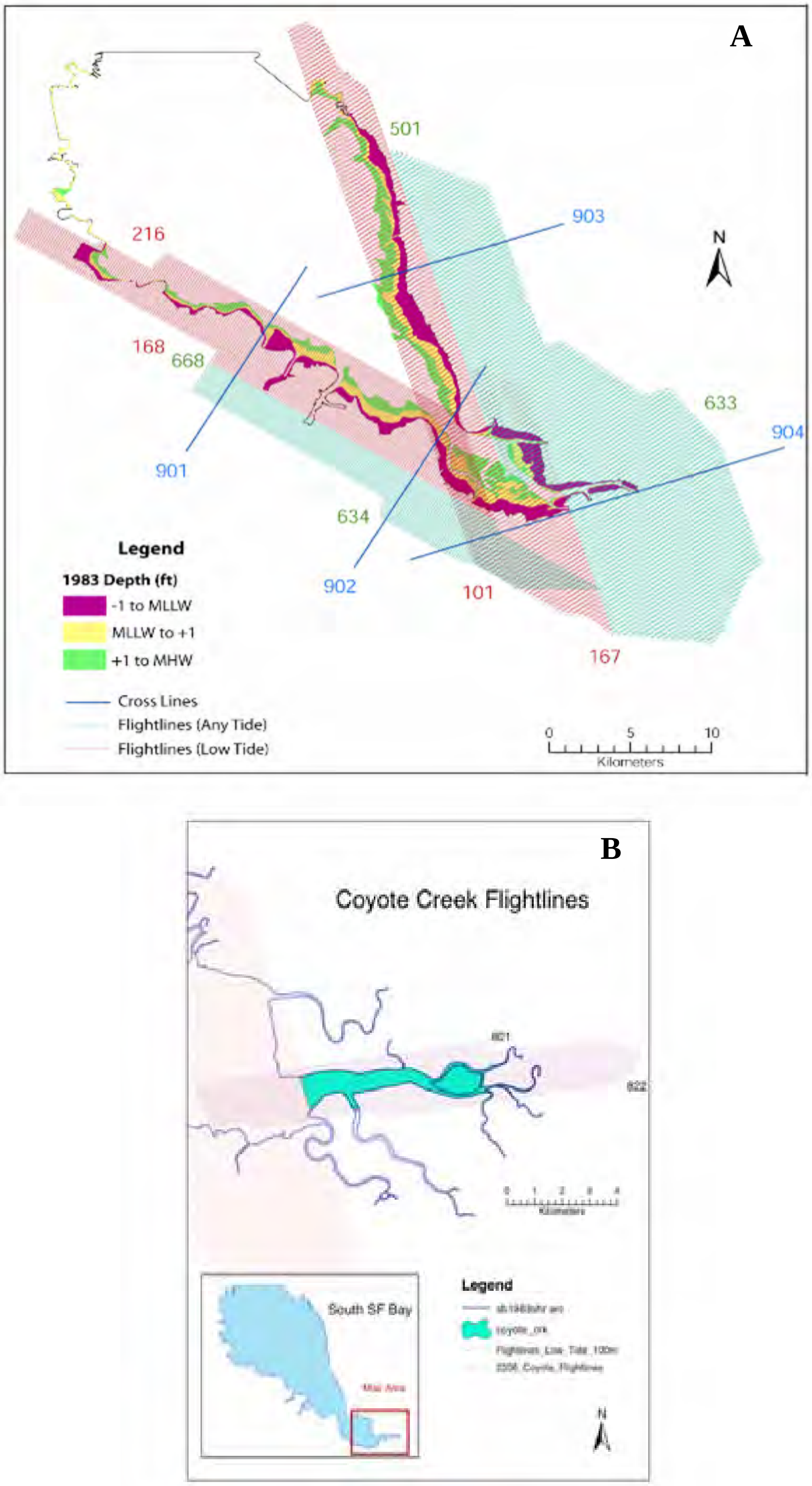


Figure 2. A) Initial flightlines for LIDAR survey. Red colored lines were flown only within specified time windows during daylight hours when the tide was below mean lower low water (MLLW). Teal colored lines were flown during all tide levels during daylight hours. B) Additional flightlines flown when tide levels were near MLLW to augment initial flightlines the Coyote Creek region.

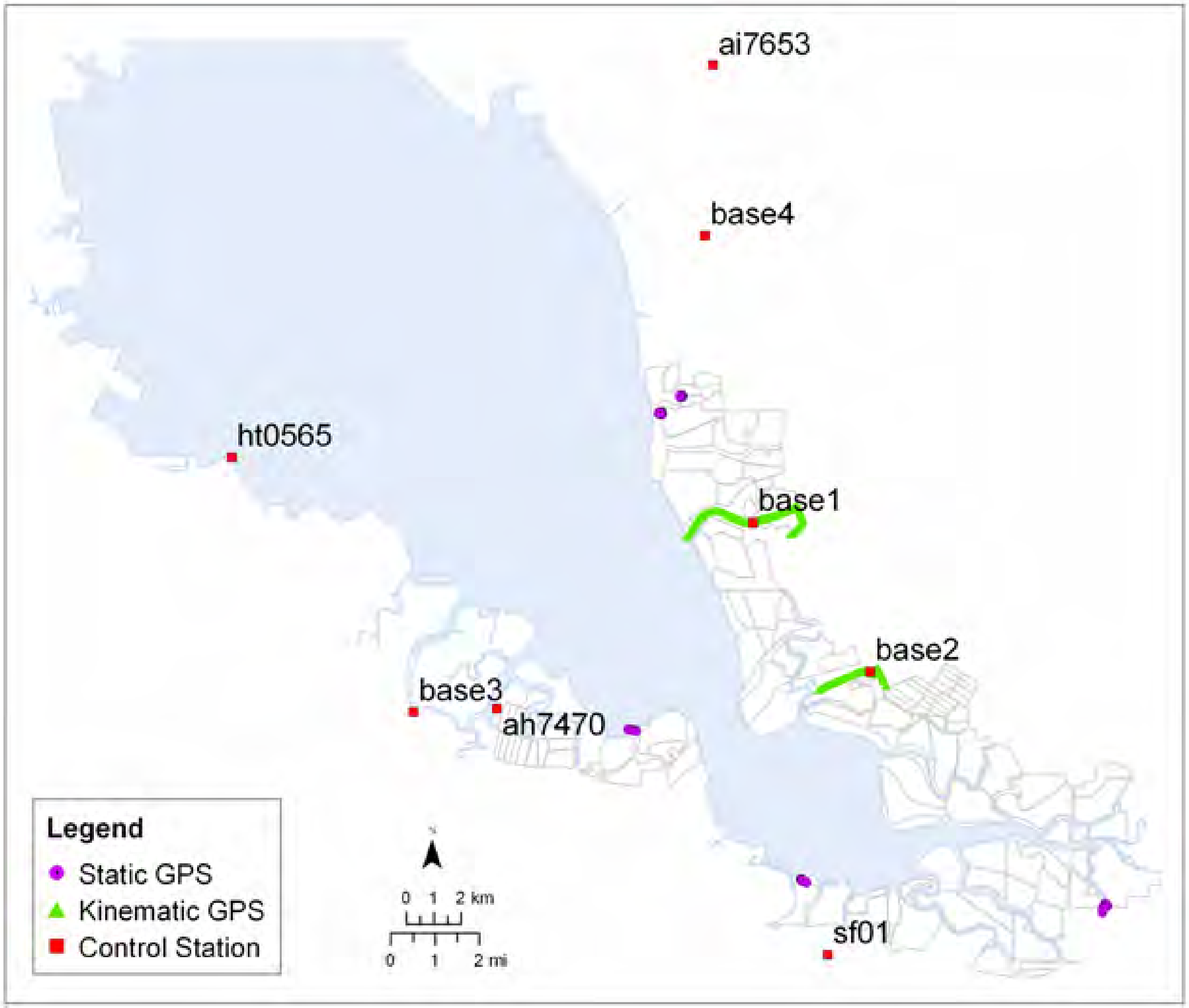


Figure 3**.** Locations of base stations and ground-truth sites. Figure from Foxgrover and Jaffe (2005).

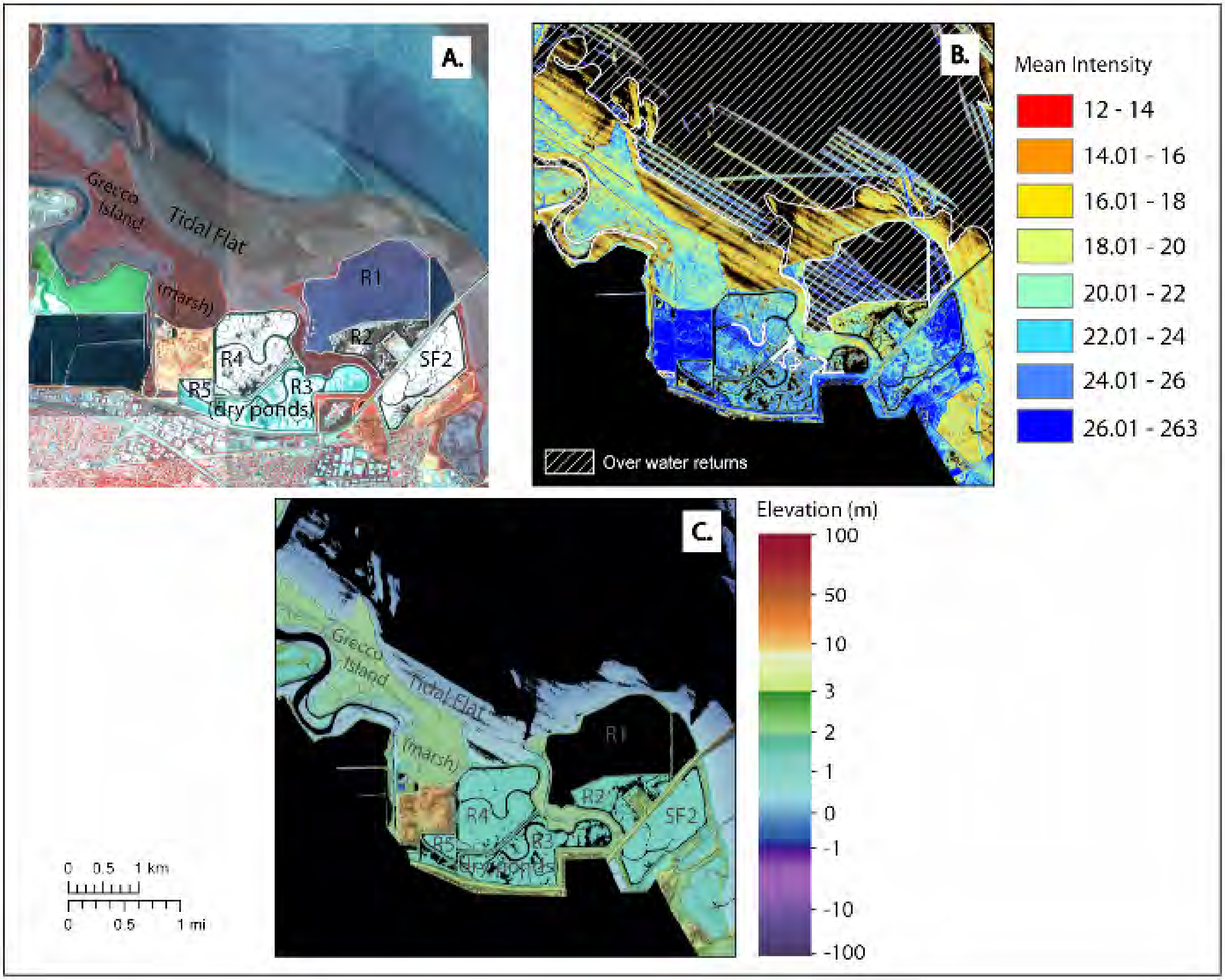


Figure 4. Sample of how IKONS satellite imagery in conjunction with LIDAR return intensity was used to mask out over-water returns. (A) IKONOS false color composite satellite imagery (1m resolution) of the Ravenswood pond area located northwest of the Dumbarton bridge (B) full feature LIDAR returns shaded according to average return intensity (averaged over 3x3m neighborhood) hachured area indicates data that was removed because the returns were over water surfaces (C) resultant DEM with over-water returns eliminated, hill-shaded by elevation.

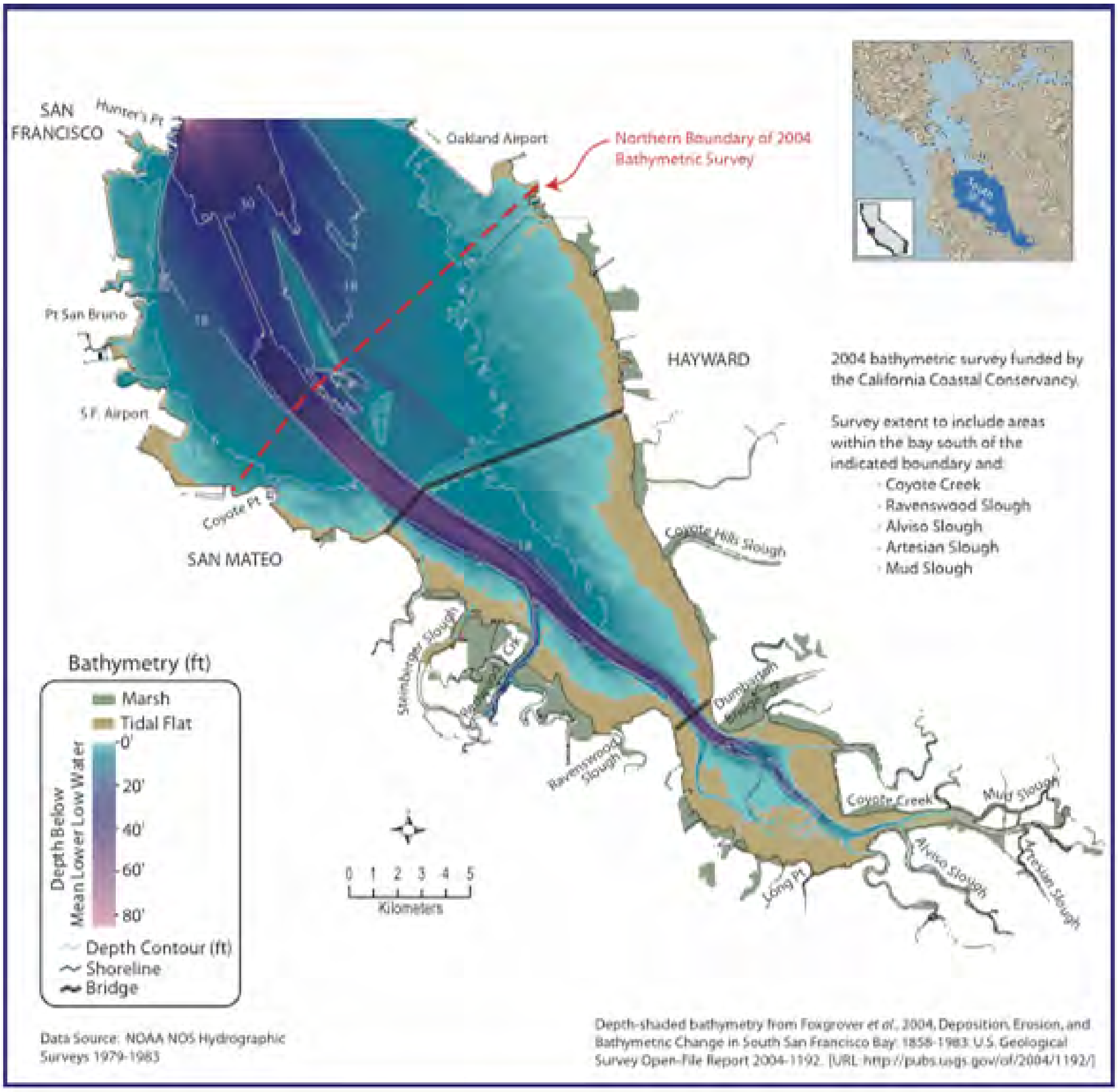


Figure 5. Range of the 2005 bathymetric survey.

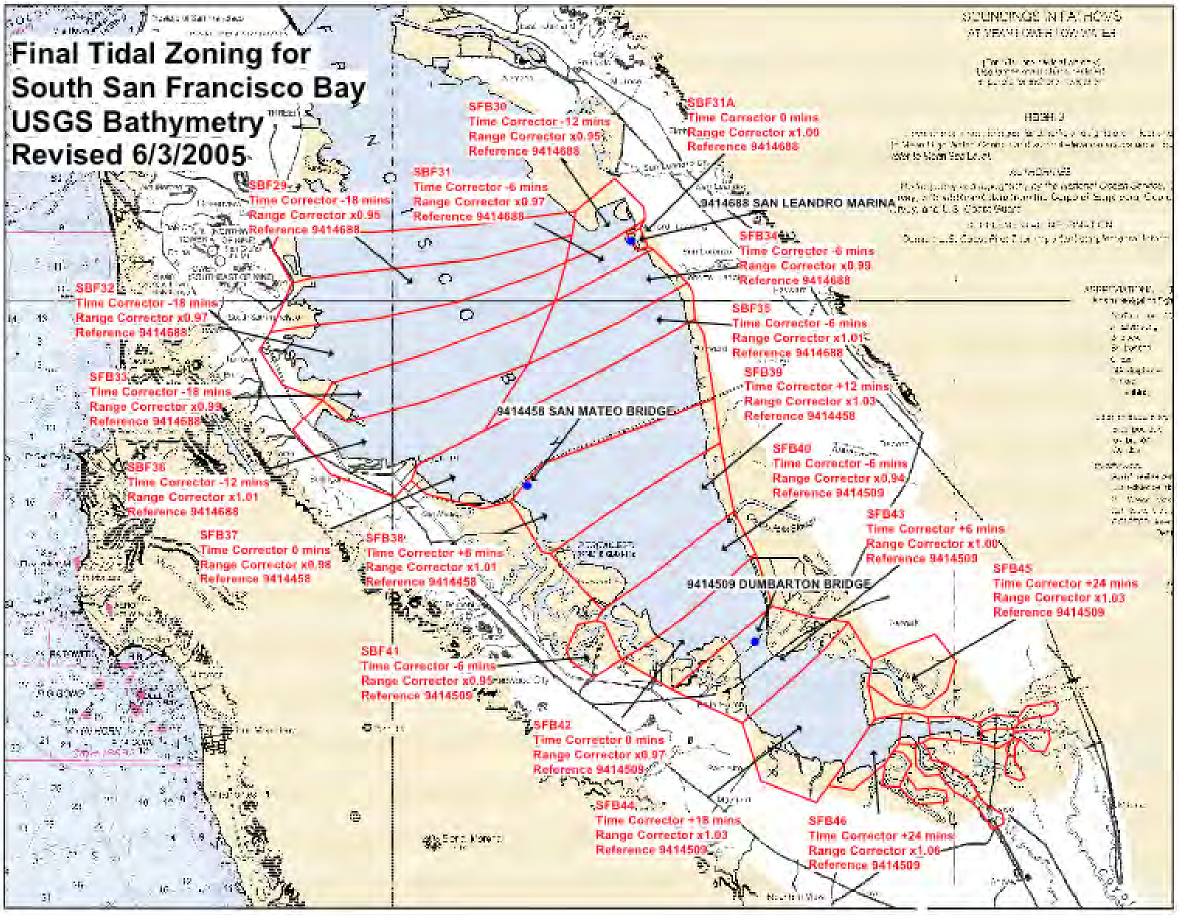


Figure 6. Tidal Zones recommended by NOAA for correcting soundings for tidal fluctuations.

Figure 7. Stilling Well for Acoustic Tide Gauge at Beacon 14 in San Leandro Marina.

Figure 8. Stilling Well for Acoustic Tide Gauge at West Fishing Pier at San Mateo Bridge.

Figure 9. Stilling Well for Acoustic Tide Gauge at PG&E Electrical Tower at Coyote Creek.

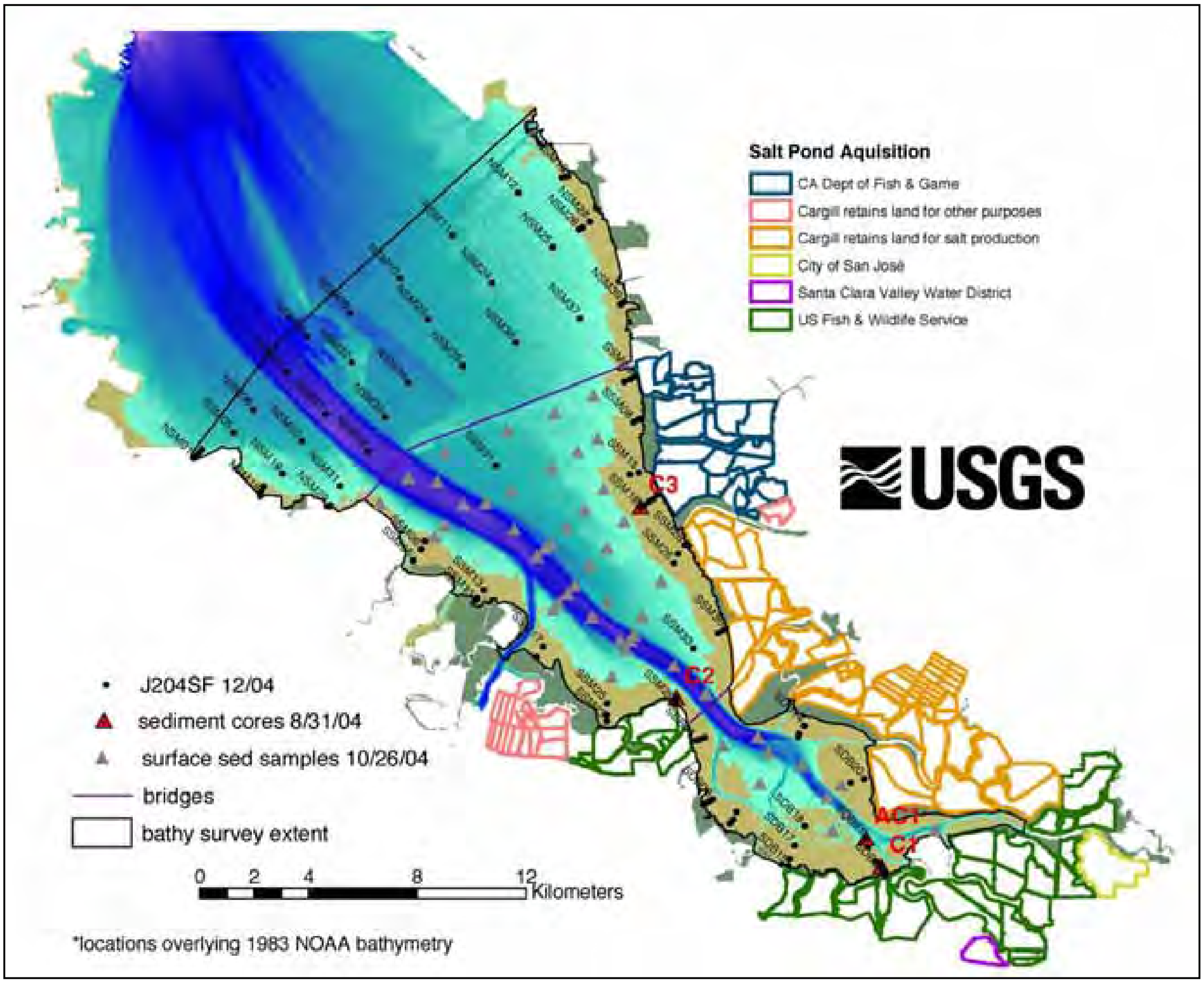


Figure 10. Surface sediment samples and short box cores collected by USGS from August to December 2004. Not shown are USGS short box cores and gravity core locations.

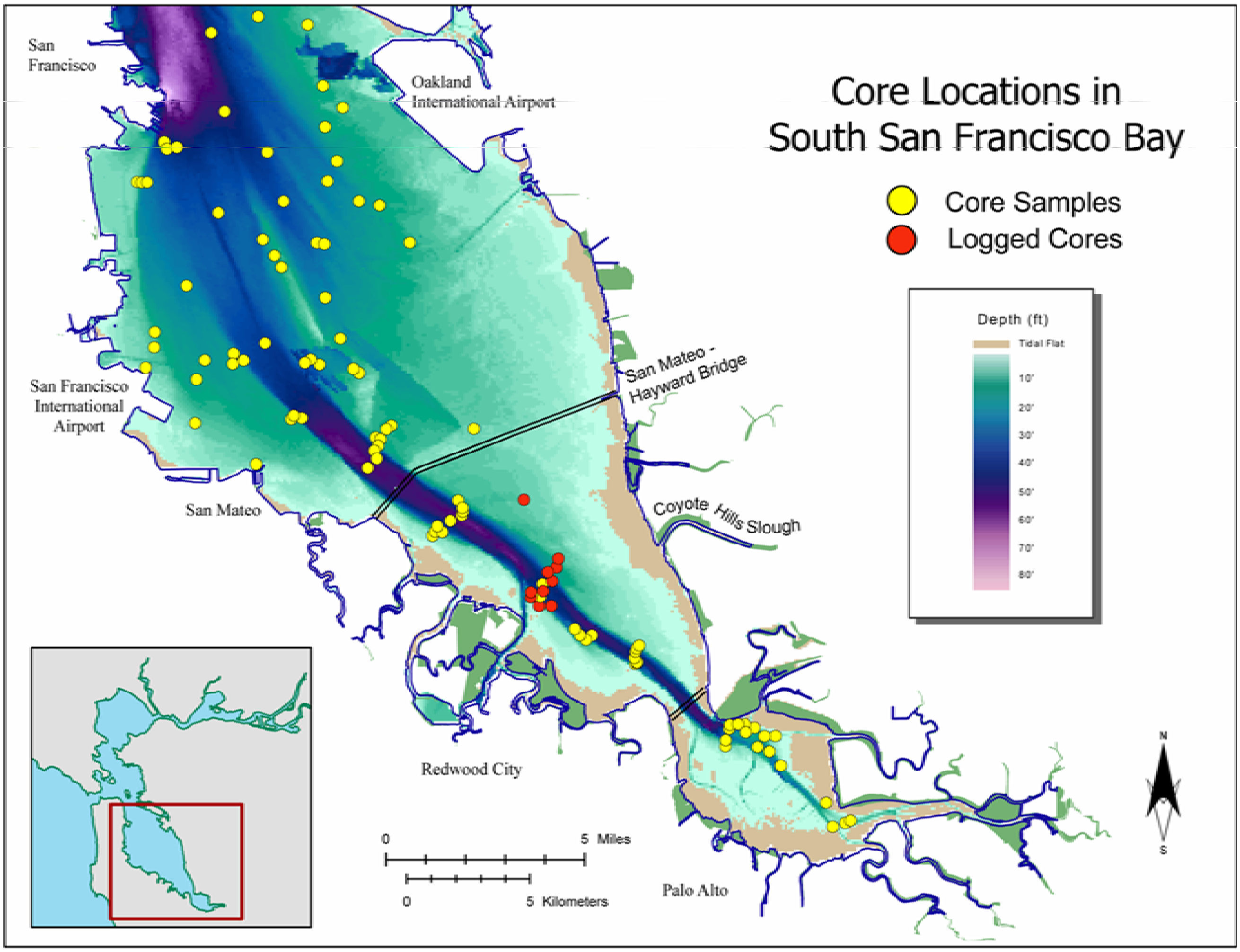


Figure 11. Sediment gravity cores collected by the USGS in the 1990s. Red circles indicate cores examined as of early summer as part of this study.

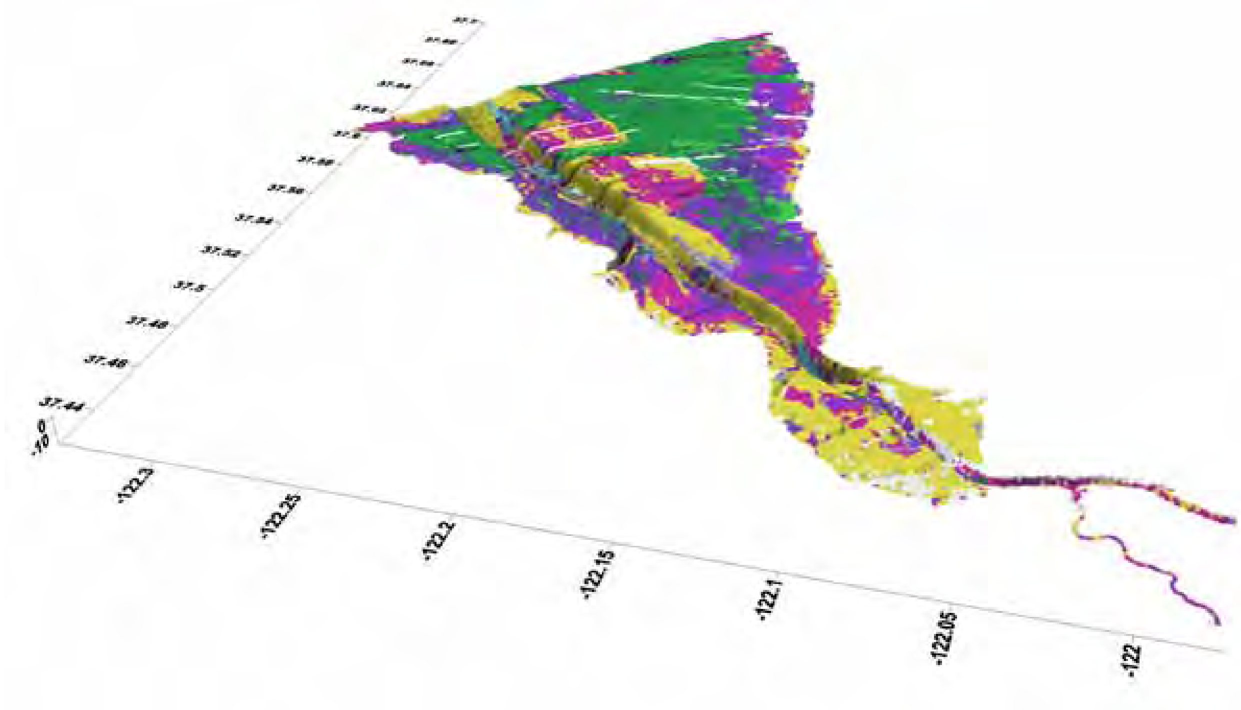


Figure 12. Acoustic seabed classification of South San Francisco Bay. Colors indicate different acoustic classes.

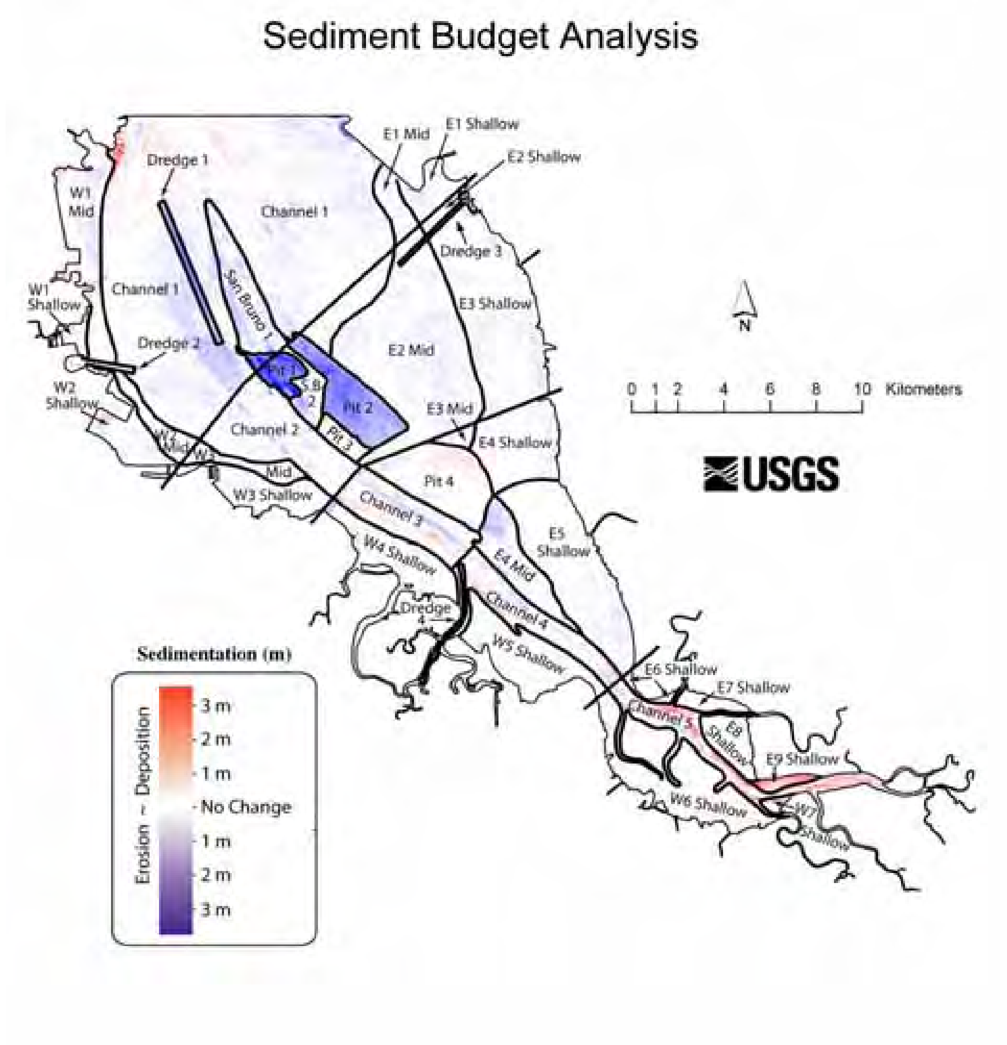


Figure 13. Sediment budget cells for the period from 1956 to 1983. Sedimentation and erosion from Foxgrover et al., 2004.

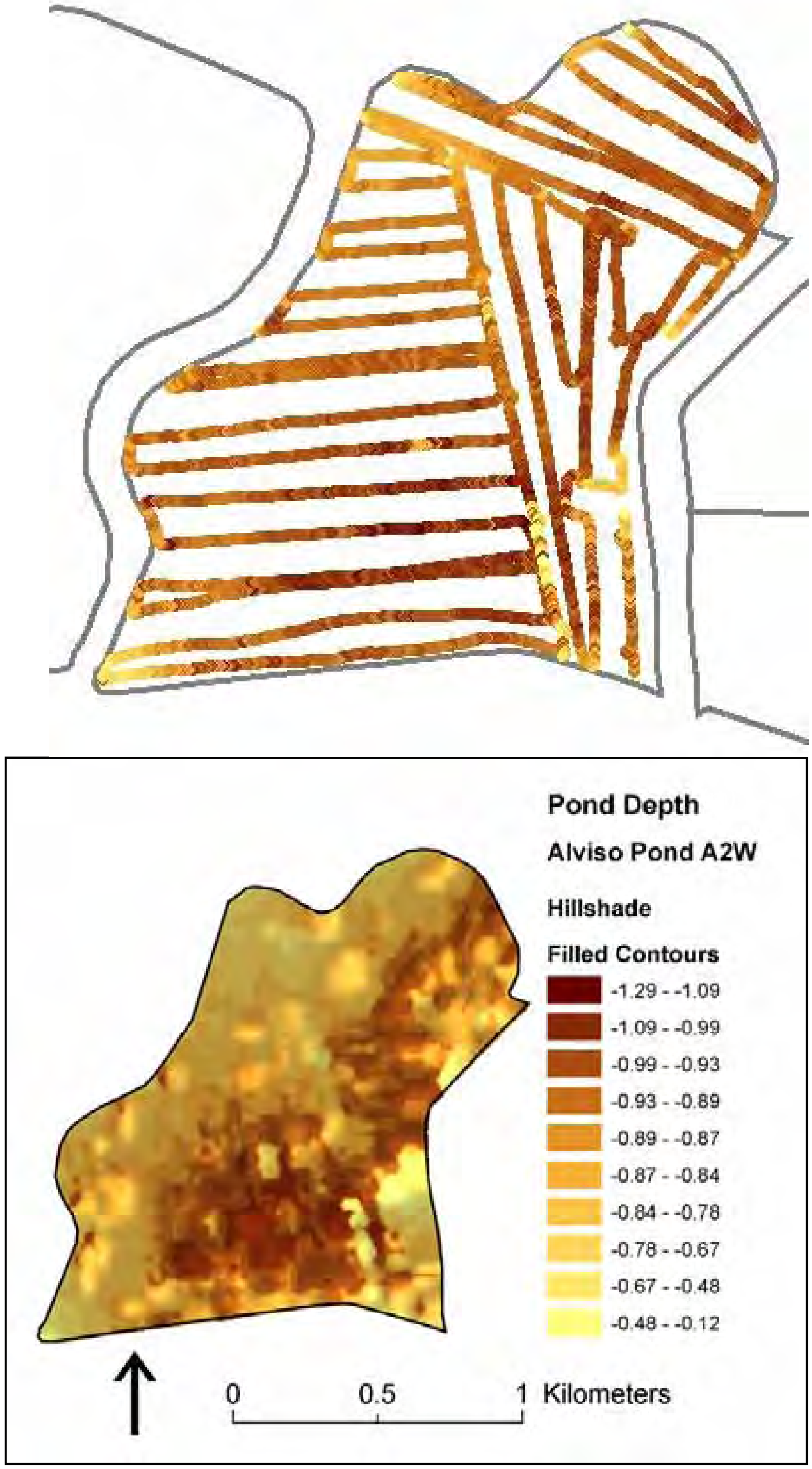


Figure 14. Example of 100-m salt pond bathymetry transect lines (above) and interpolated ESRI grid (below), showing relative water depths in pond A2W. Relative water depths were later adjusted to NAVD88 with staff gage survey information.

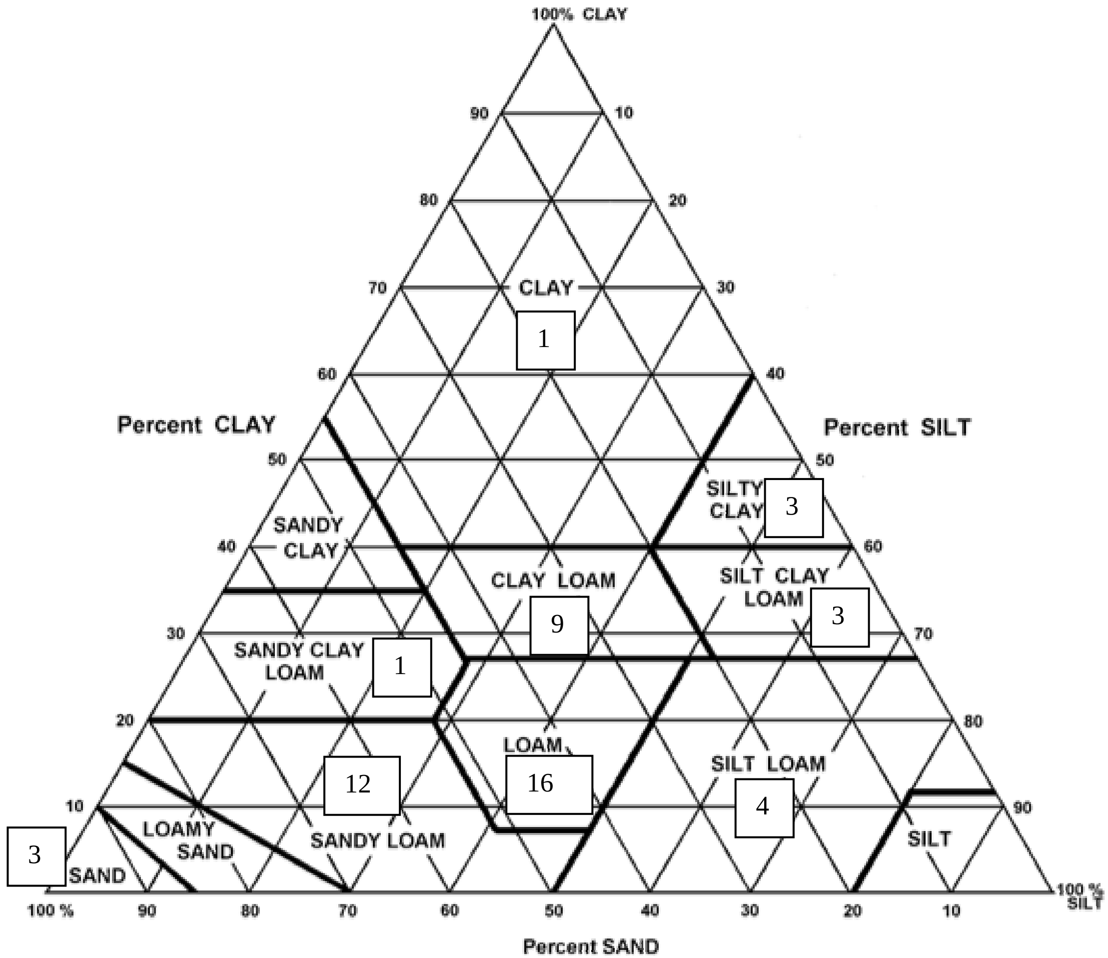


Figure 15. Soil Texture Triangle, numbers in boxes indicate number of salt ponds with soil type, San Francisco Bay, CA.

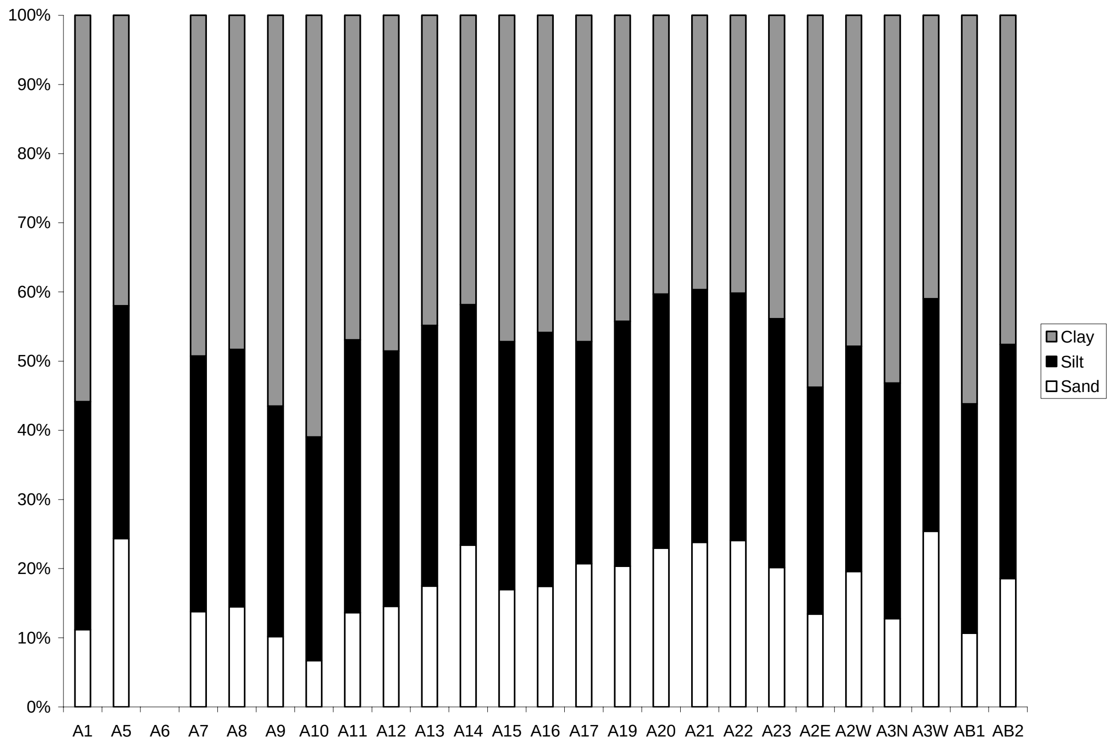


Figure 16. Soil texture profile for Alviso salt ponds, San Francisco Bay, CA.

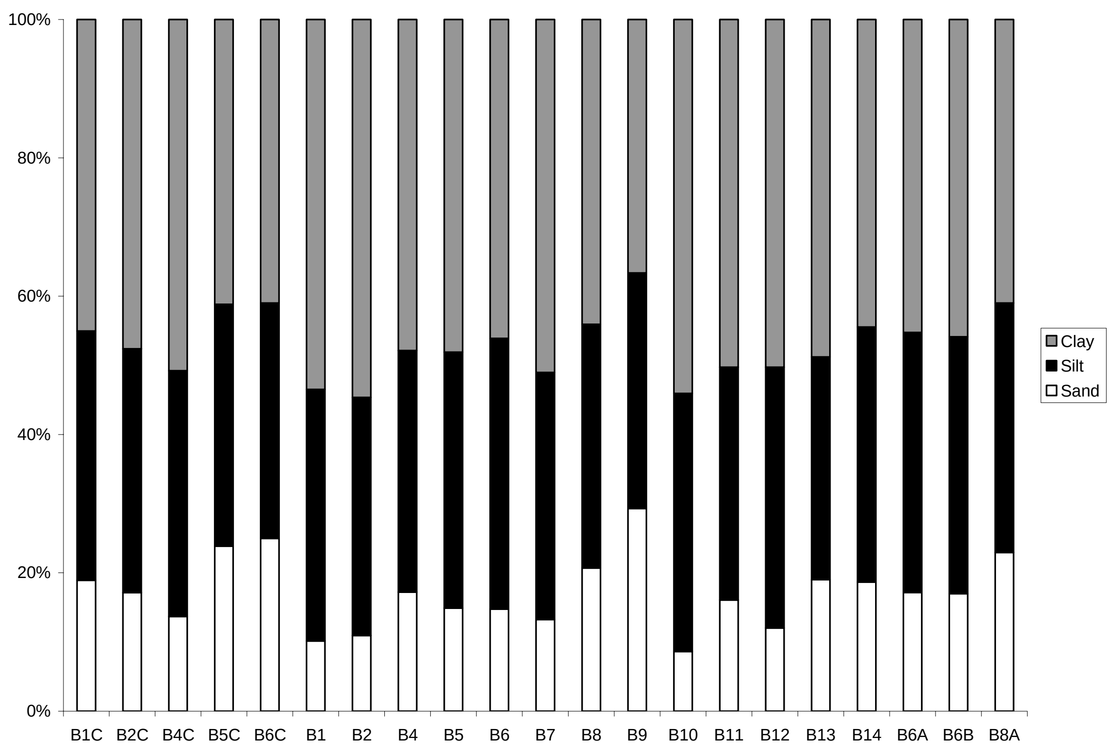


Figure 17. Soil texture profile for Eden Landing salt ponds, San Francisco Bay, CA.

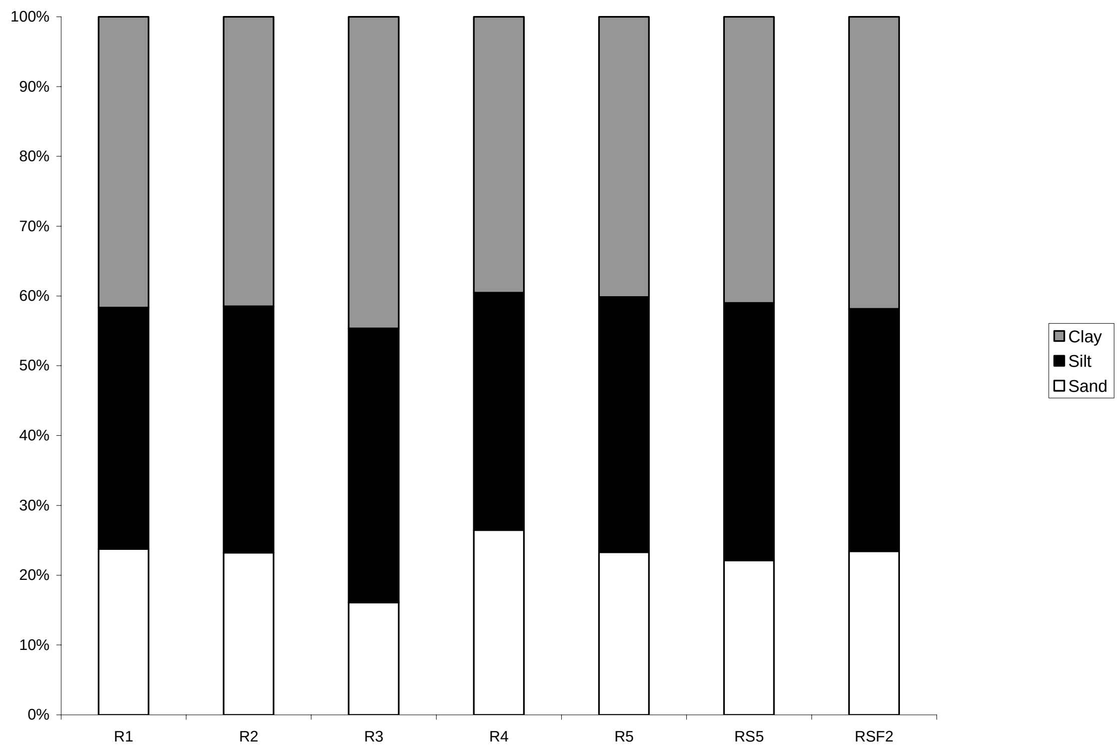


Figure 18. Soil texture profile for Ravenswood salt ponds, San Francisco Bay, CA.

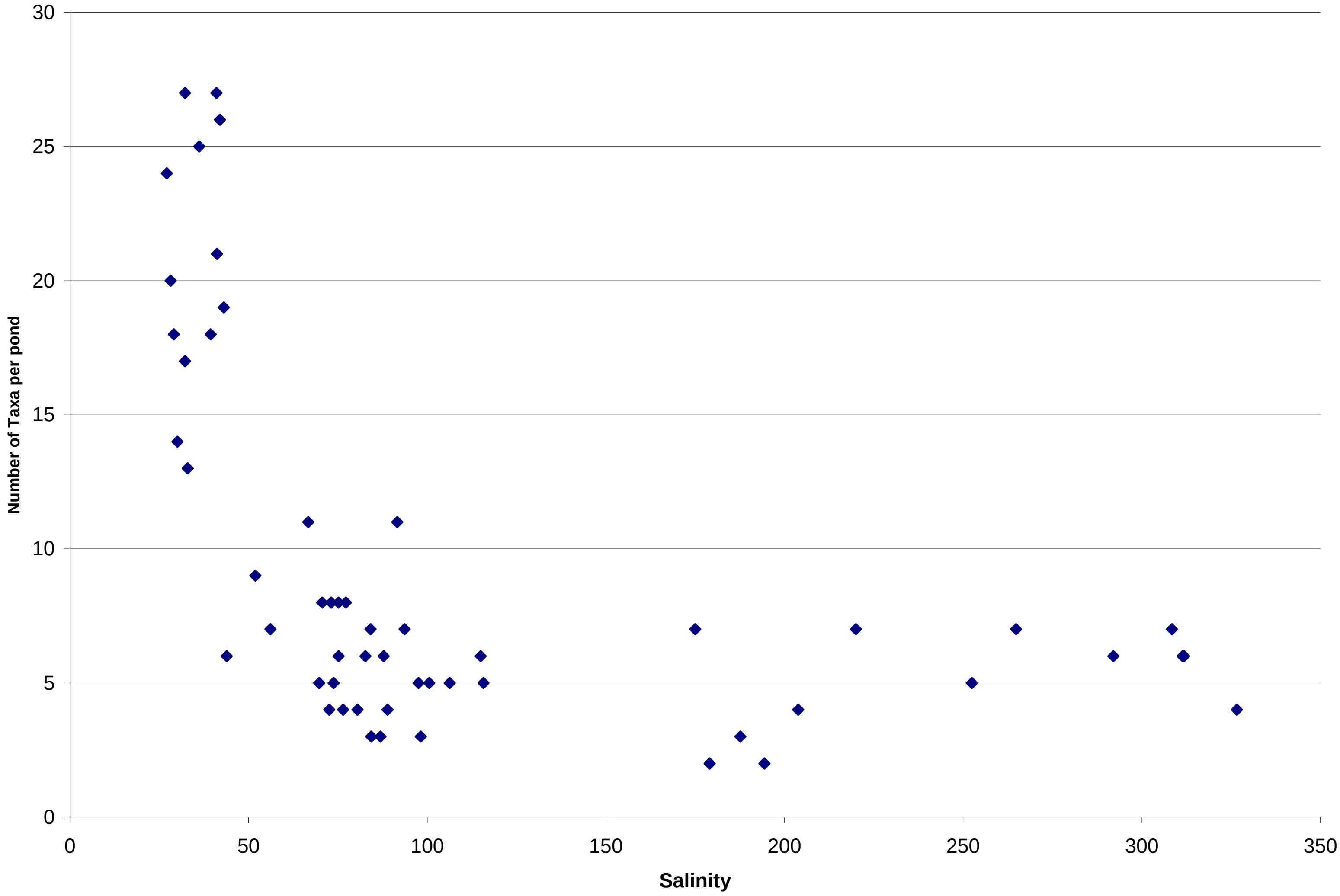


Figure 19. Invertebrate taxa richness vs salinity in salt ponds, San Francisco Bay, CA.

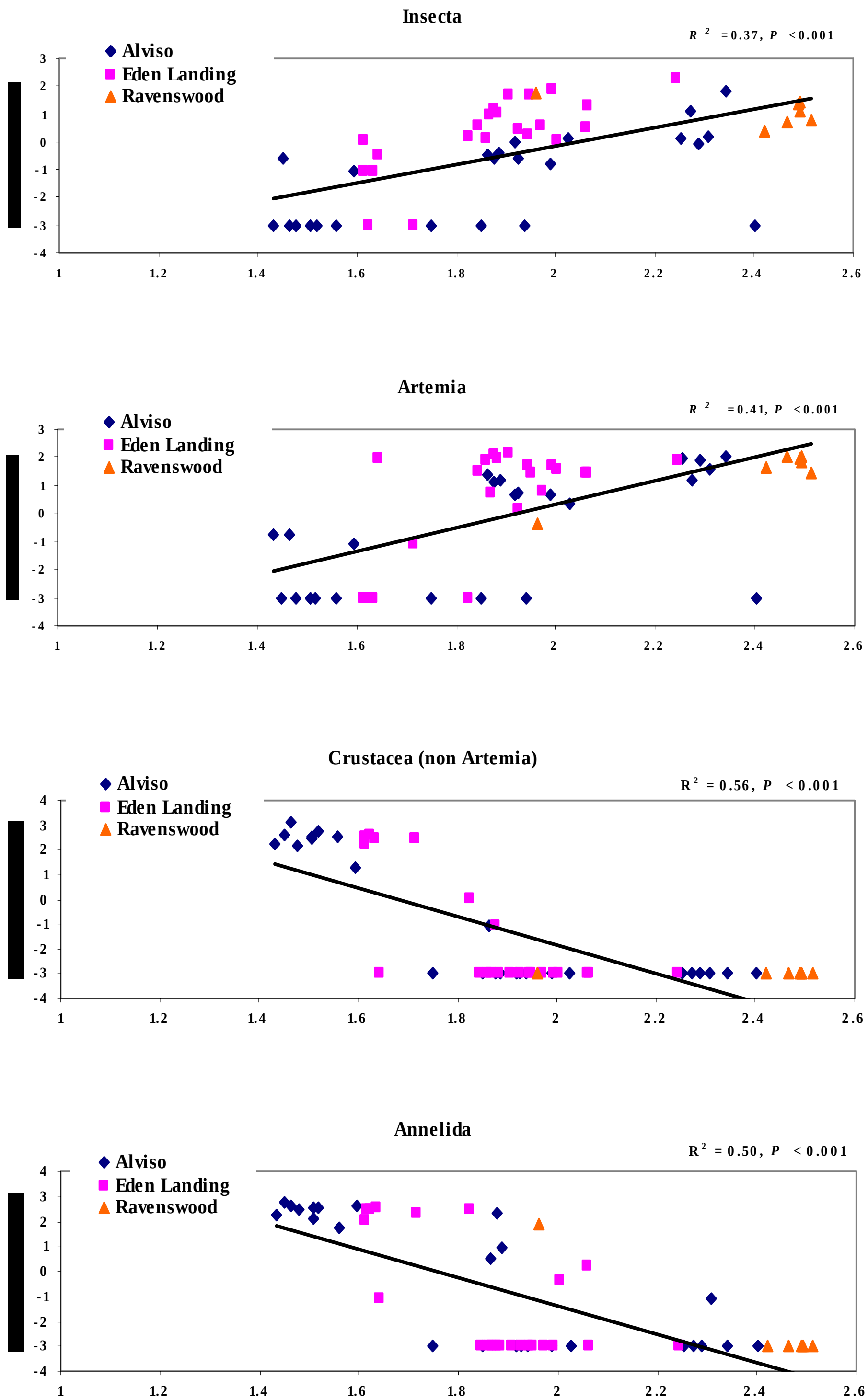


Figure 20. Relations between log transformed estimates of invertebrate abundance and salinity sampled at south bay salt ponds. R^2 and P values refer to regression based on all values, pond complexes illustrated for graphical purposes, San Francisco Bay, CA.

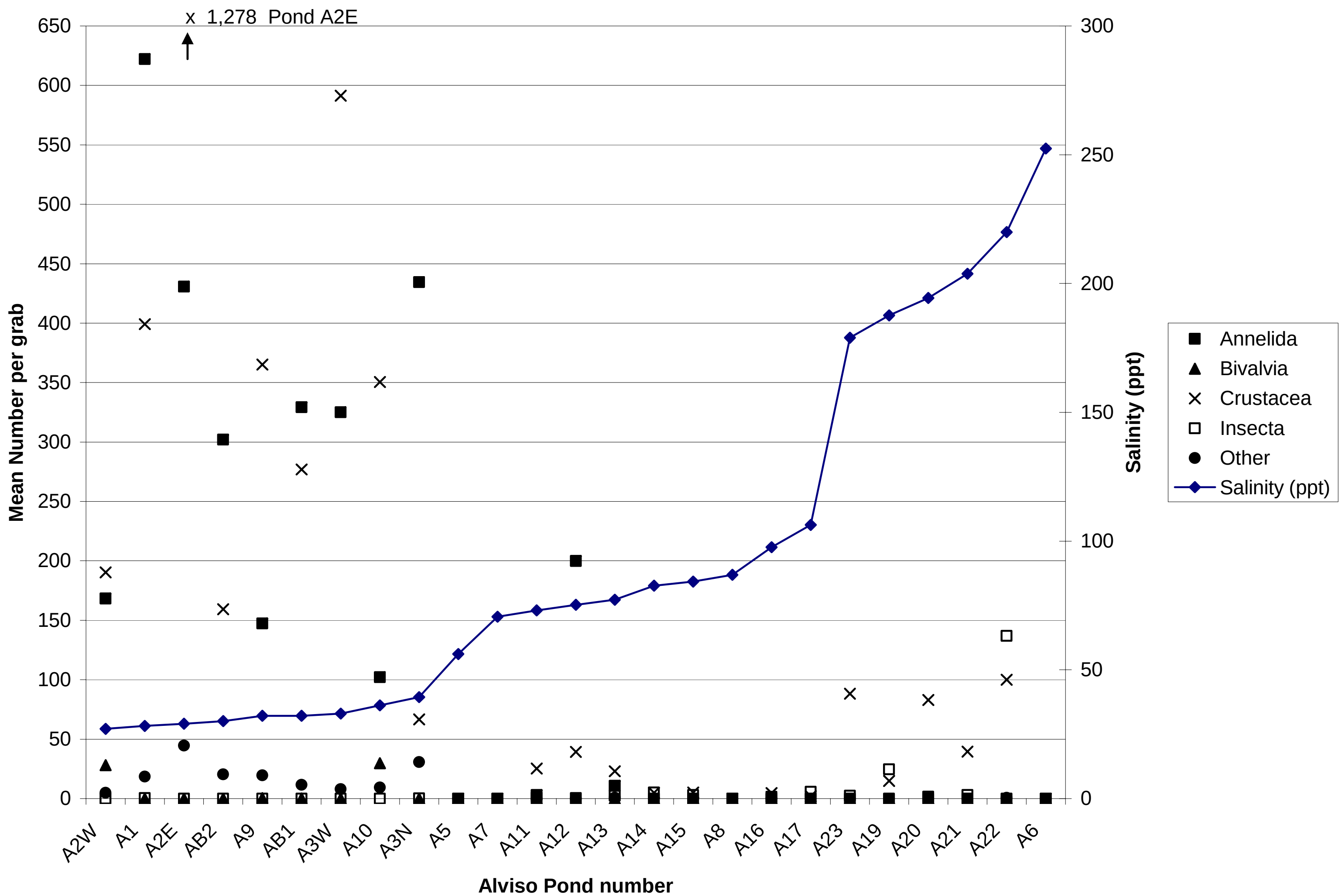


Figure 21. Mean number of invertebrates per benthic sample at each Alviso salt pond and salinity, San Francisco Bay, CA.

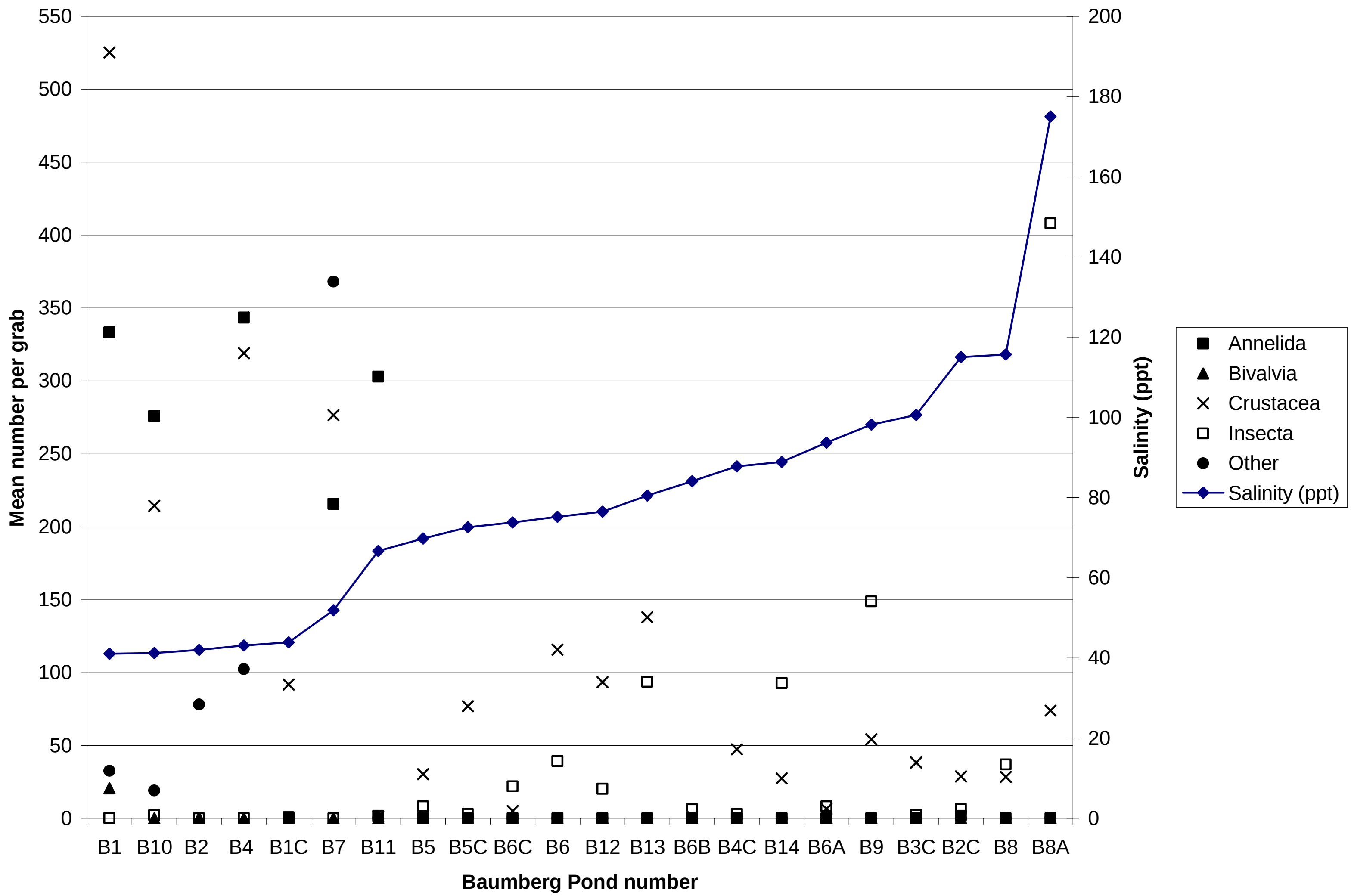


Figure 22. Mean number of invertebrates per benthic sample at each Eden Landing salt pond and salinity, San Francisco Bay, CA.

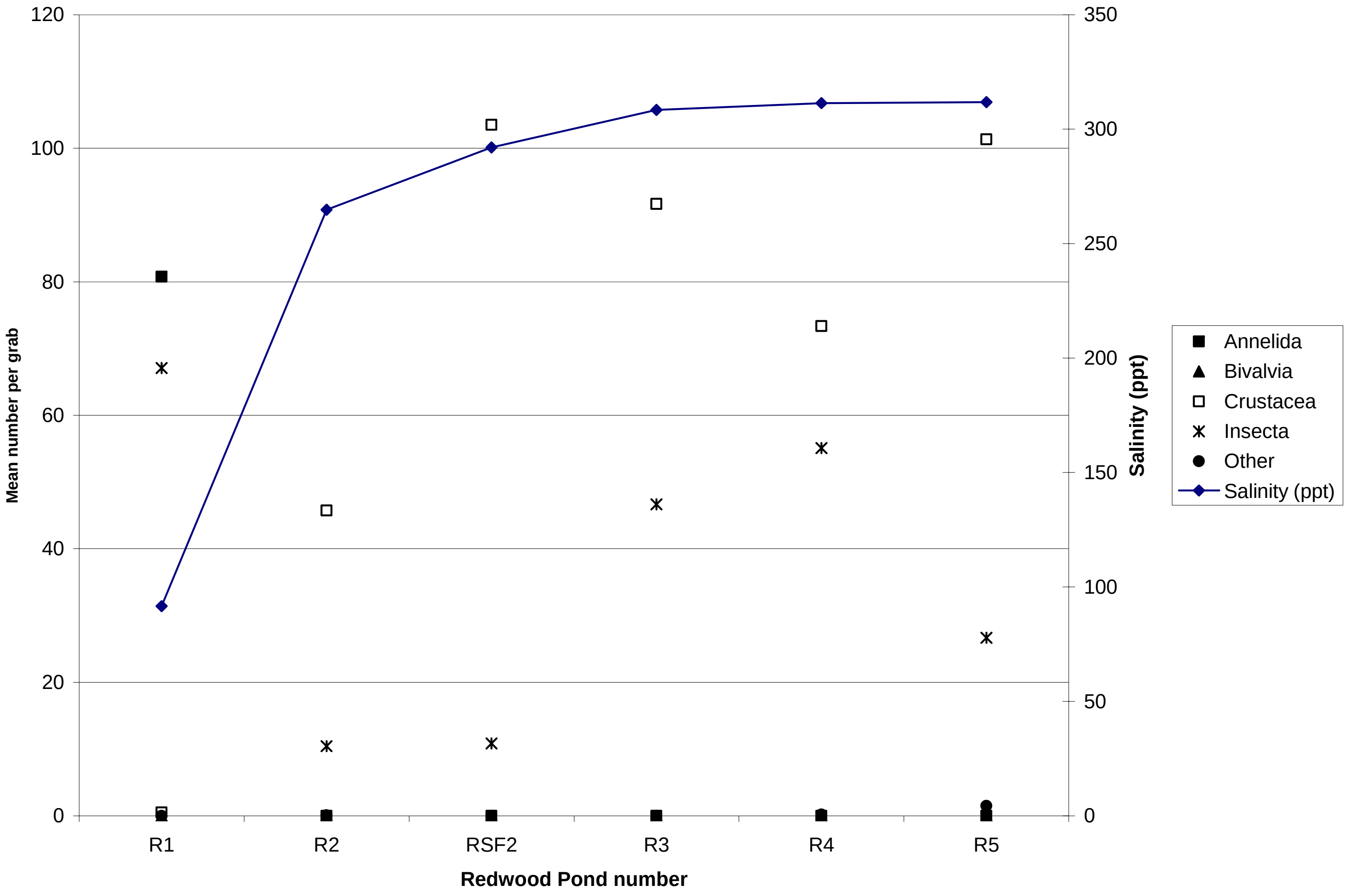


Figure 23. Mean number of invertebrates per benthic sample at each Ravenswood salt pond and salinity, San Francisco Bay, CA.

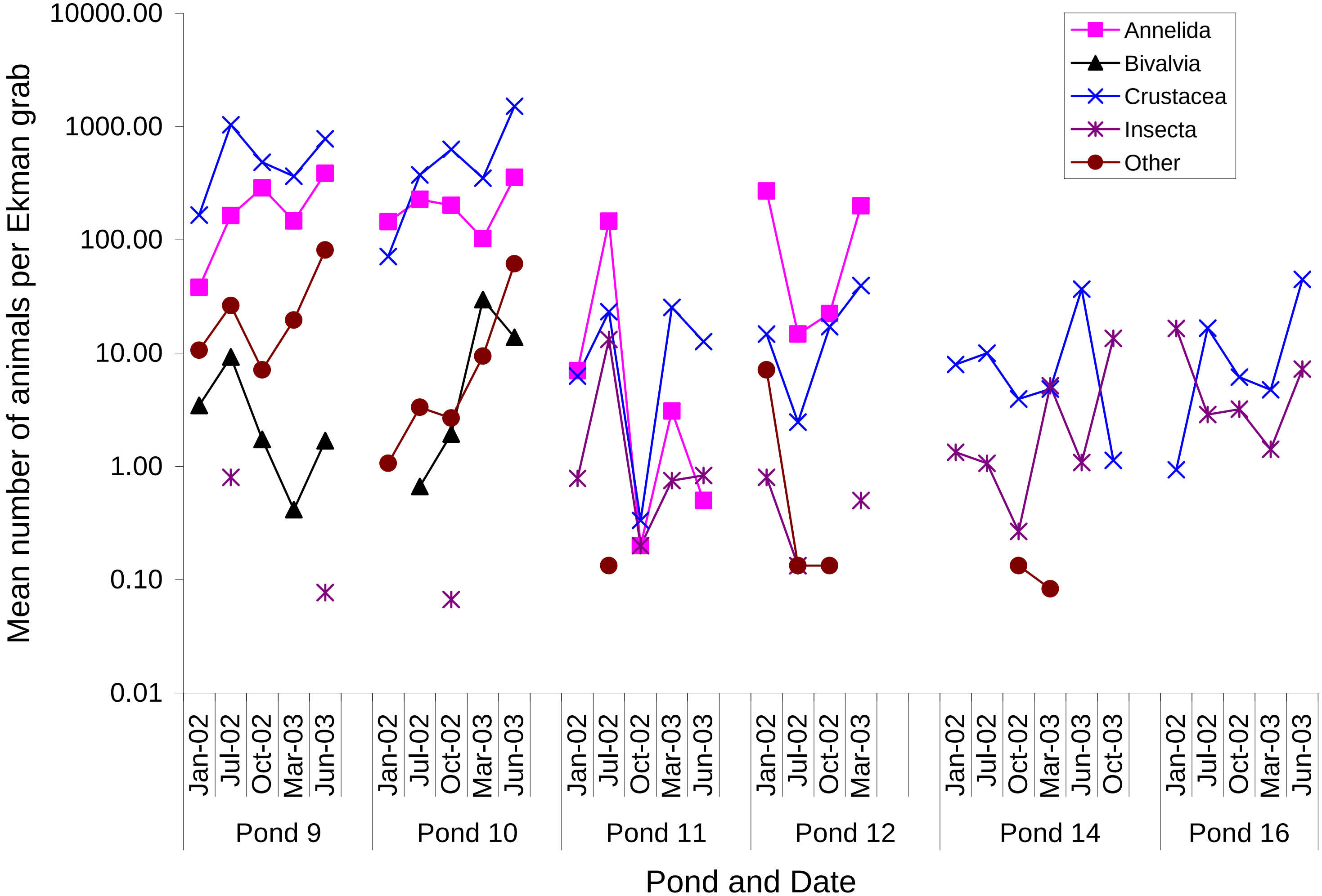


Figure 24. Data from an ongoing seasonal USGS Place-based study of 6 Alviso ponds initiated in 2002, average number of invertebrates per benthic grab each season, San Francisco Bay, CA.

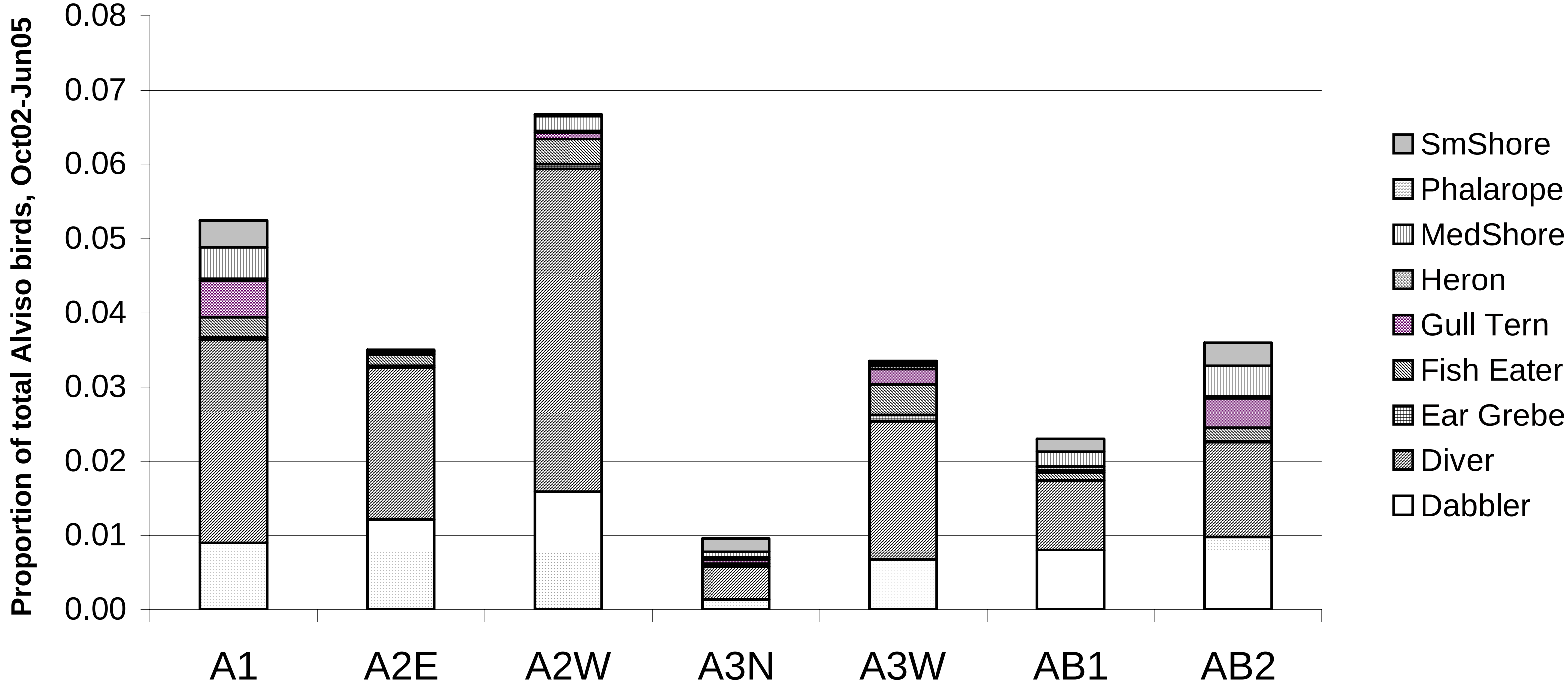


Figure 25. Proportion of total Alviso bird counts (October 2002-June 2005) per pond for each foraging guild, Alviso salt ponds A1, A2W, A2E, A3N, A3W, AB1, and AB2, San Francisco Bay, CA.

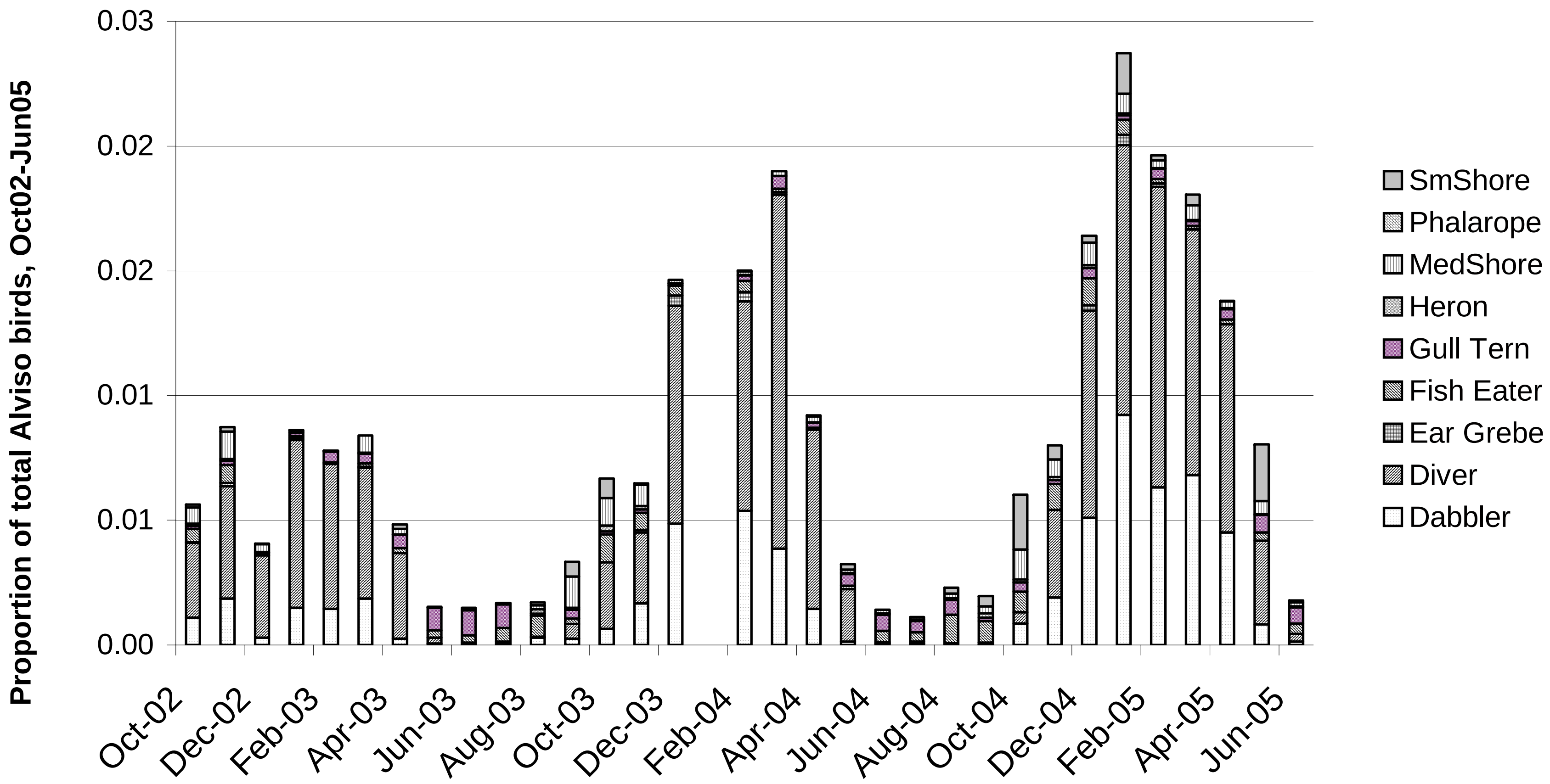


Figure 26. Proportion of total Alviso bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Alviso salt ponds A1, A2W, A2E, A3W, A3N, AB1, and AB2, San Francisco Bay, CA.

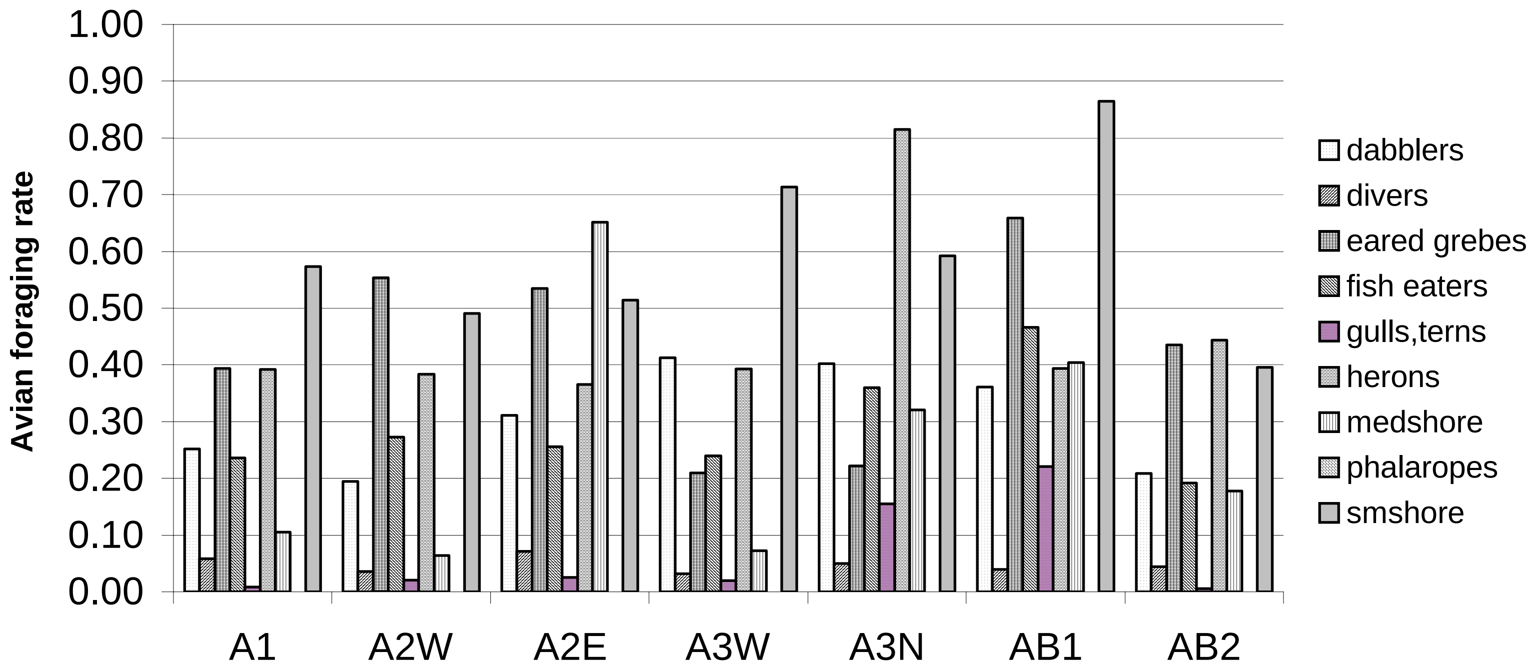


Figure 27. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Alviso salt ponds A1, A2W, A2E, A3W, A3N, AB1, and AB2, San Francisco Bay, CA.

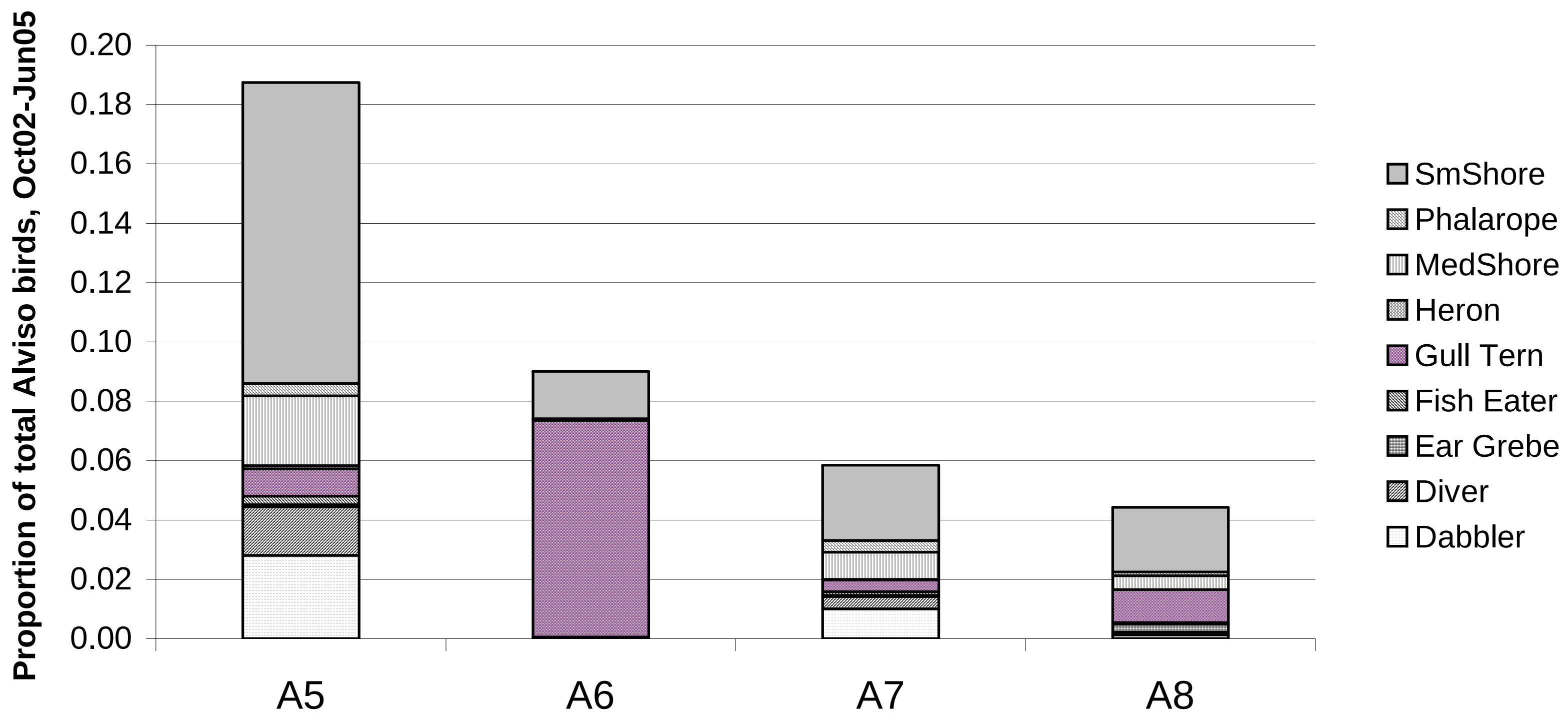


Figure 28. Proportion of total Alviso bird counts (October 2002-June 2005) per pond for each foraging guild, Alviso salt ponds A5-A8, San Francisco Bay, CA.

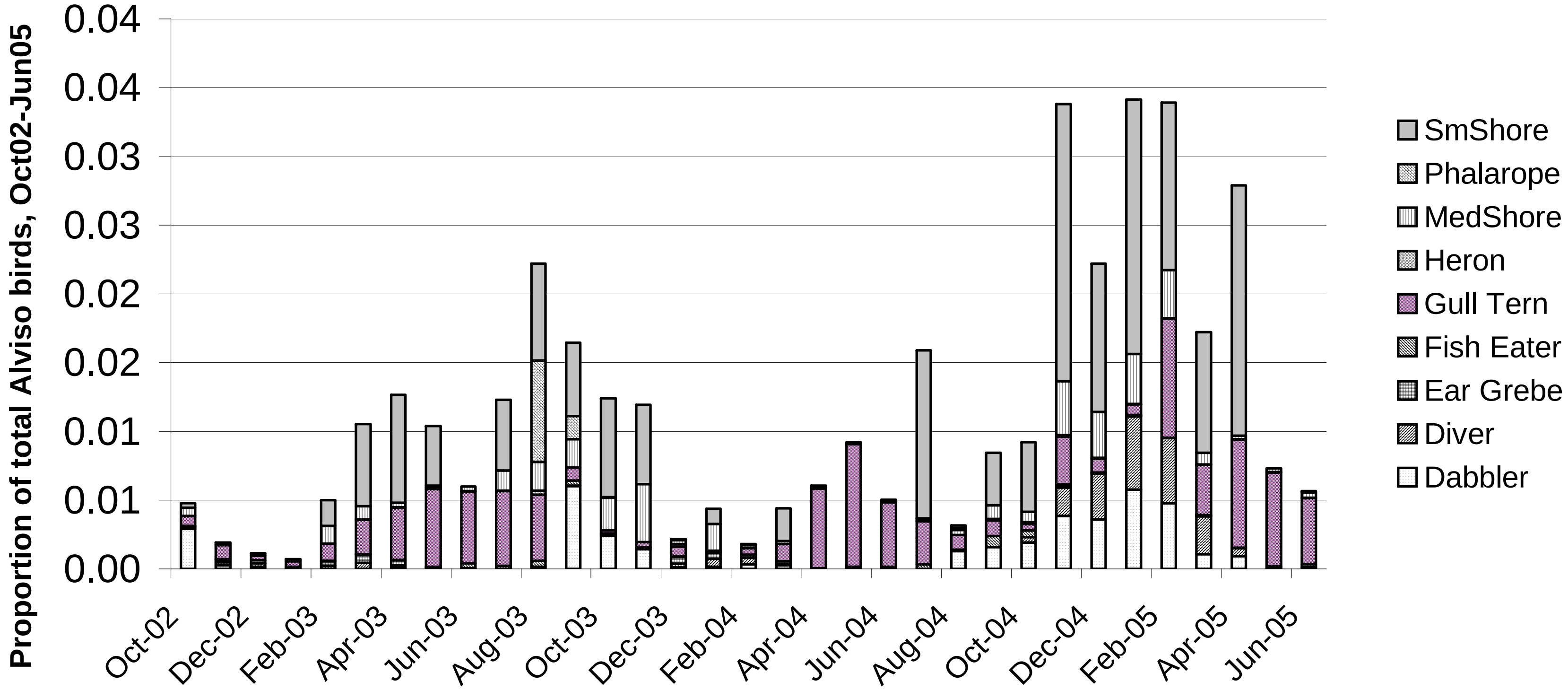


Figure 29. Proportion of total Alviso bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Alviso salt ponds A5, A6, A7, and A8, San Francisco Bay, CA.

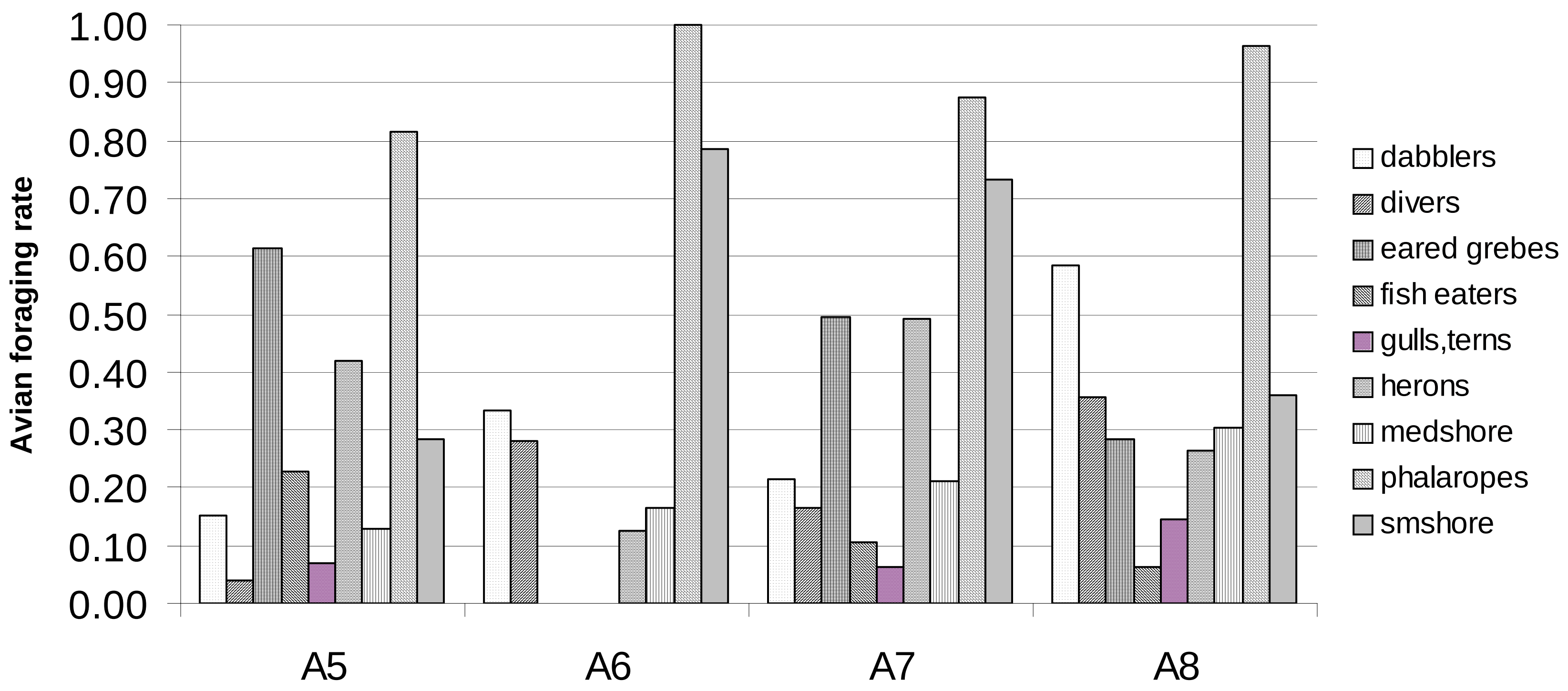


Figure 30. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Alviso salt ponds A5, A6, A7, and A8, San Francisco Bay, CA.

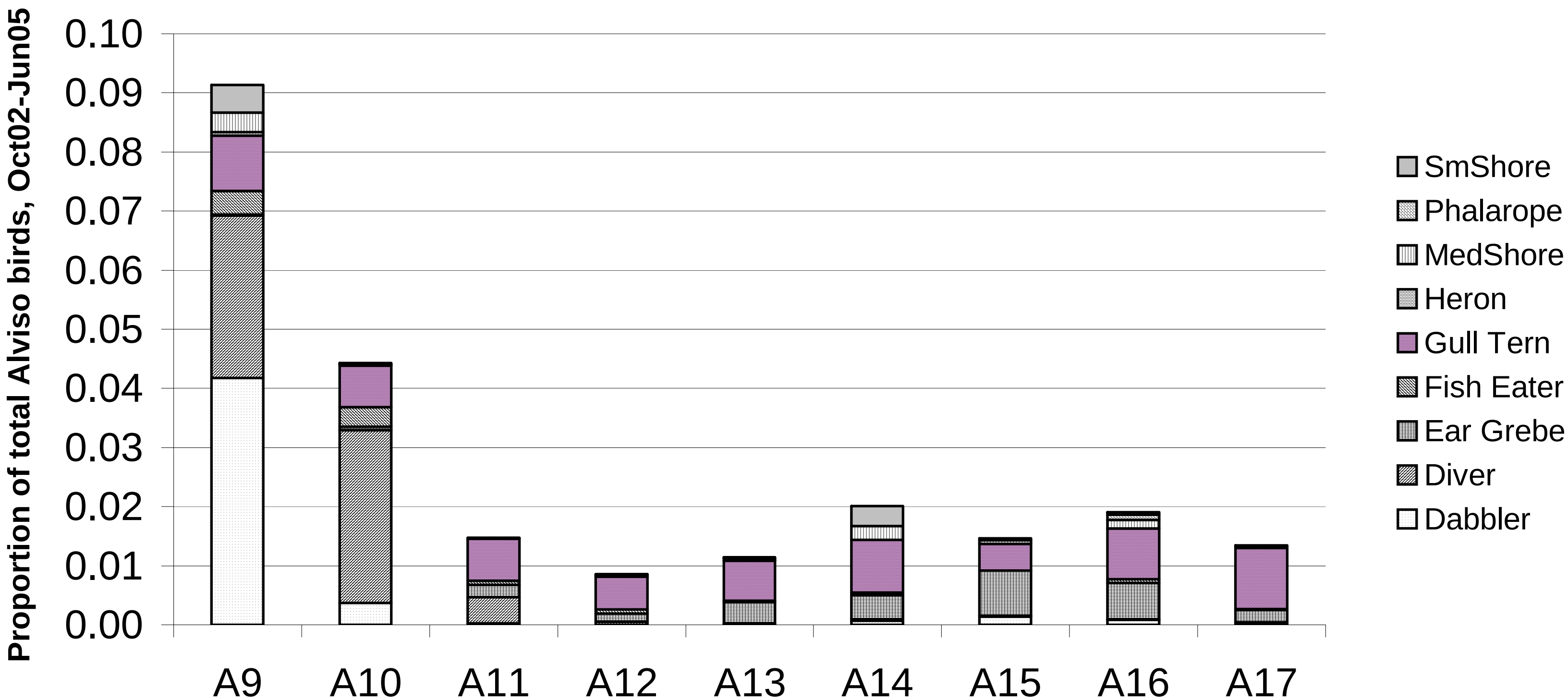


Figure 31. Proportion of total Alviso bird counts (October 2002-June 2005) per pond for each foraging guild, Alviso salt ponds A9-A17, San Francisco Bay, CA.

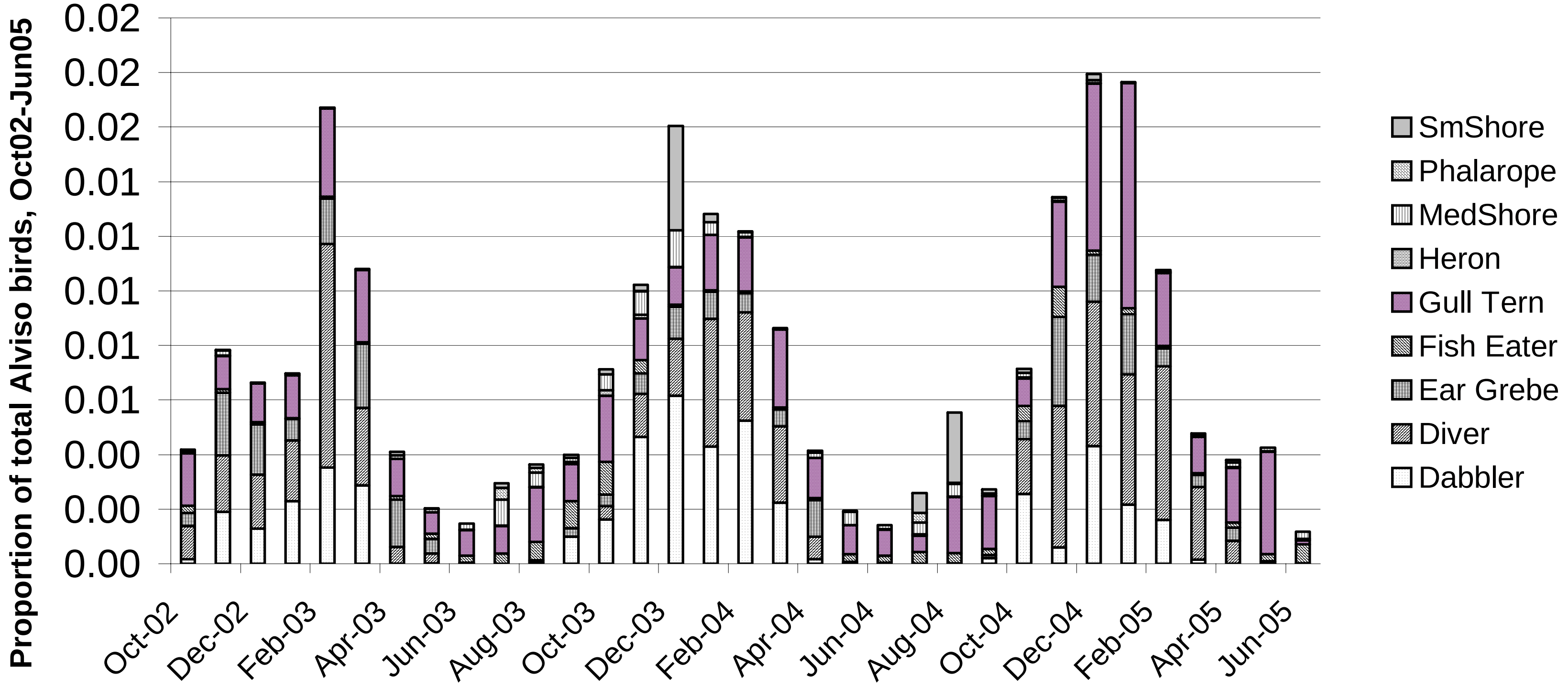


Figure 32. Proportion of total Alviso bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Alviso salt ponds A9-A17, San Francisco Bay, CA.

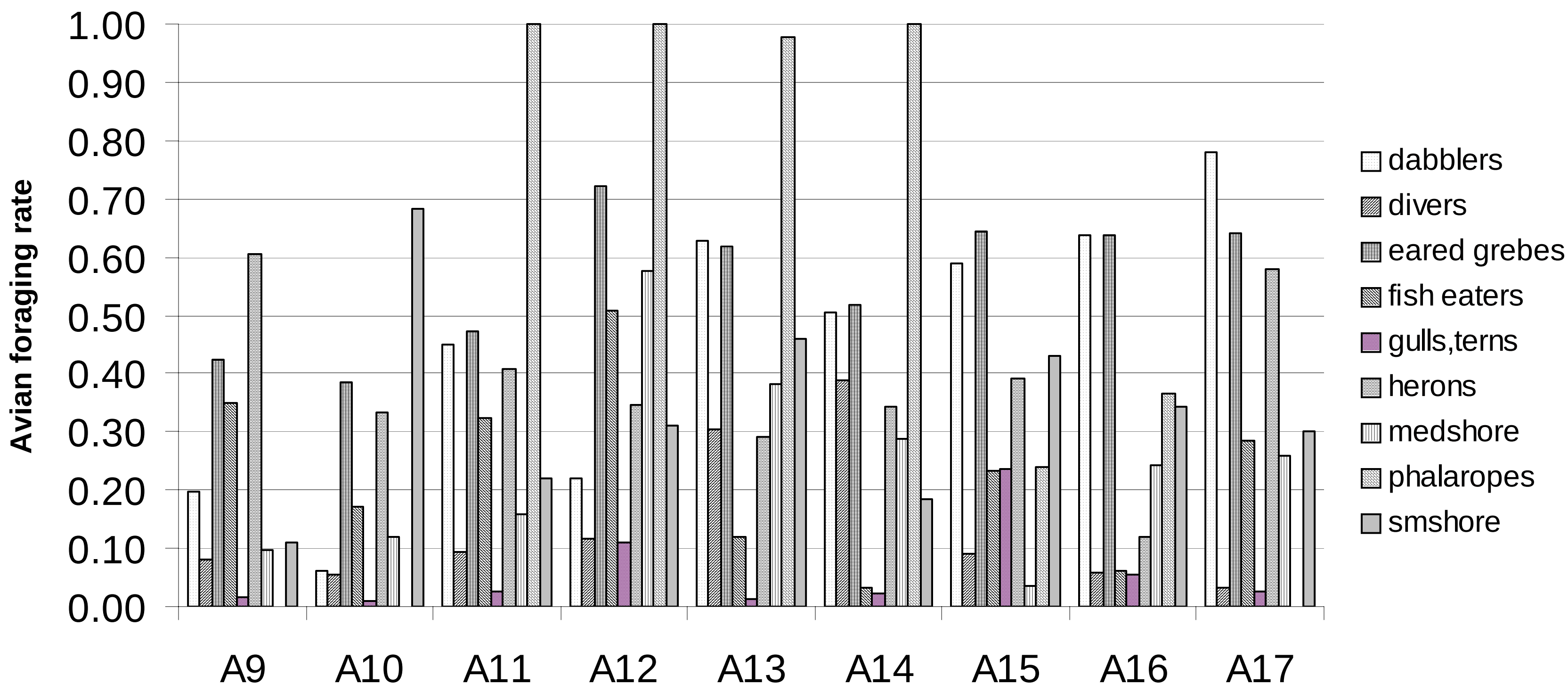


Figure 33. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Alviso salt ponds A9-A17, San Francisco Bay, CA.

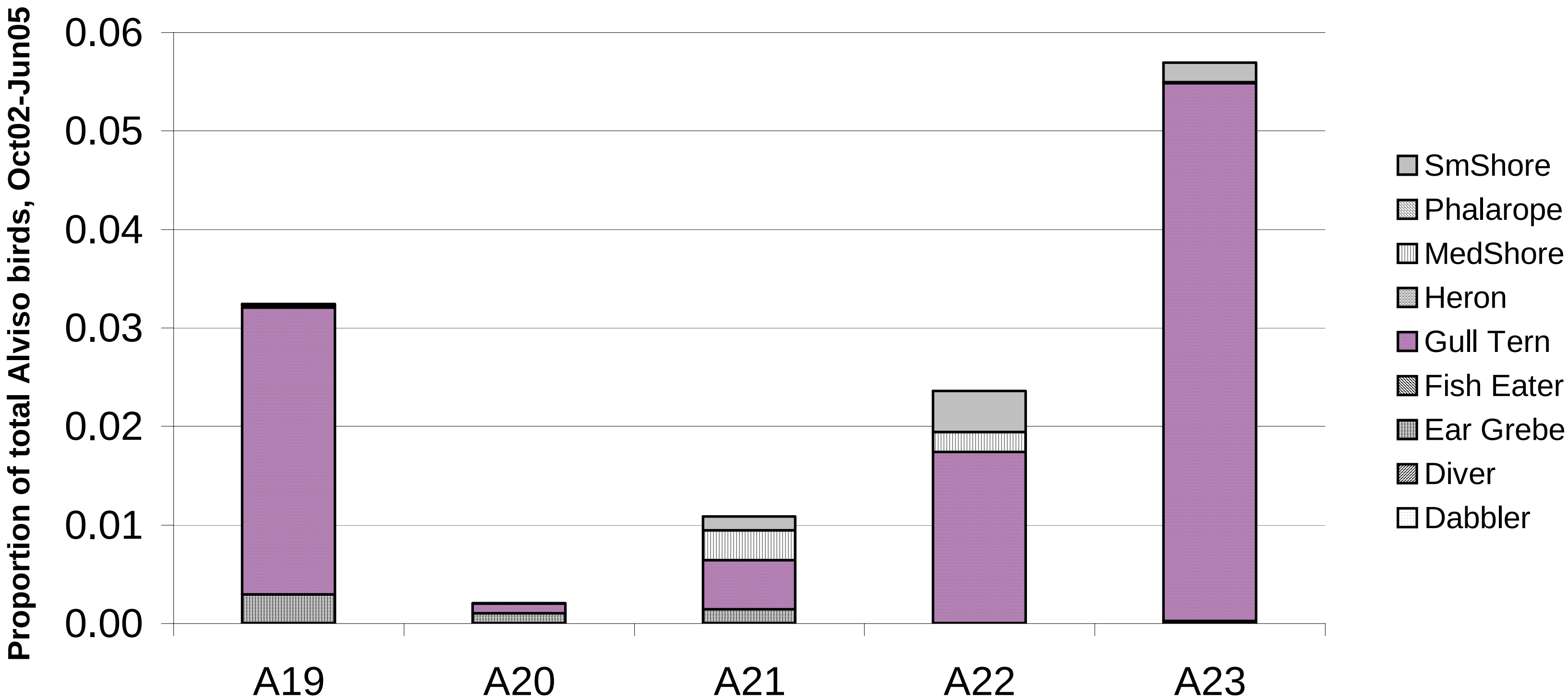


Figure 34. Proportion of total Alviso bird counts (October 2002-June 2005) per pond for each foraging guild, Alviso salt ponds A19-A23, San Francisco Bay, CA.

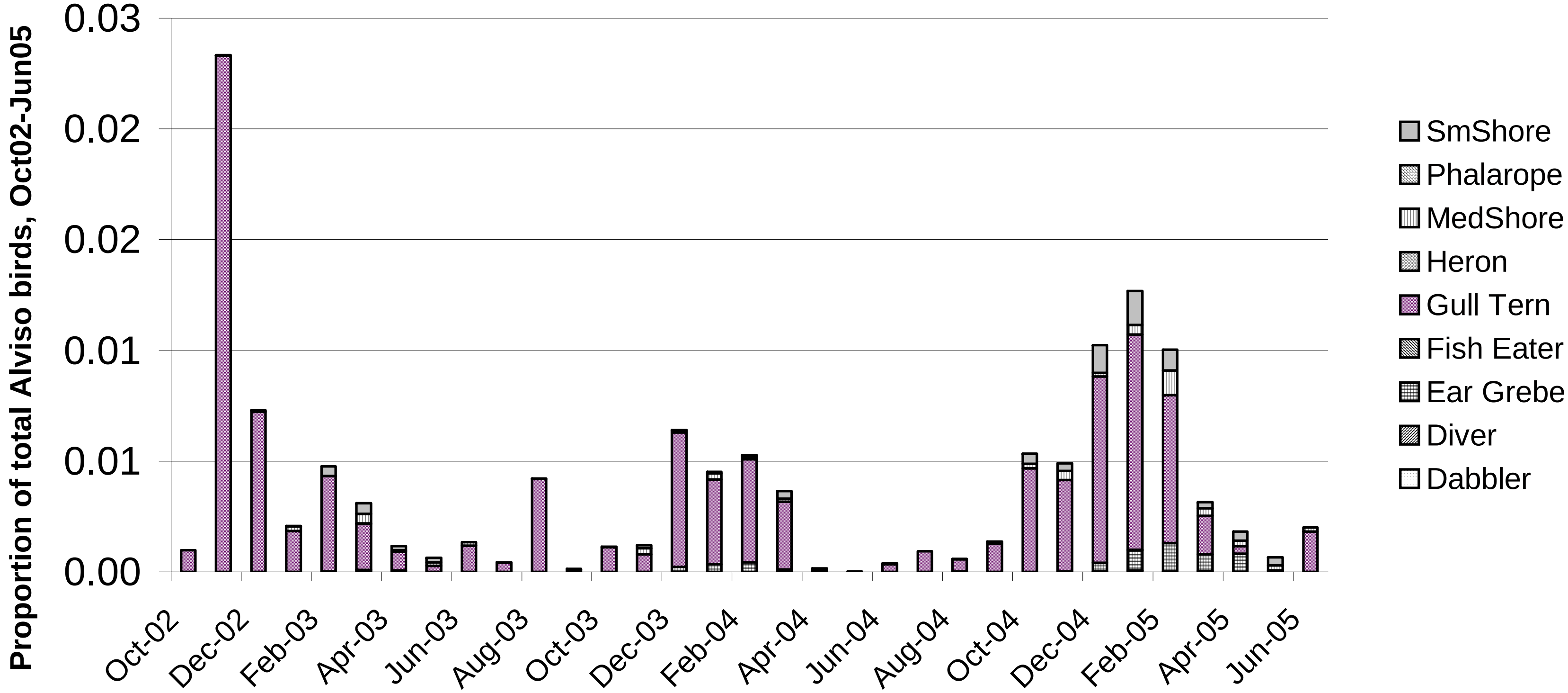


Figure 35. Proportion of total Alviso bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Alviso salt ponds A19-A23, San Francisco Bay, CA.

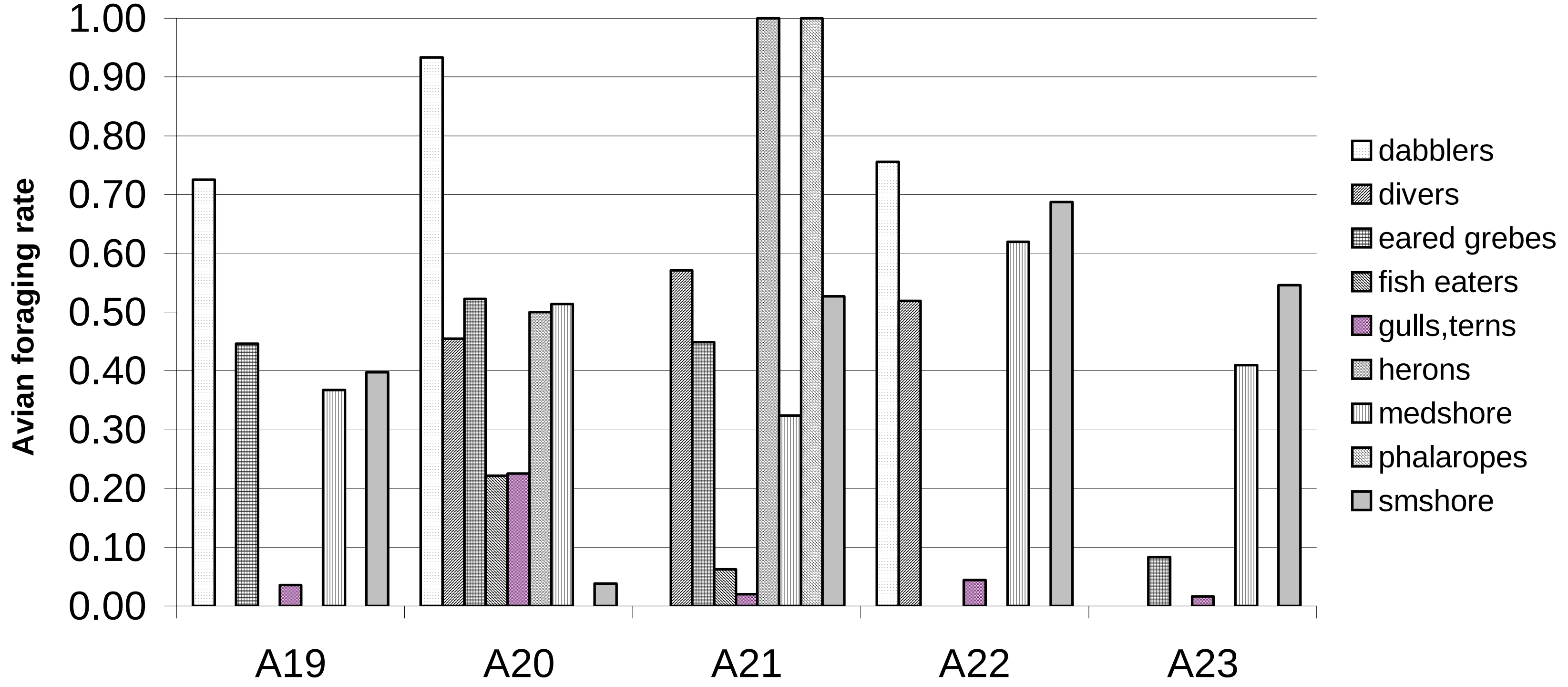


Figure 36. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Alviso salt ponds A19-A23, San Francisco Bay, CA.

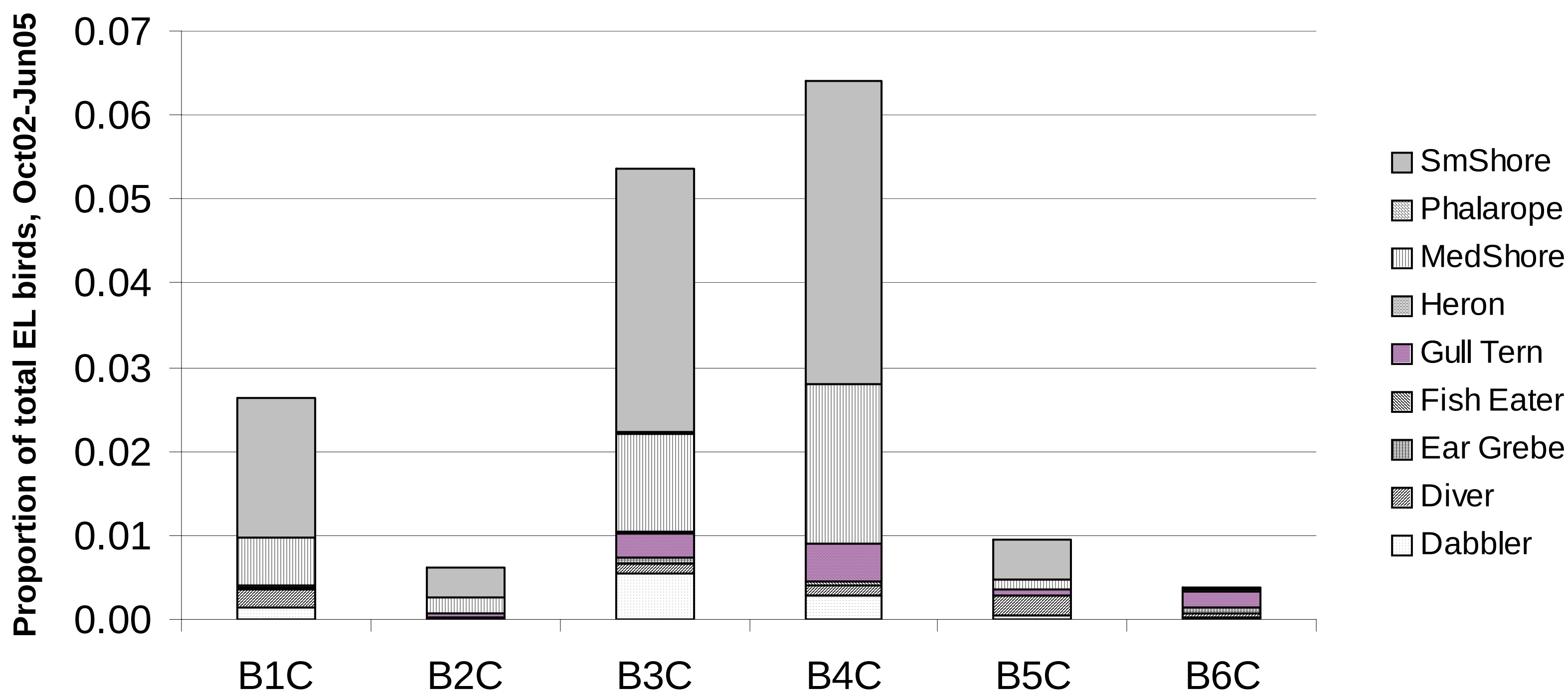


Figure 37. Proportion of total Eden Landing bird counts (October 2002-June 2005) per pond for each foraging guild, Eden Landing salt ponds B1C-B6C, San Francisco Bay, CA.

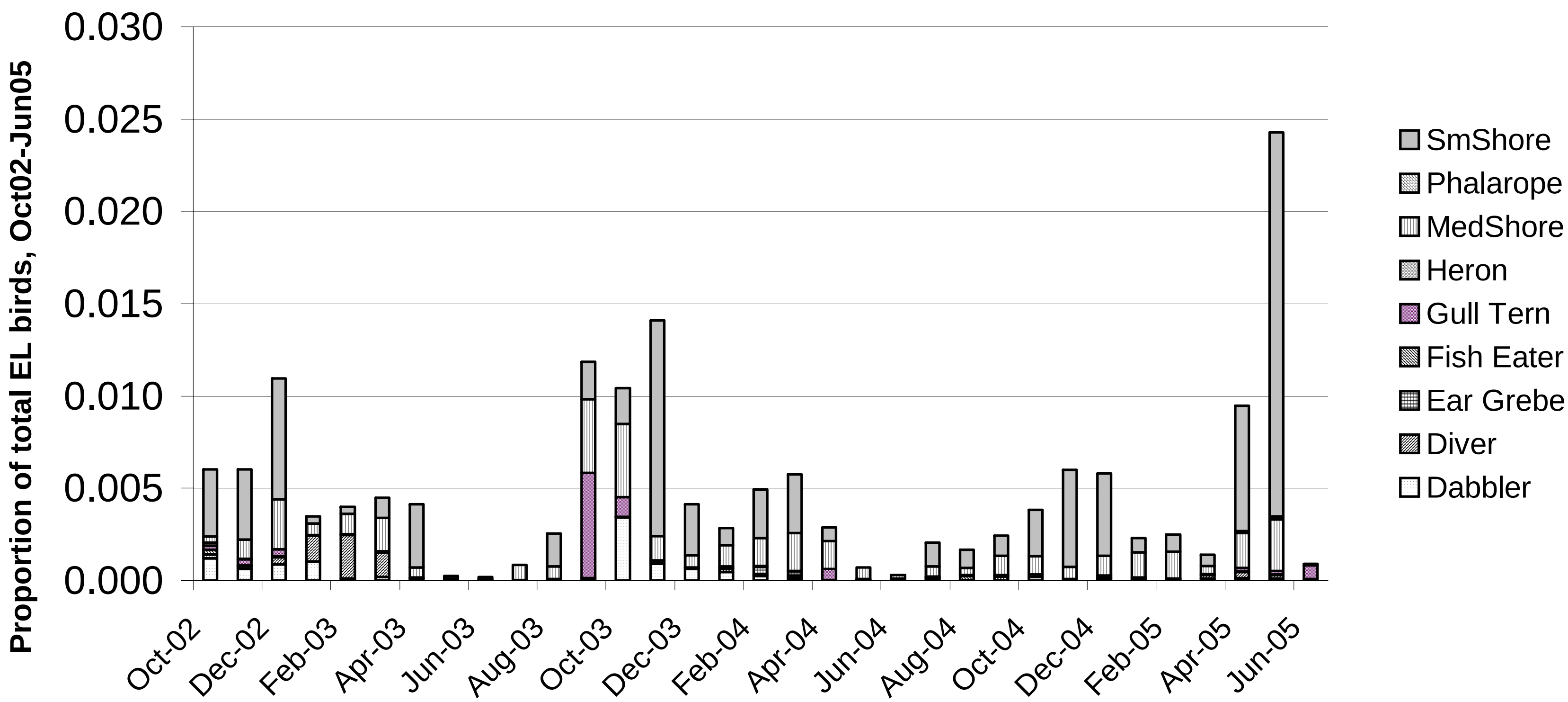


Figure 38. Proportion of total Eden Landing bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Eden Landing salt ponds B1C-B6C, San Francisco Bay, CA.

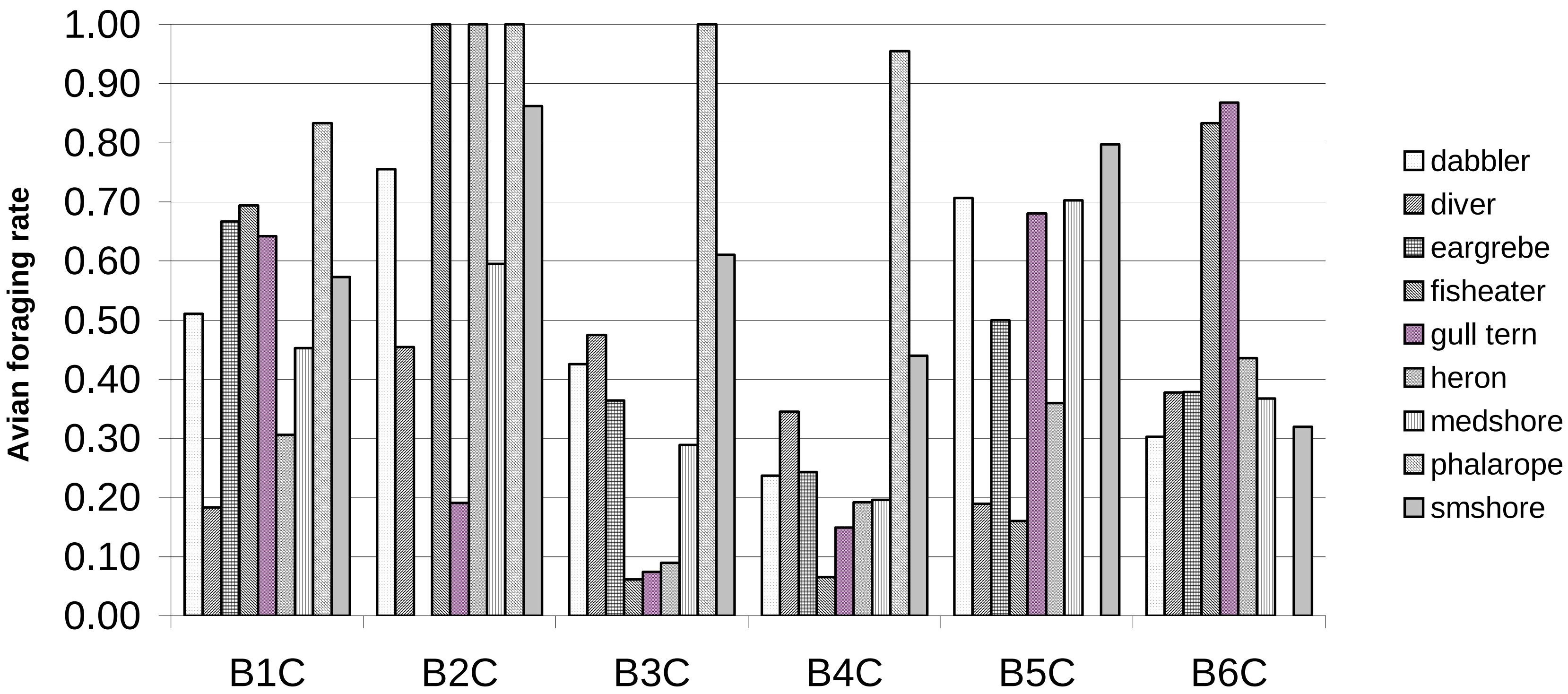


Figure 39. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Eden Landing salt ponds B1C-B6C, San Francisco Bay, CA.

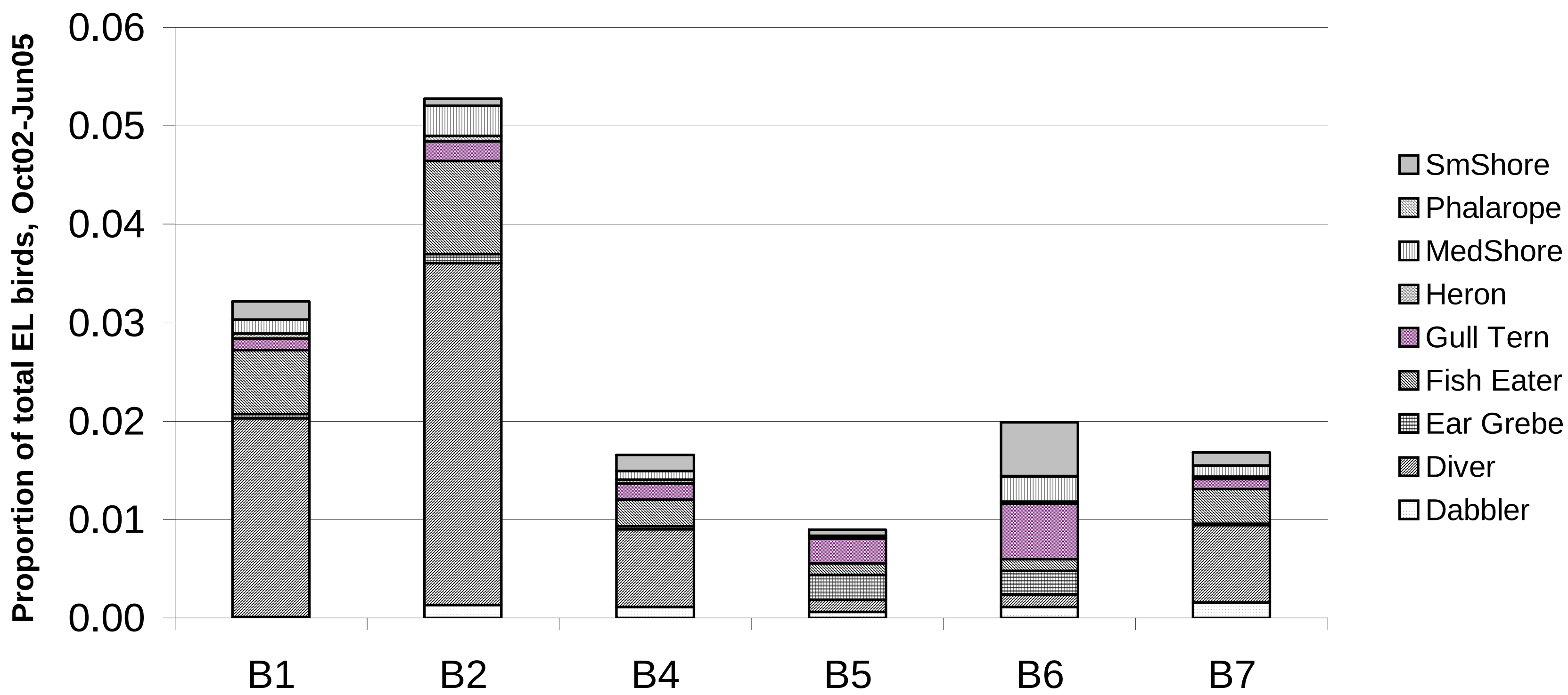


Figure 40. Proportion of total Eden Landing bird counts (October 2002-June 2005) per pond for each foraging guild, Eden Landing salt ponds B1-B7, San Francisco Bay, CA.

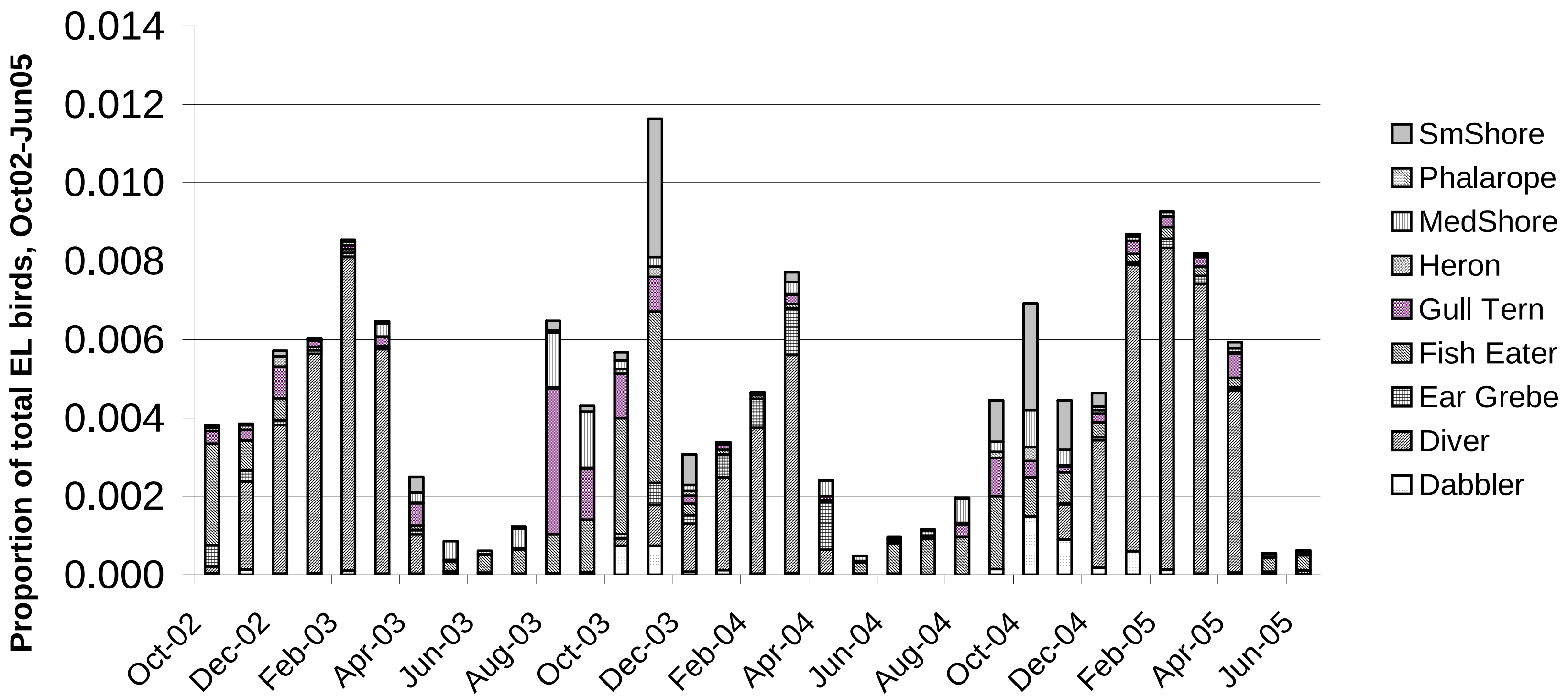


Figure 41. Proportion of total Eden Landing bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Eden Landing salt ponds B1-B7, San Francisco Bay, CA.

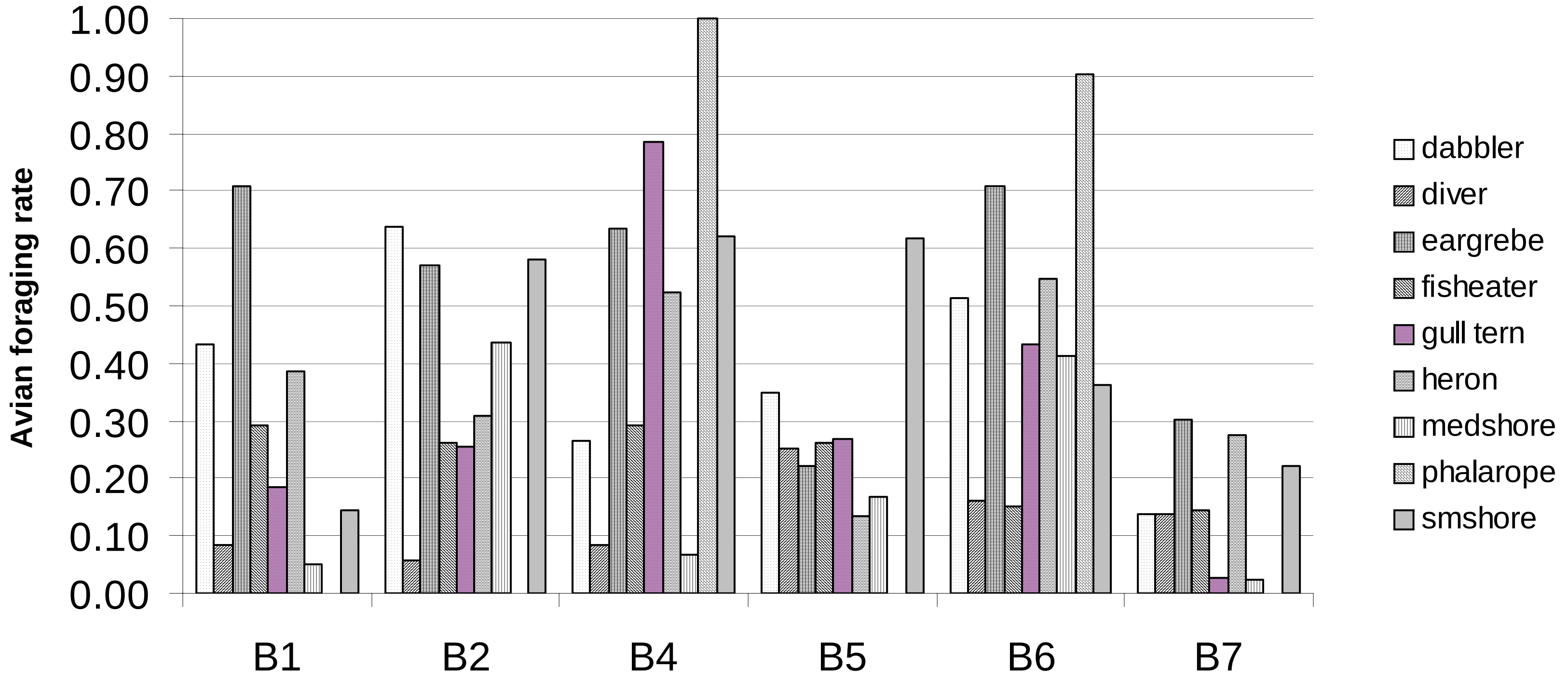


Figure 42. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Eden Landing salt ponds B1-B7, San Francisco Bay, CA.

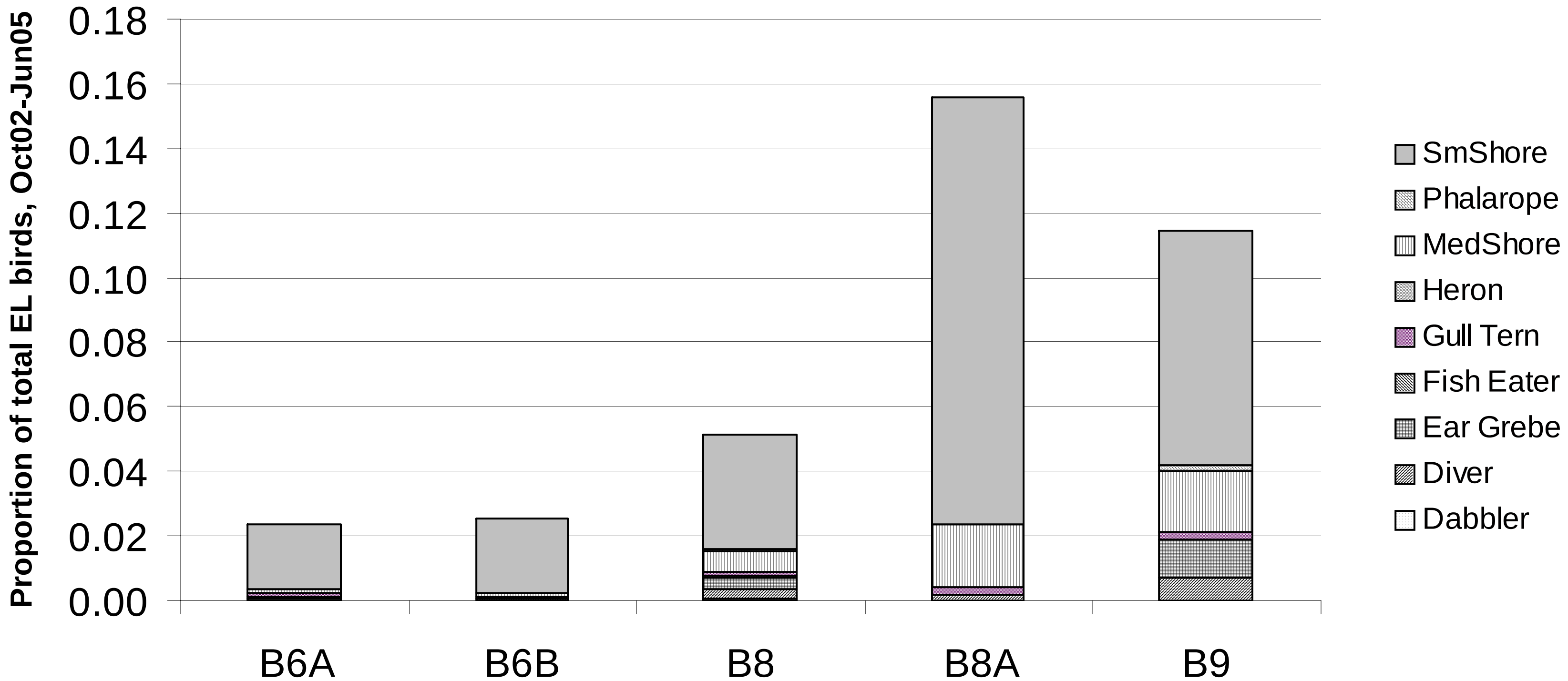


Figure 43. Proportion of total Eden Landing bird counts (October 2002-June 2005) per pond for each foraging guild, Eden Landing salt ponds B6A, B6B, B8, B8A, and B9, San Francisco Bay, CA.

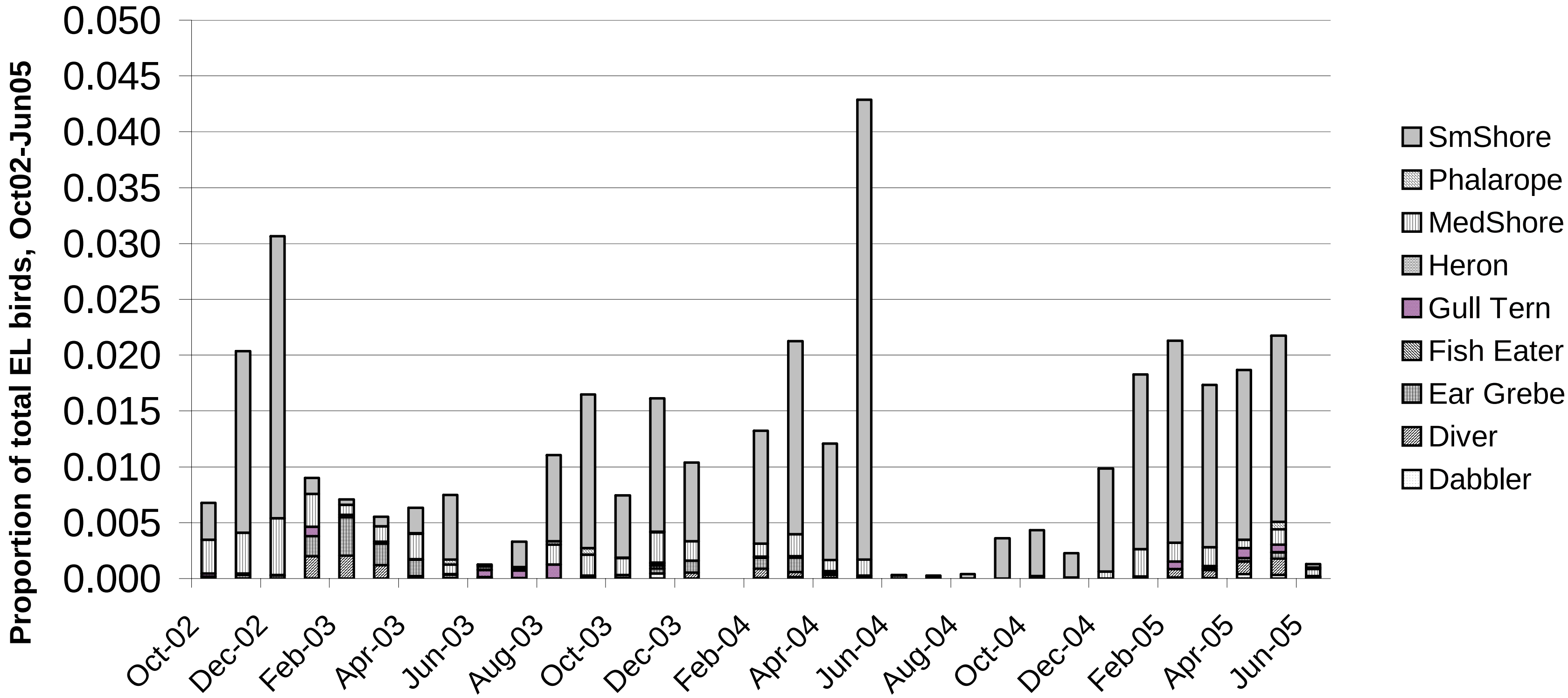


Figure 44. Proportion of total Eden Landing bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Eden Landing salt ponds B6A, B6B, B8, B8A, and B9, San Francisco Bay, CA.

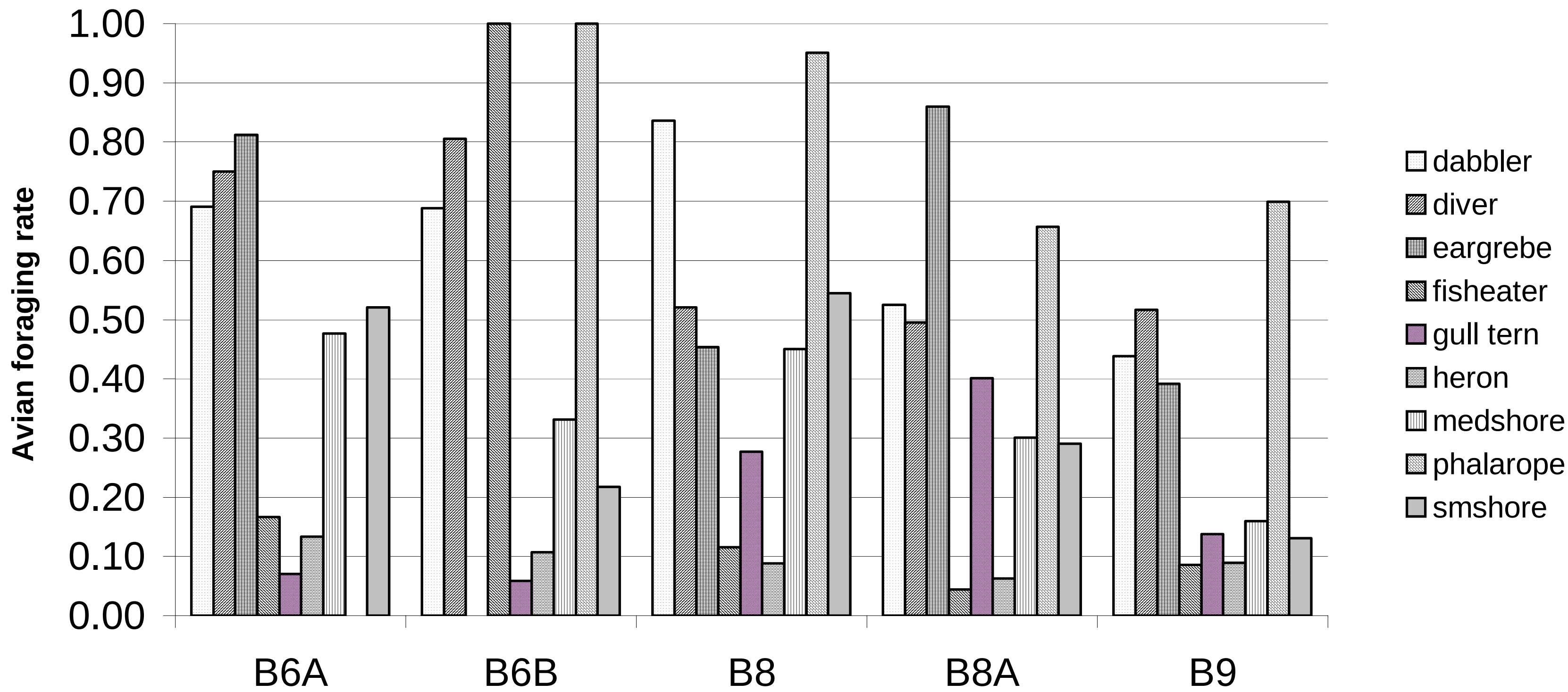


Figure 45. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Eden Landing salt ponds B6A, B6B, B8, B8A, and B9, San Francisco Bay, CA.

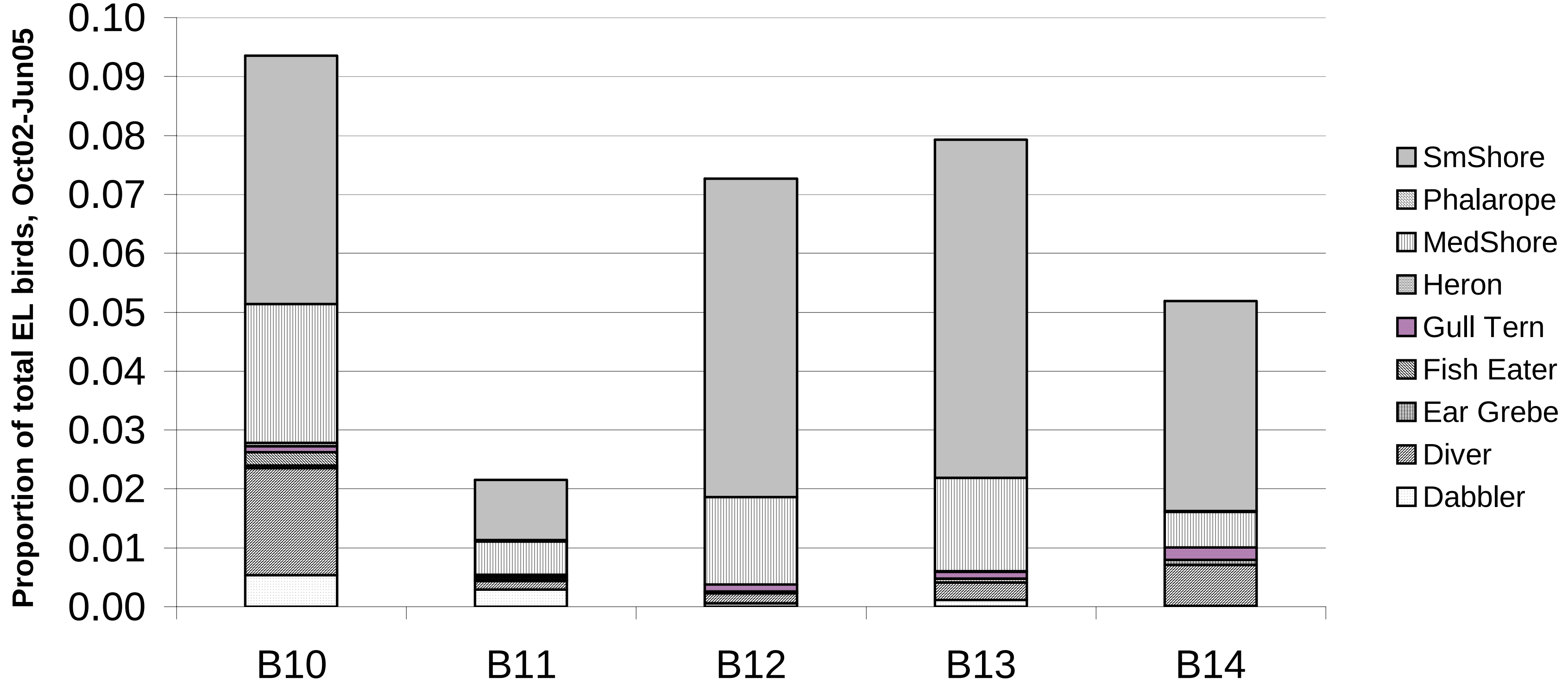


Figure 46. Proportion of total Eden Landing bird counts (October 2002-June 2005) per pond for each foraging guild, Eden Landing salt ponds B10-B14, San Francisco Bay, CA.

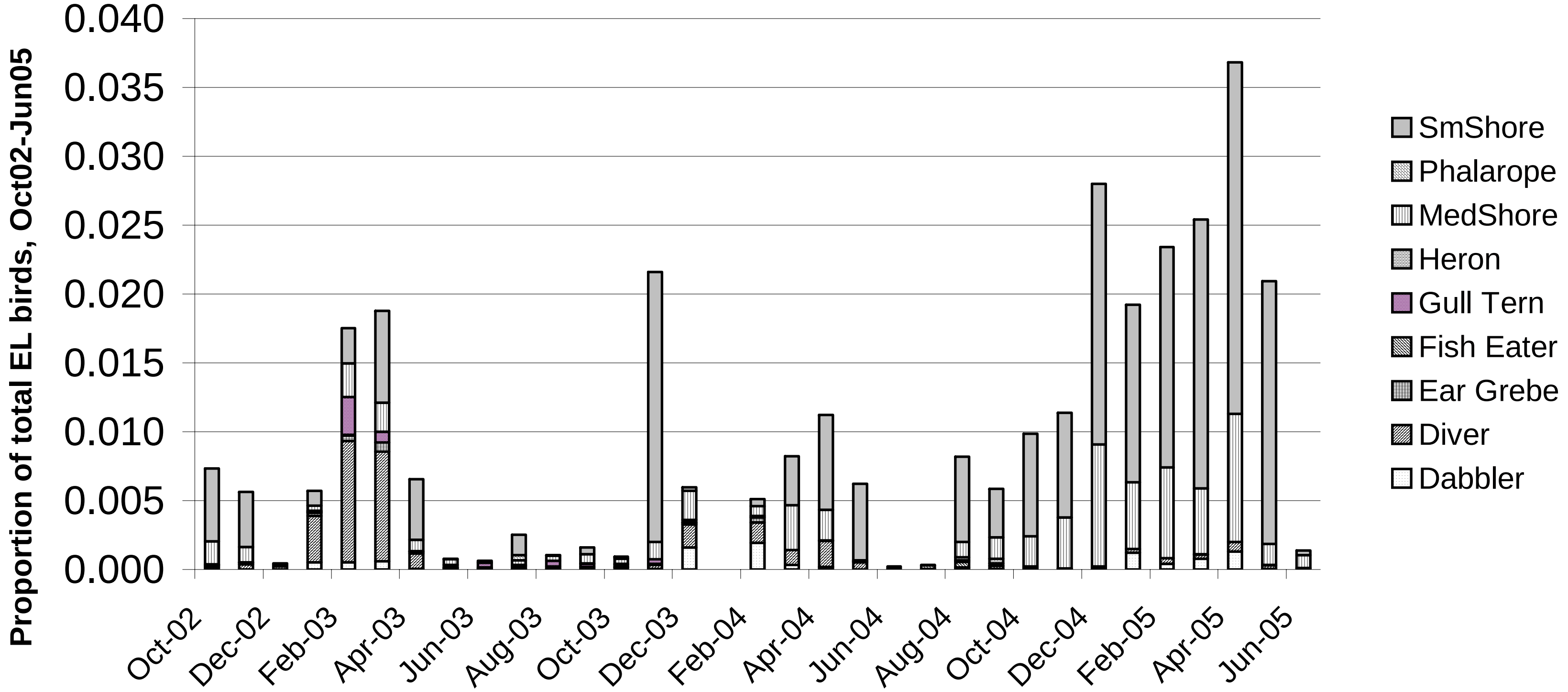


Figure 47. Proportion of total Eden Landing bird counts (October 2002-June2005) represented monthly by avian foraging guilds at Eden Landing salt ponds B10-B14, San Francisco Bay, CA.

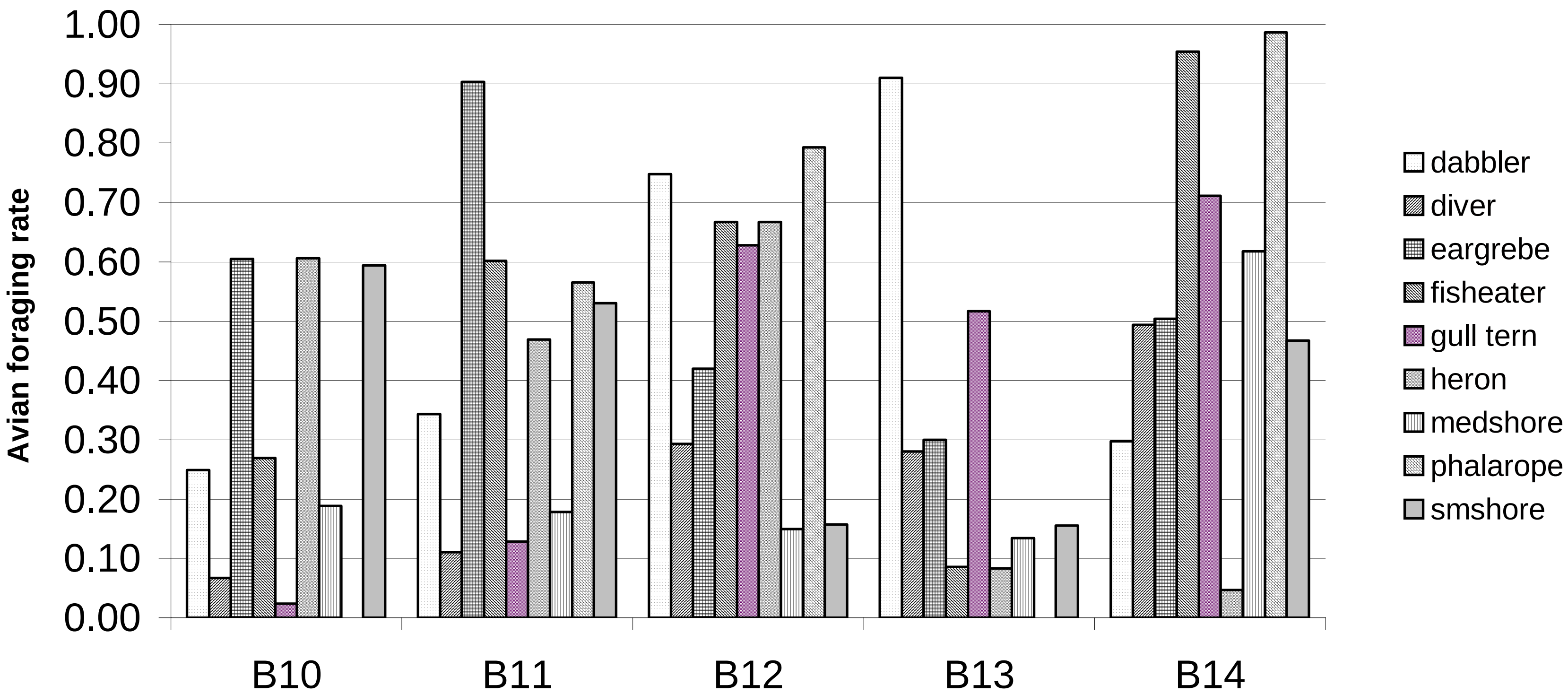


Figure 48. Proportion of birds recorded foraging at time of observation (October 2002-June2005) represented by avian foraging guilds at Eden Landing salt ponds B10-B14, San Francisco Bay, CA.

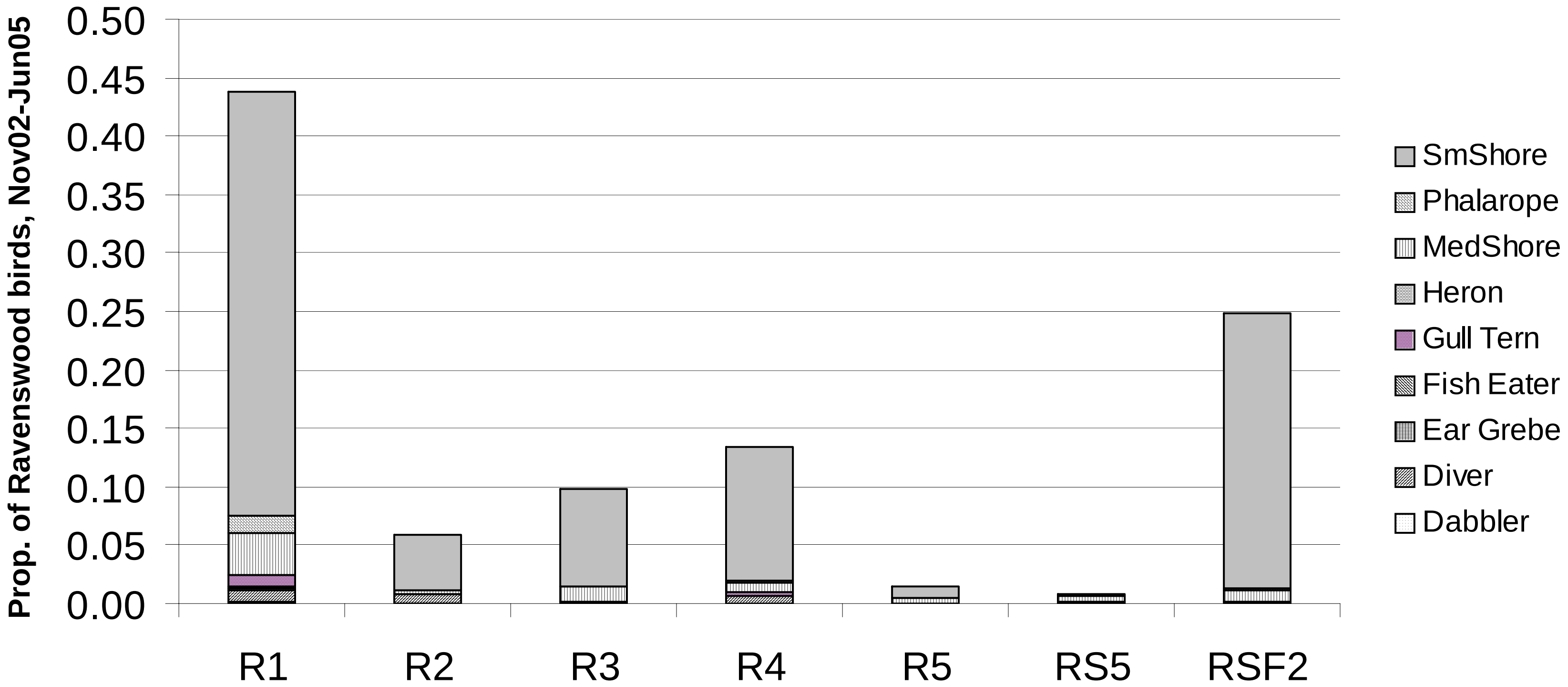


Figure 49. Proportion of total Ravenswood bird counts (November 2002-June 2005) per pond for each foraging guild, Ravenswood salt ponds, San Francisco Bay, CA.

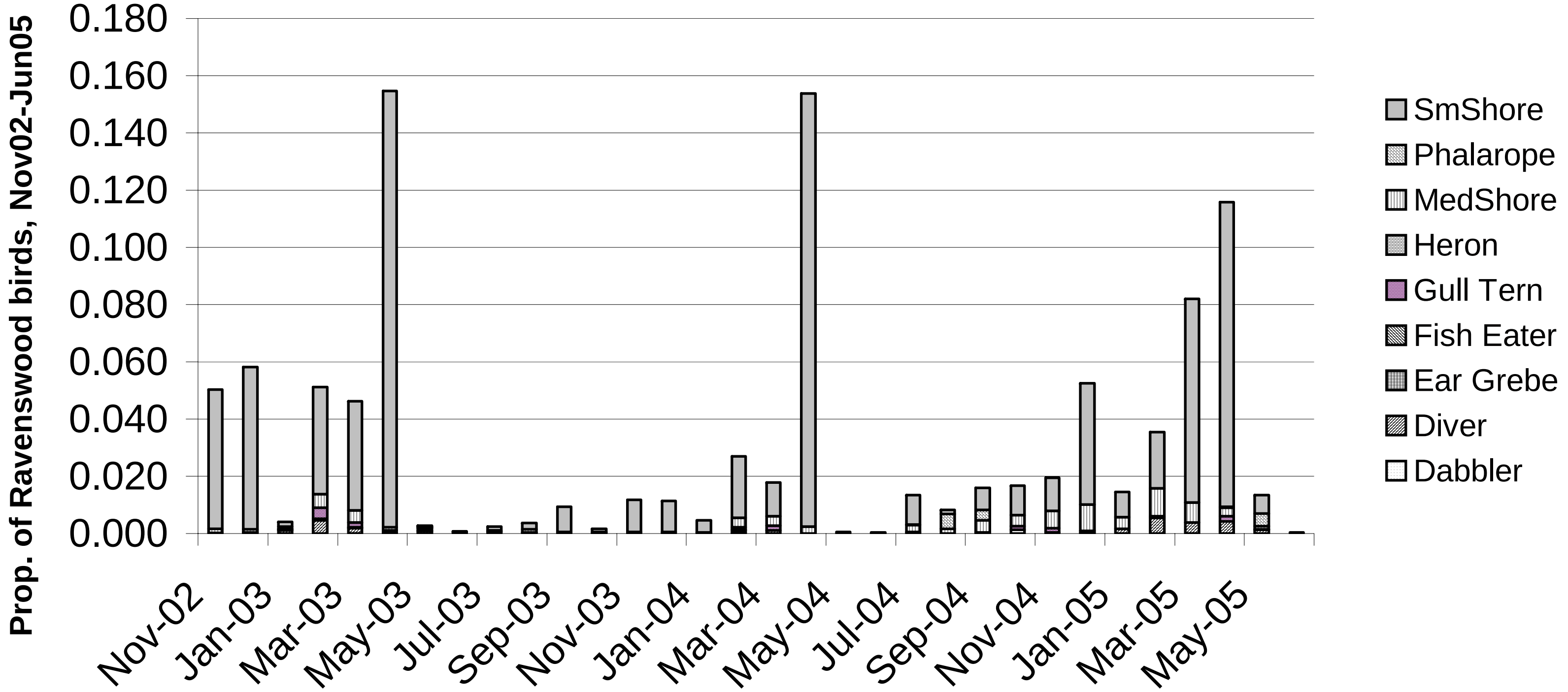


Figure 50. Proportion of total Ravenswood bird counts (November 2002-June2005) represented monthly by avian foraging guilds at Ravenswood salt ponds, San Francisco Bay, CA.

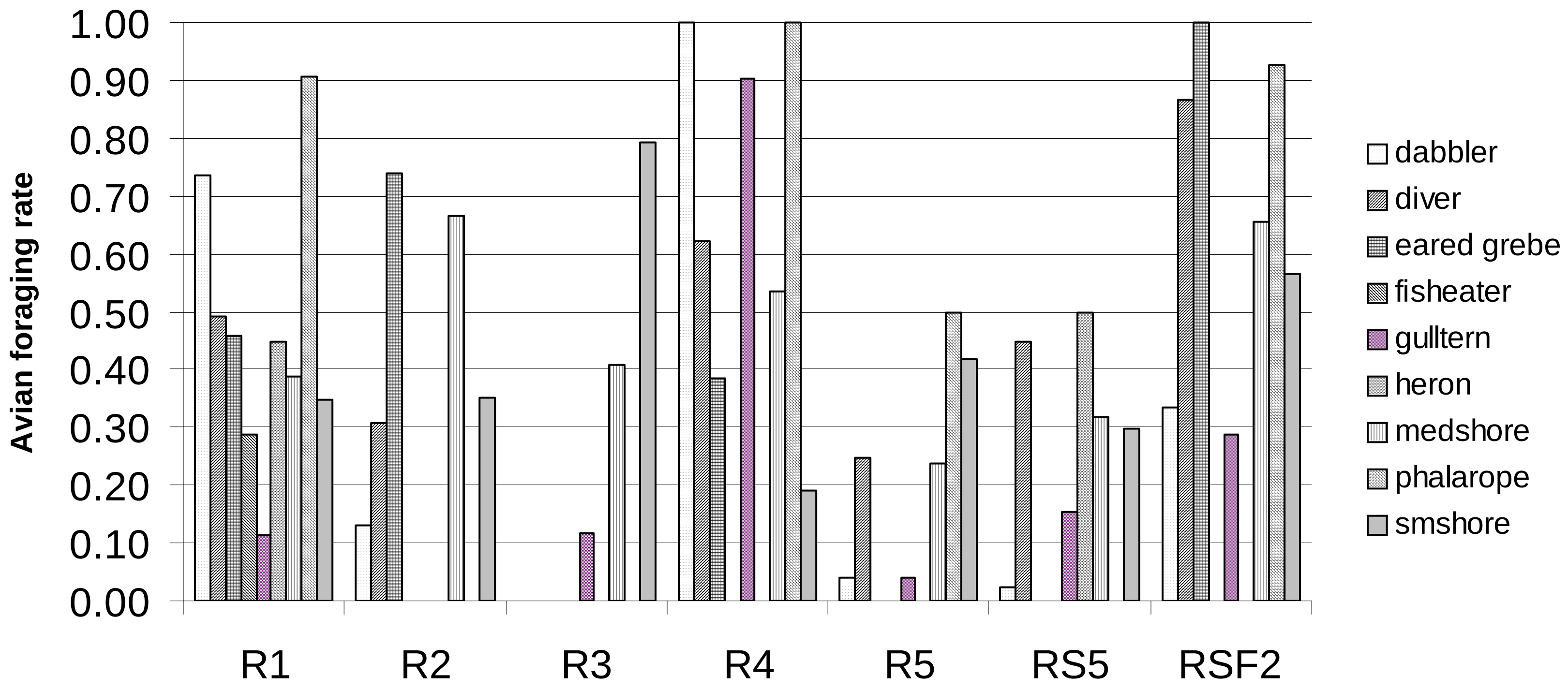


Figure 51. Proportion of birds recorded foraging at time of observation (November 2002-June2005) represented by avian foraging guilds at Ravenswood salt ponds, San Francisco Bay, CA.

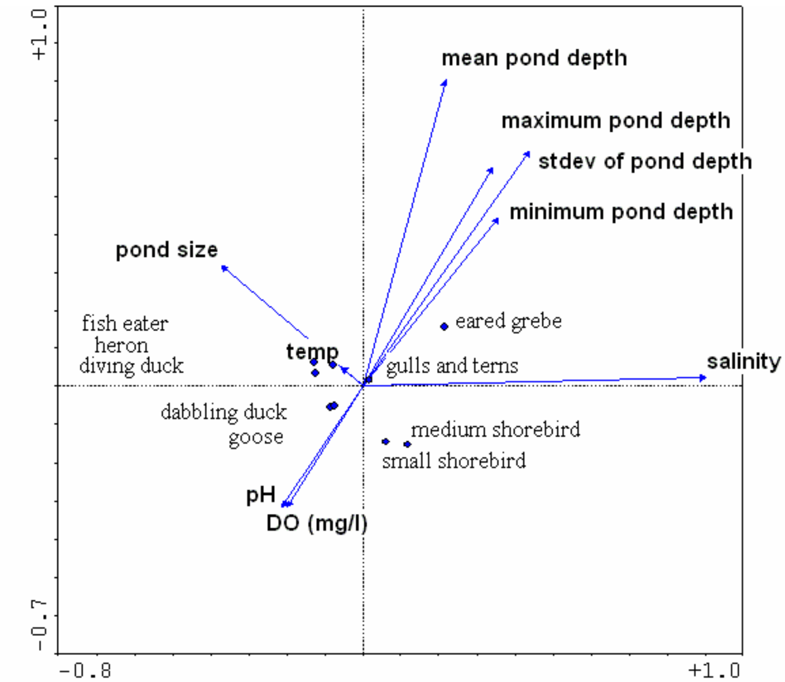


Figure 52. Foraging guild – environmental variable biplot resulting from canonical correspondence analysis of avian foraging guilds during the month of April, 2002-2005, with salt pond characteristics, San Francisco Bay, CA.

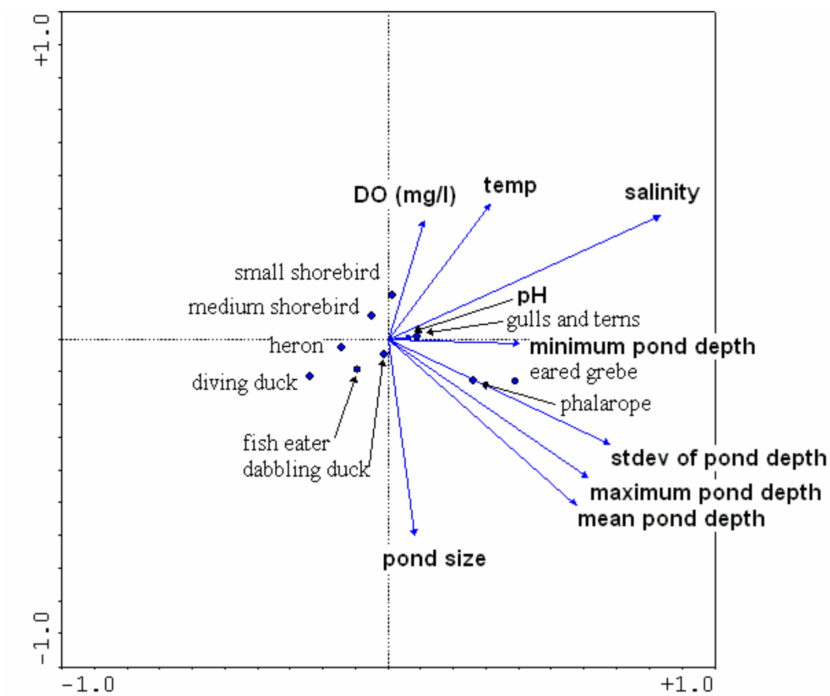


Figure 53. Foraging guild – environmental variable biplot resulting from canonical correspondence analysis of avian foraging guilds during the month of September, 2002-2005, with salt pond characteristics, San Francisco Bay, CA.

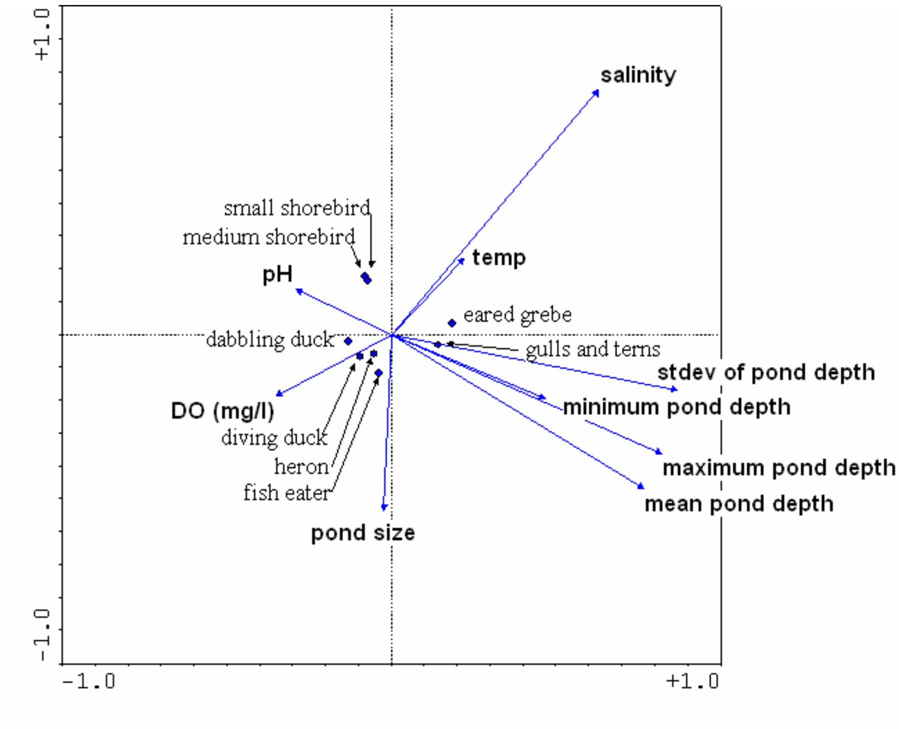


Figure 54. Foraging guild – environmental variable biplot resulting from canonical correspondence analysis of avian foraging guilds during the winter months (December-February), 2002-2005, with salt pond characteristics, San Francisco Bay, CA.

Figure 55a. Average salinity (ppt), measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

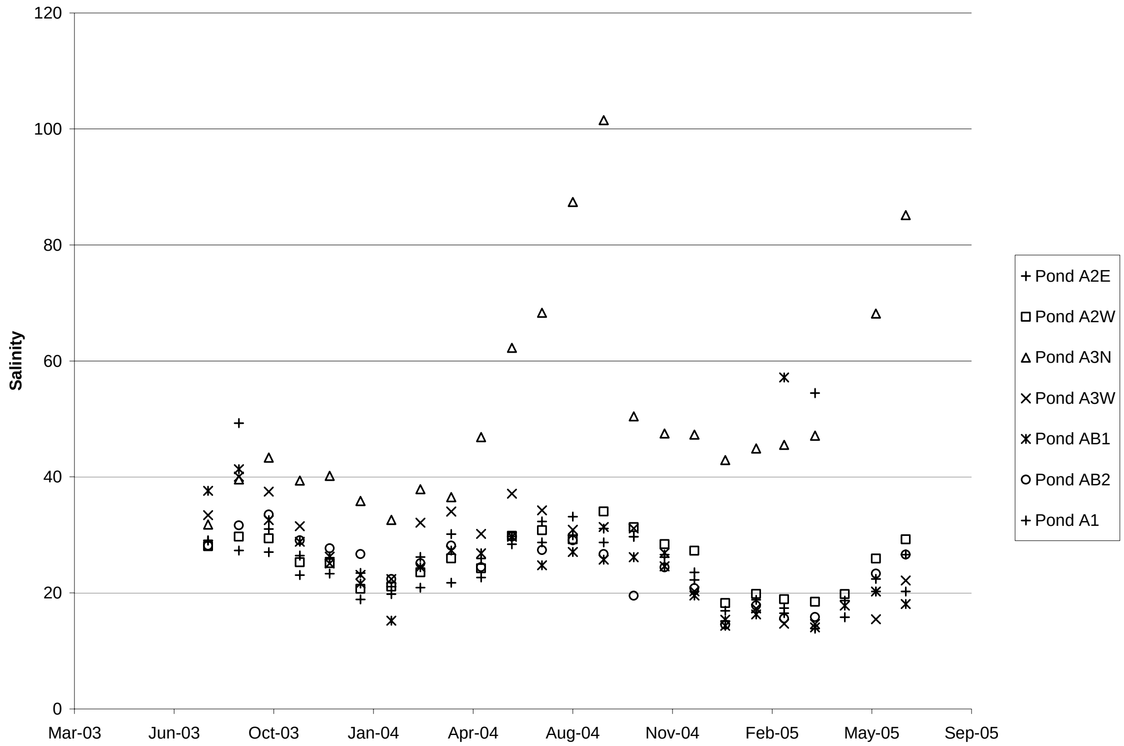


Figure 55b. Standard deviation of salinity, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

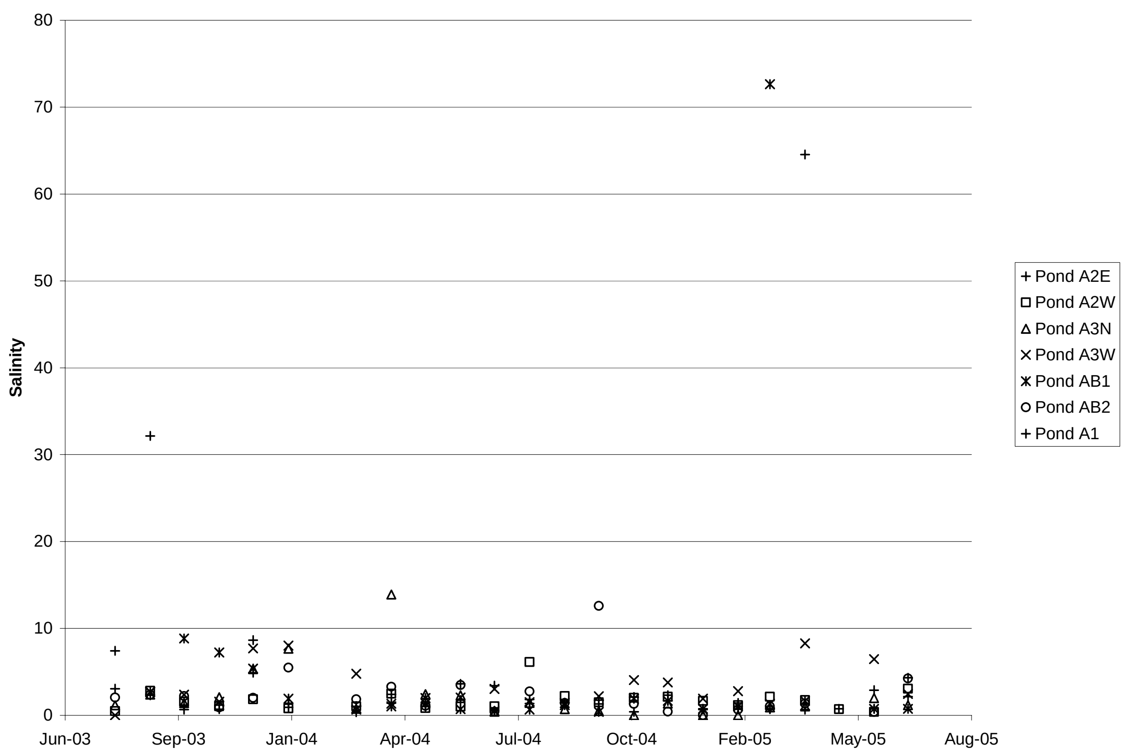


Figure 56a. Average dissolved oxygen (mg/l), measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

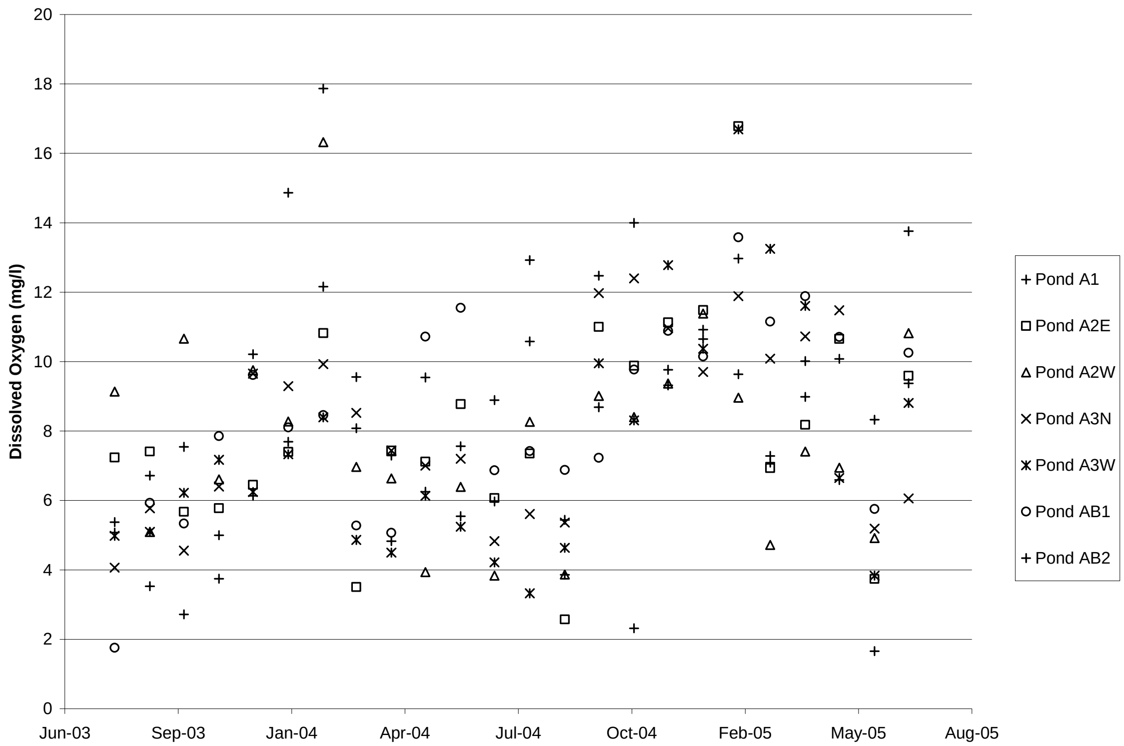


Figure 56b. Standard deviation of dissolved oxygen, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

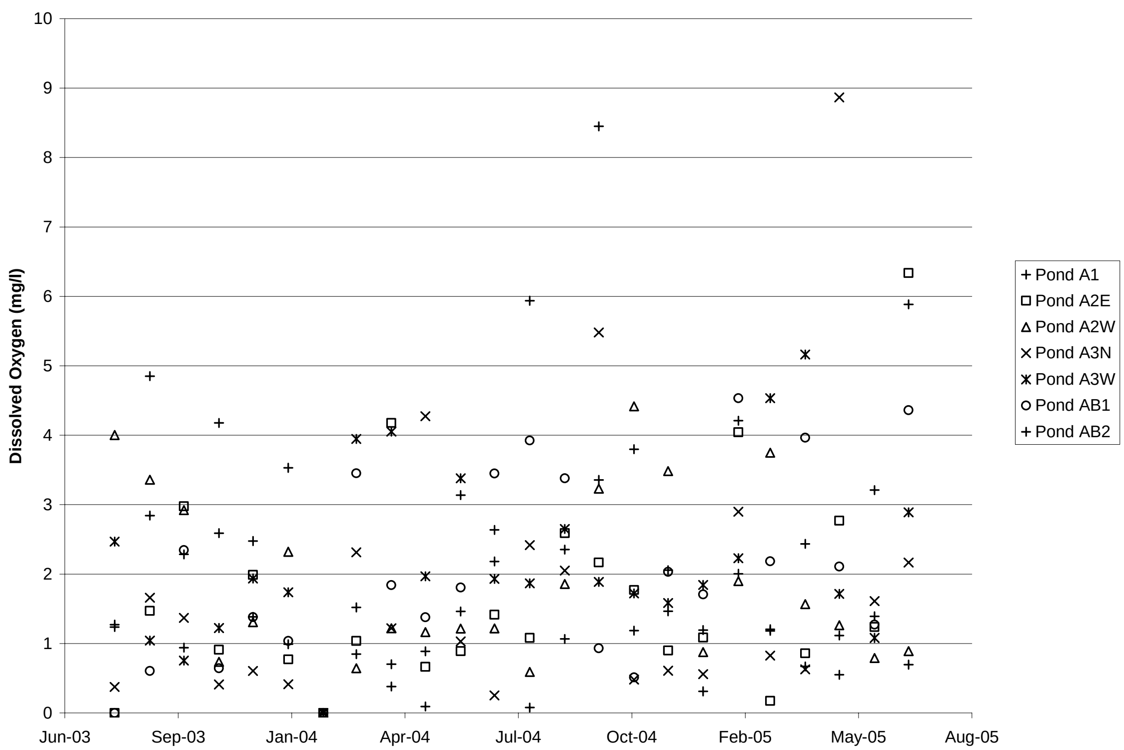


Figure57a. Average water temperature (°C), measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

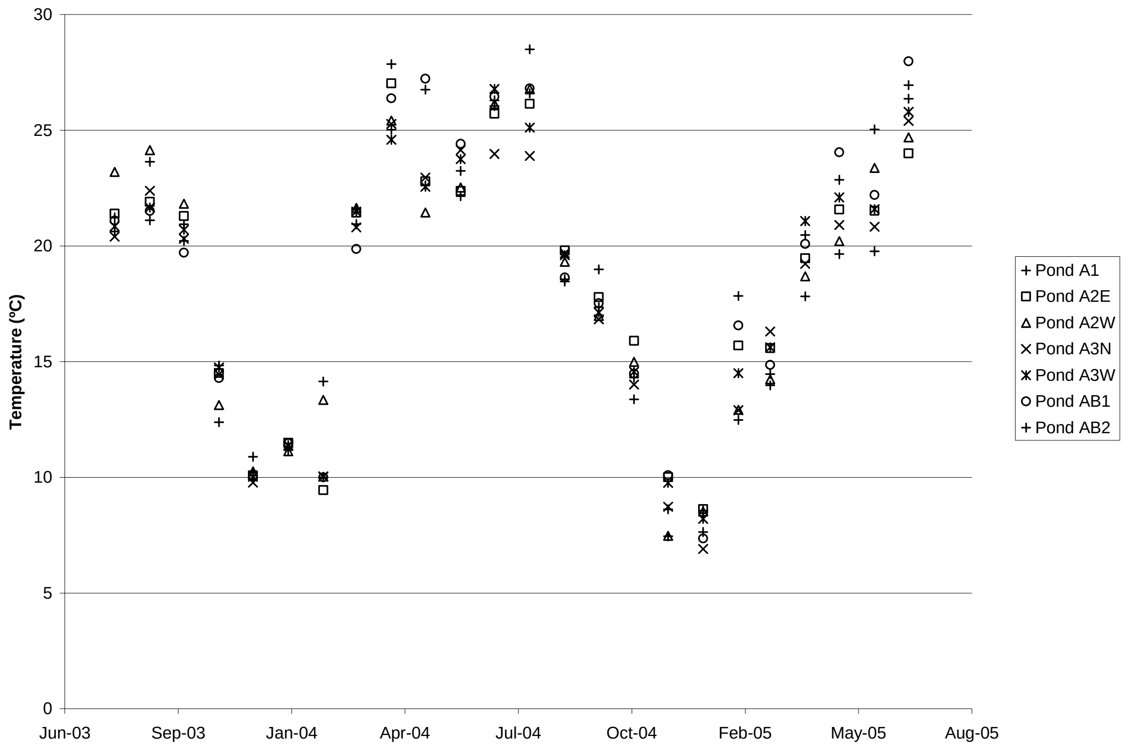


Figure 57b. Standard deviation of water temperature, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

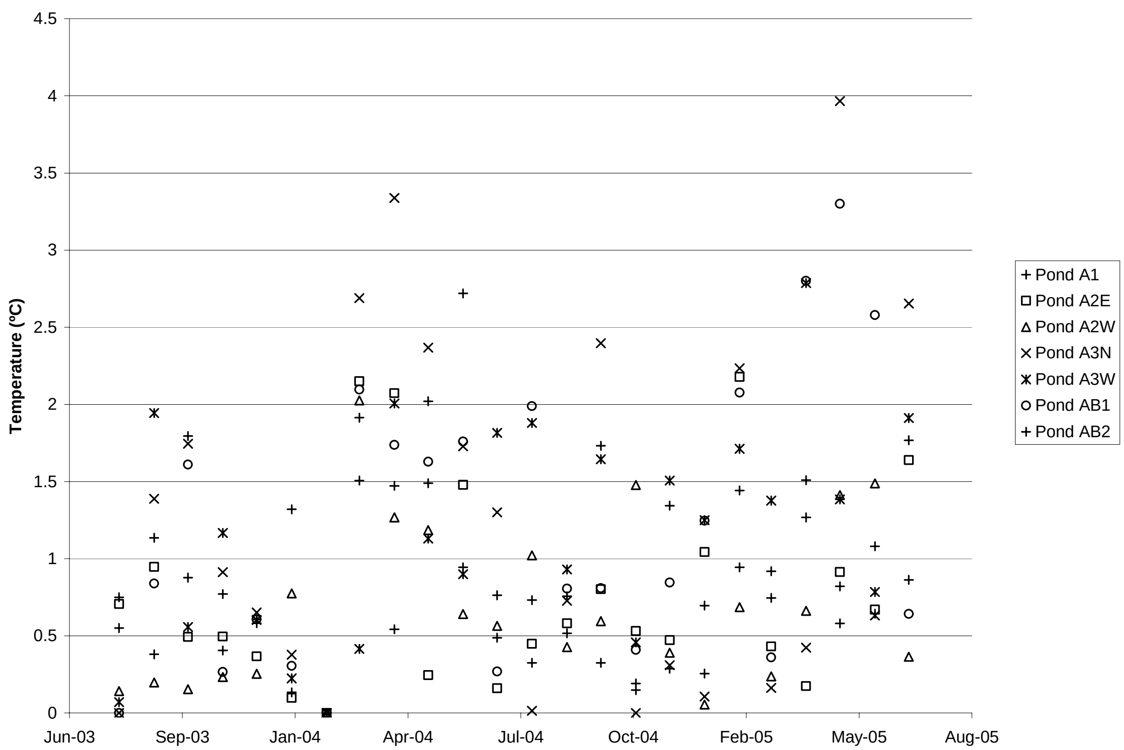


Figure 58a. Average pH, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

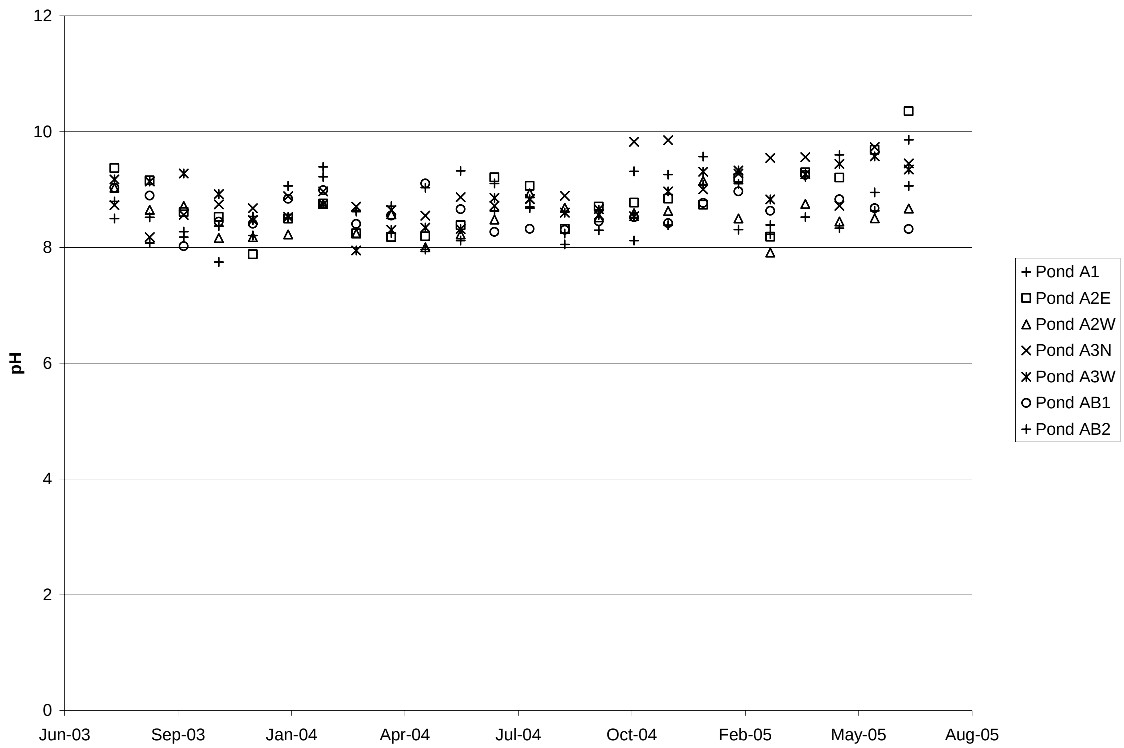


Figure 58b. Standard deviation of pH, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

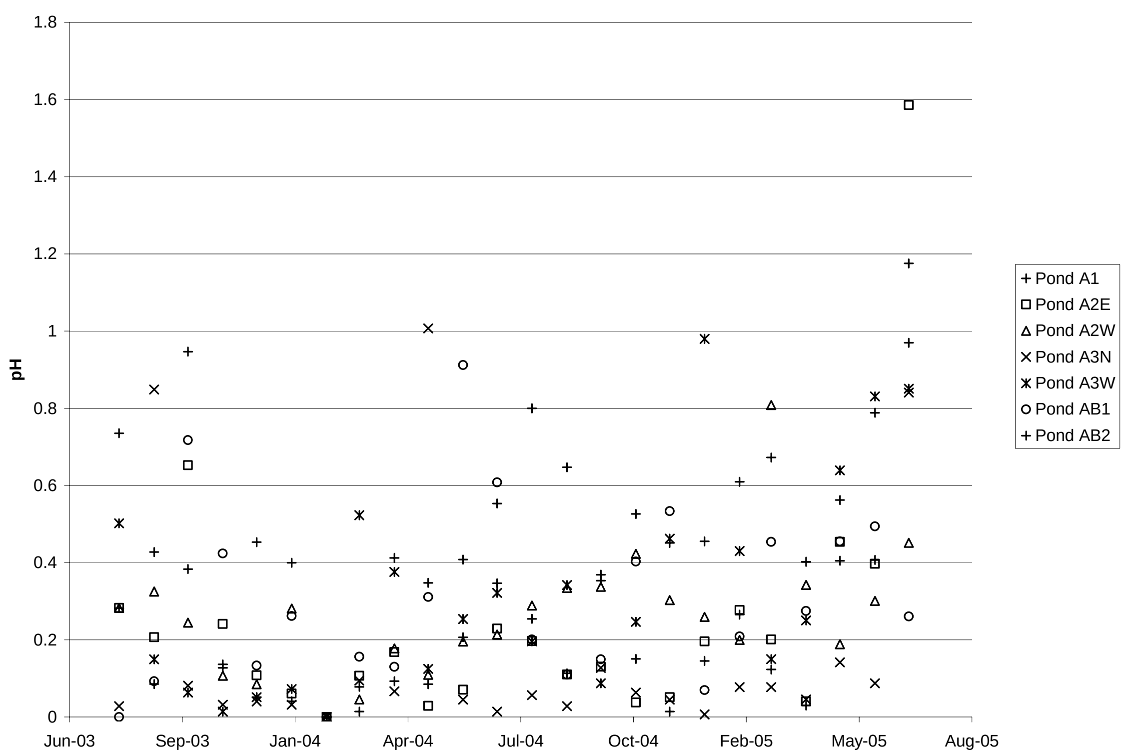


Figure 59a. Average turbidity (NTU), measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

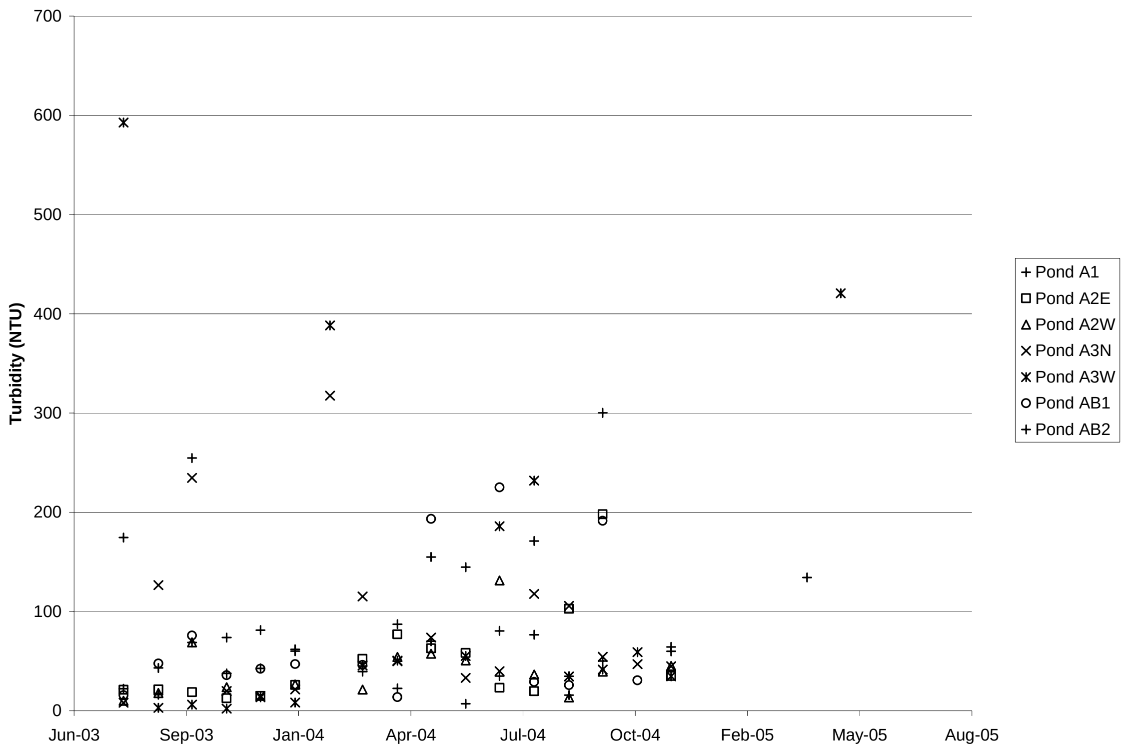


Figure 59b. Standard deviation of average turbidity, measured at ponds A2E, A2W, A3N, A3W, AB1, AB2, and A1, Alviso salt ponds, San Francisco Bay, CA.

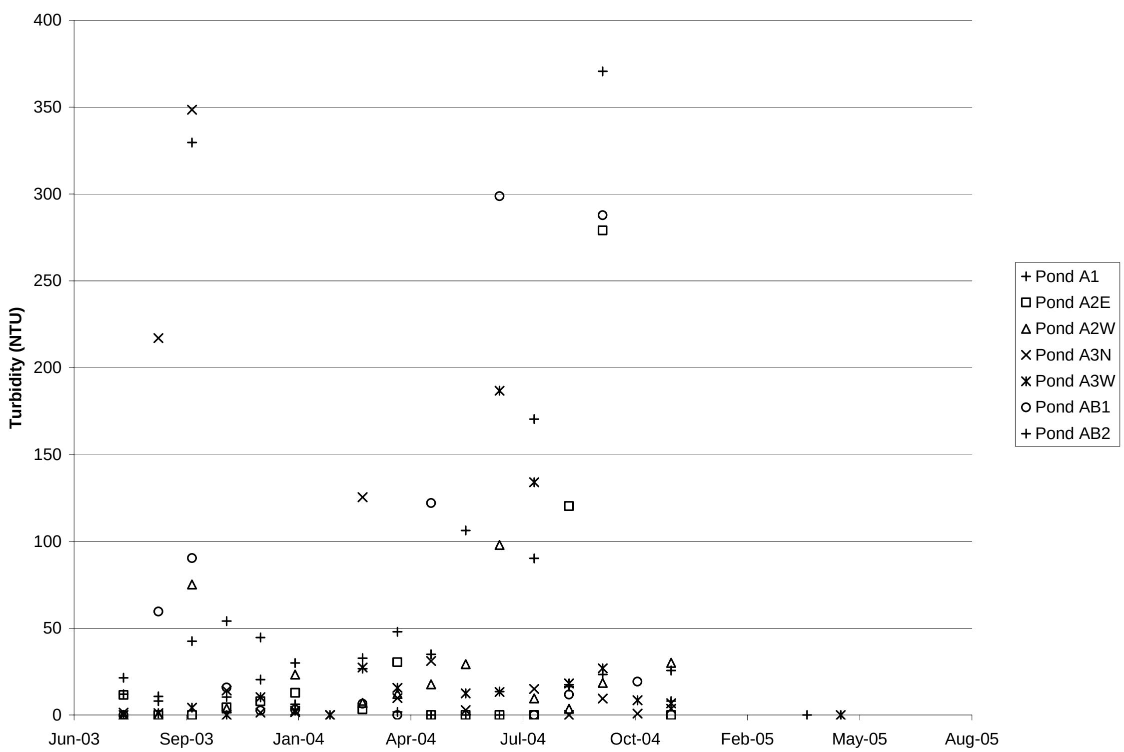


Figure 60a. Average salinity (ppt), ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

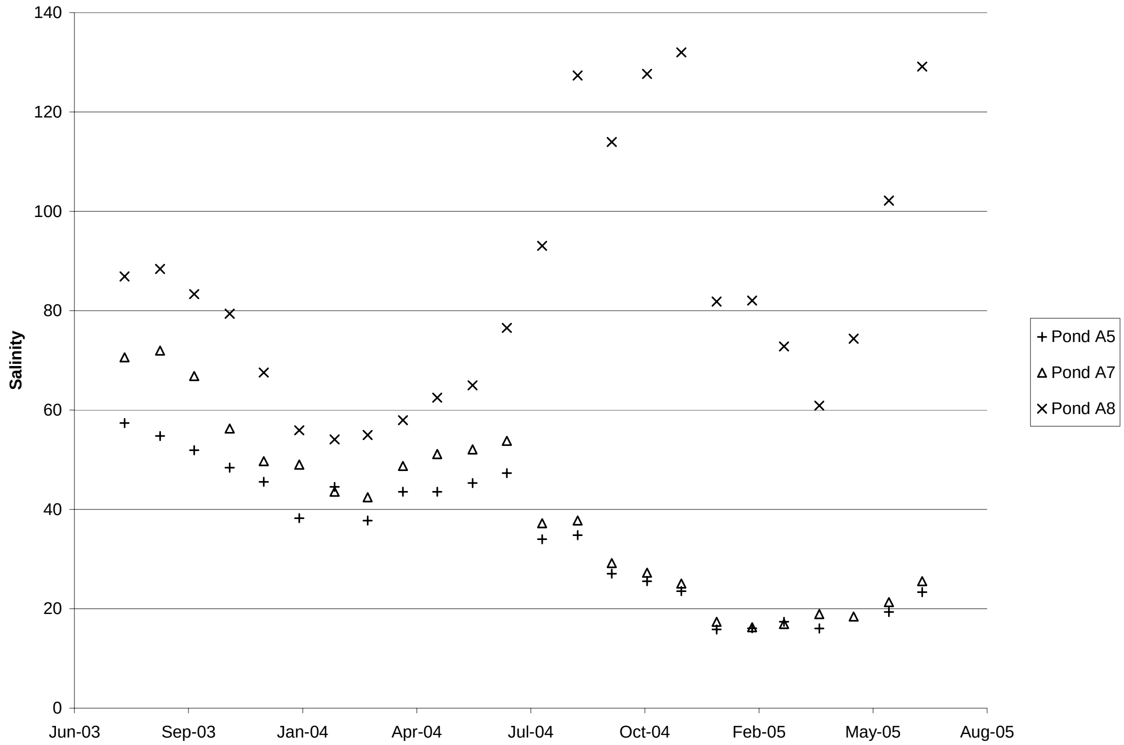


Figure 60b. Standard deviation of salinity, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

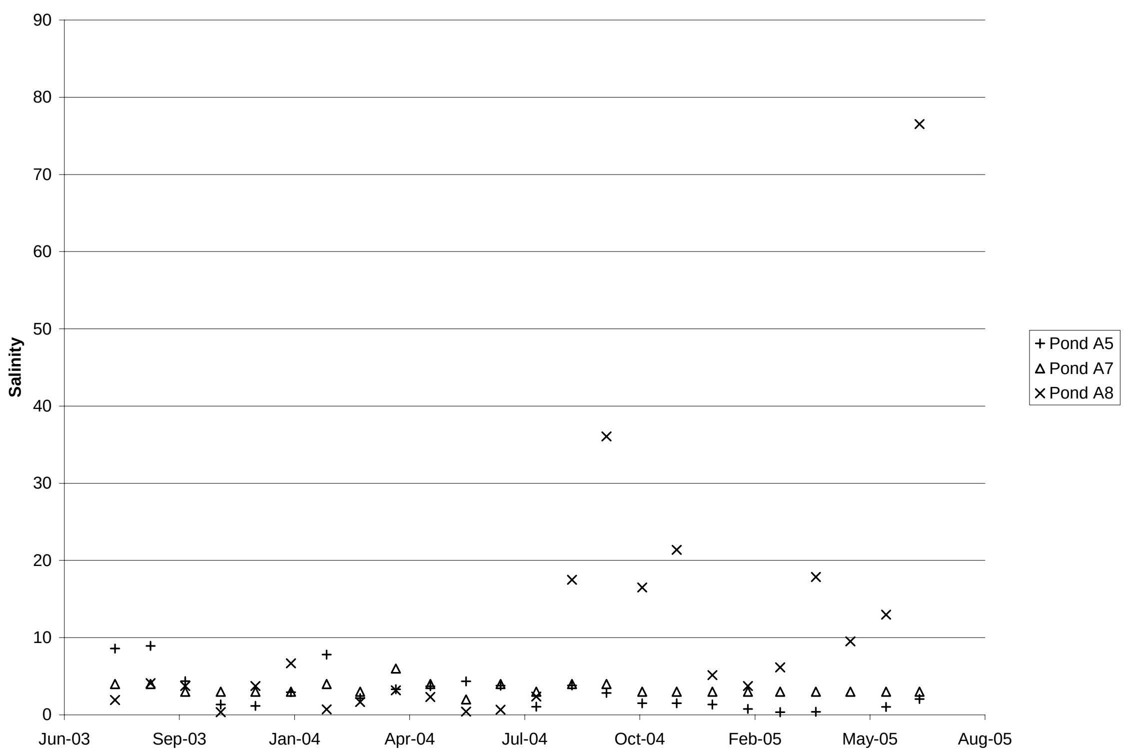


Figure 61a. Average dissolved oxygen (mg/l), ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

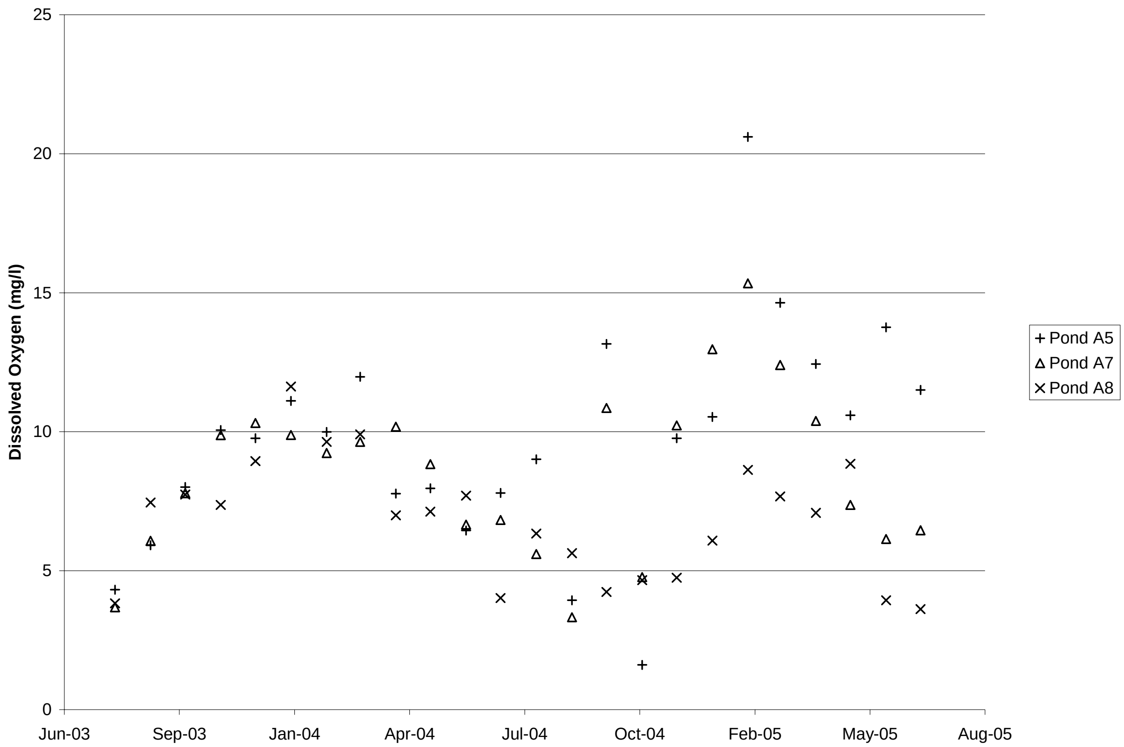


Figure 61b. Standard deviation of dissolved oxygen, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

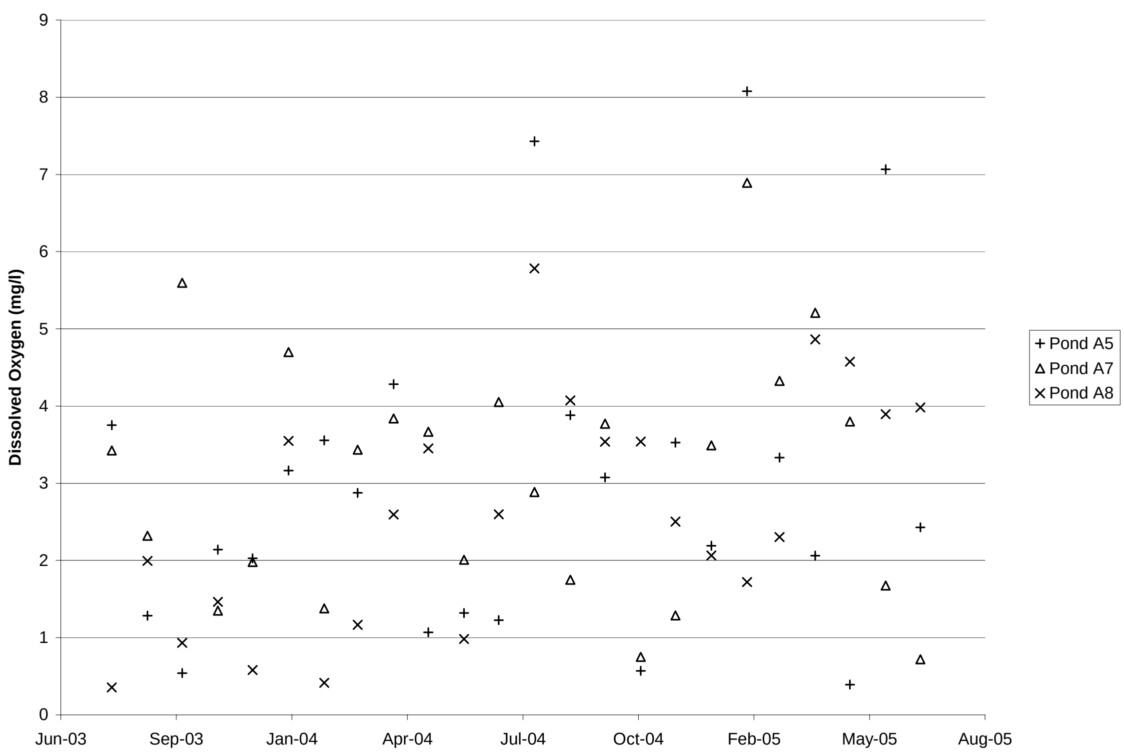


Figure 62a. Average water temperature (°C), ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

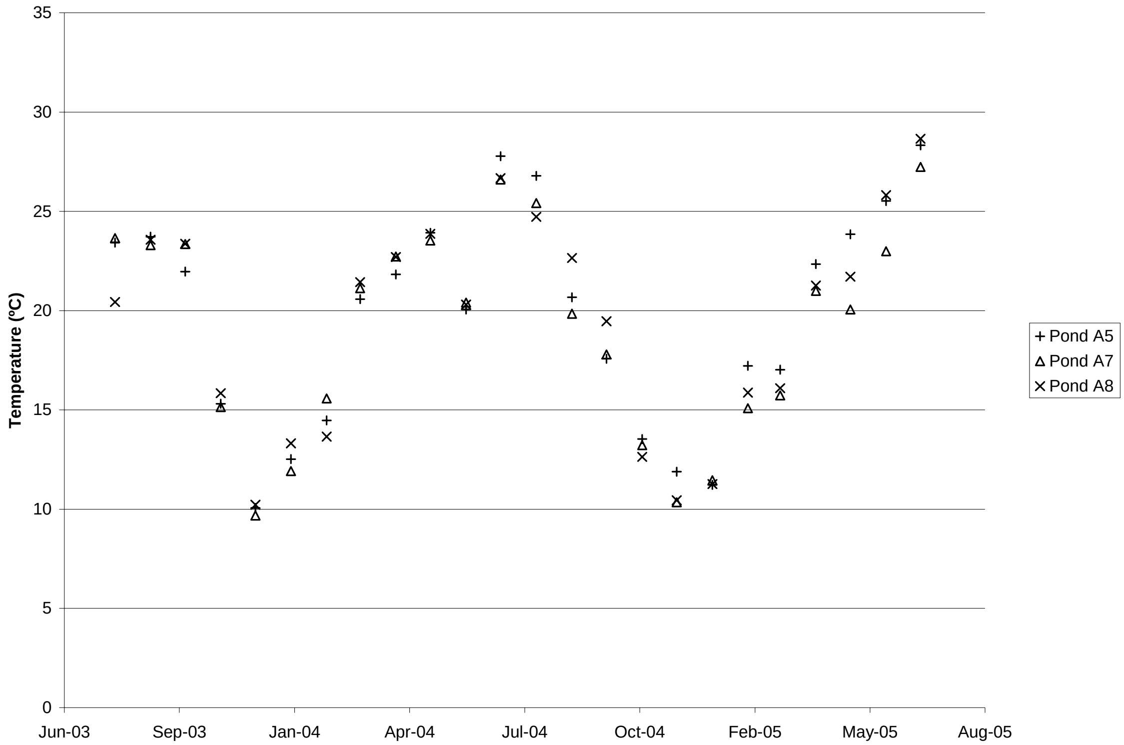


Figure 62b. Standard deviation of water temperature, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

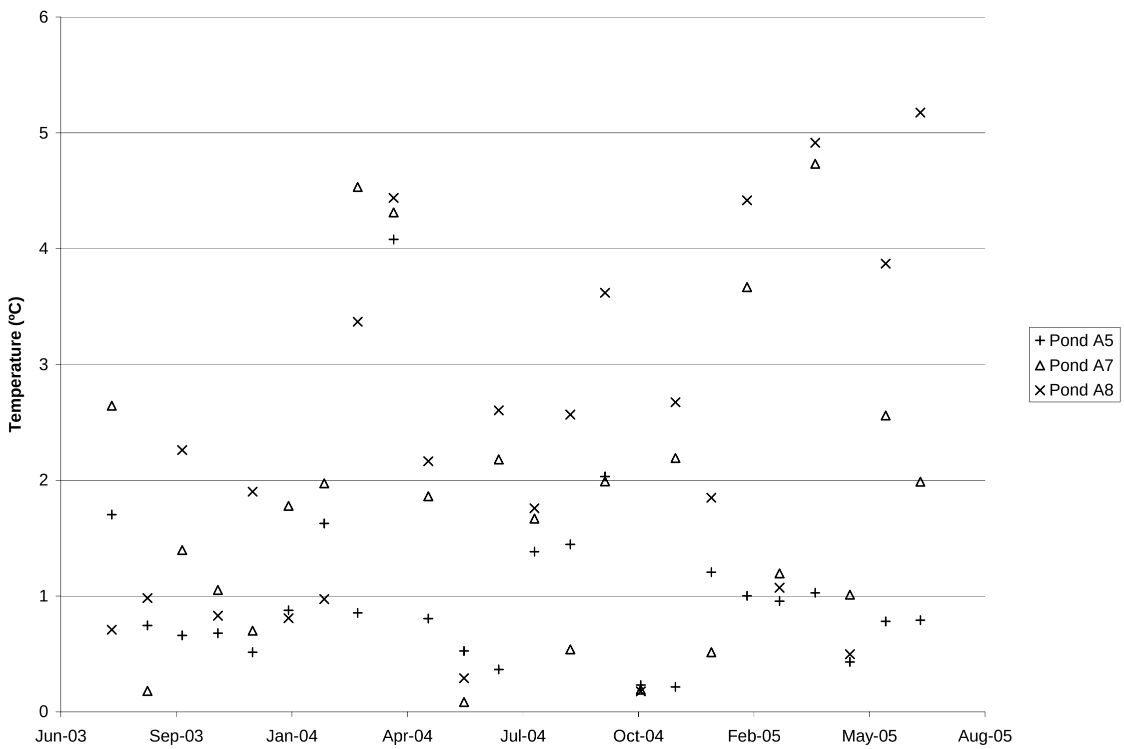


Figure 63a. Average pH, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

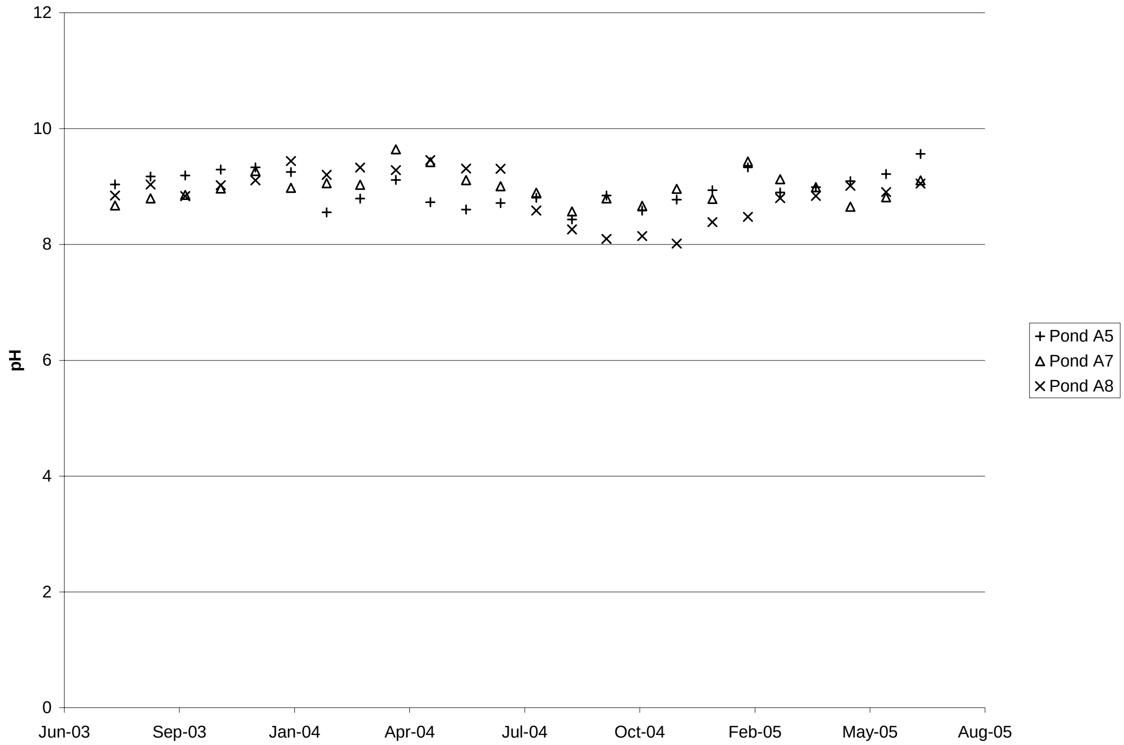


Figure 63b. Standard deviation of average pH, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

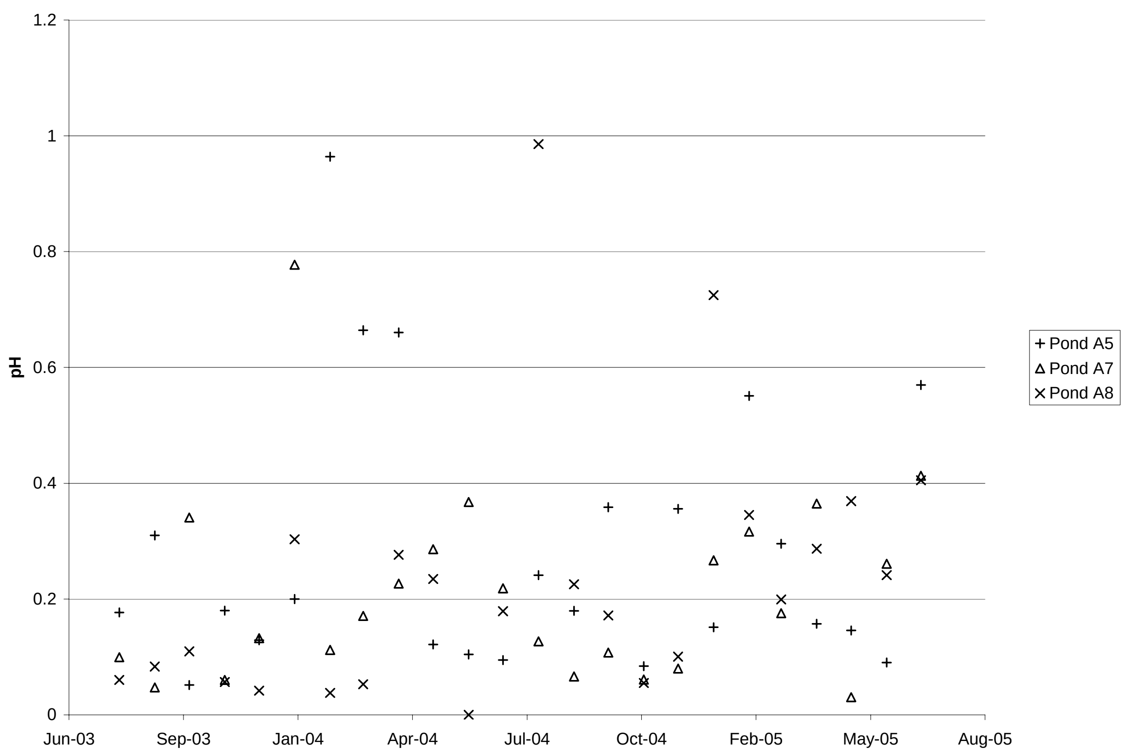


Figure 64a. Average turbidity (NTU), ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

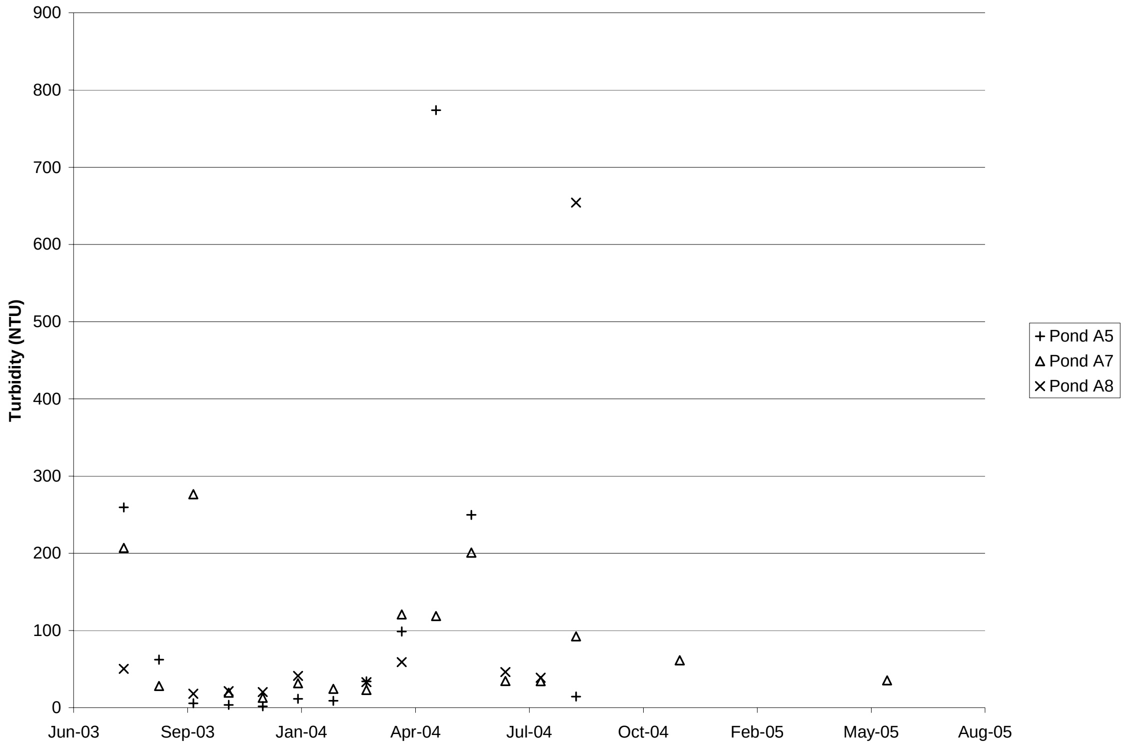


Figure 64b. Standard deviation of average turbidity, ponds A5-A8, Alviso salt ponds, San Francisco Bay, CA.

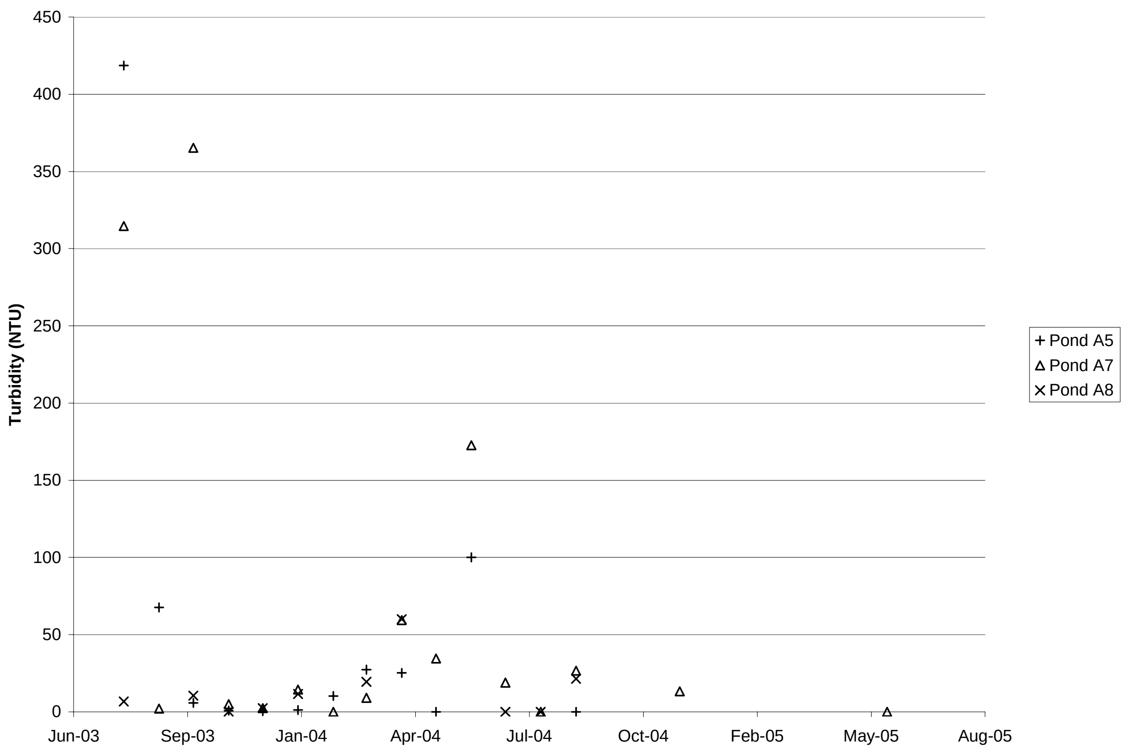


Figure 65a. Average salinity (ppt), Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

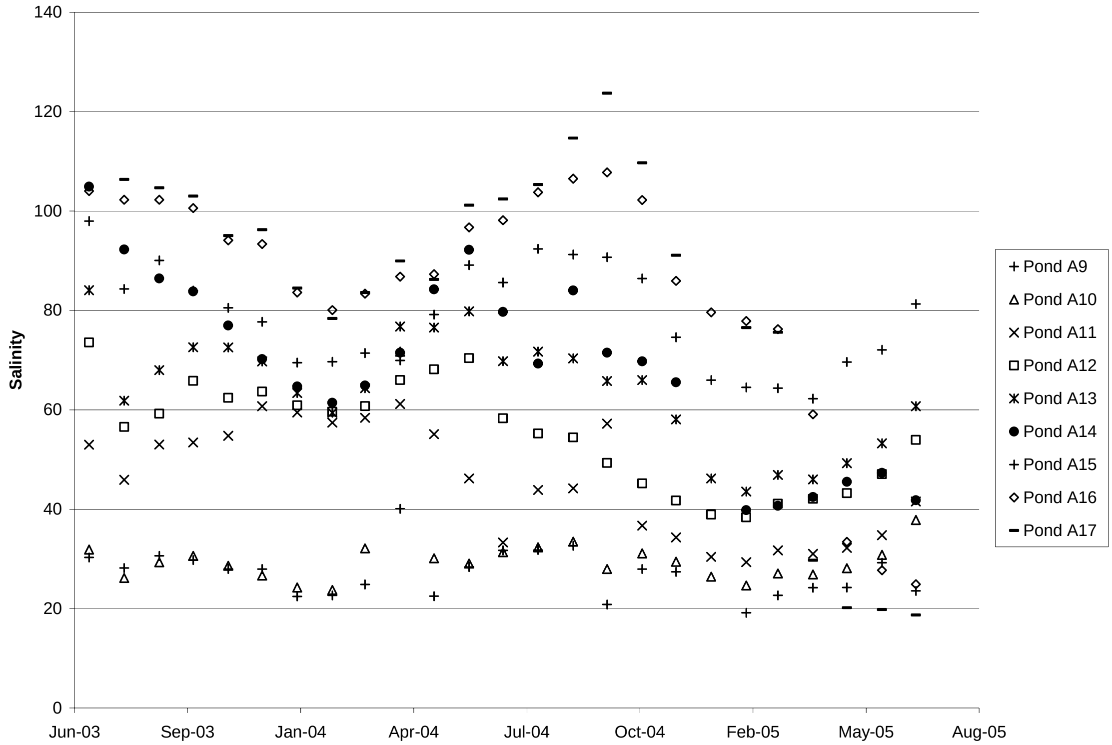


Figure 65b. Standard deviation of salinity, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

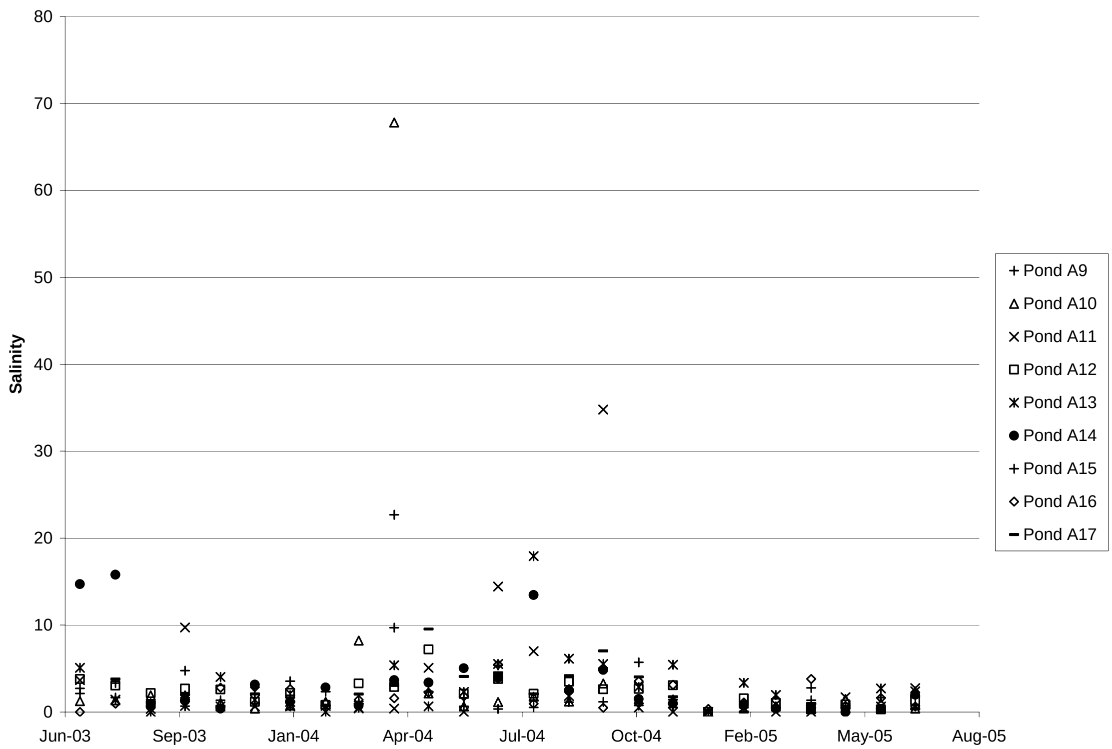


Figure 66a. Average dissolved oxygen (mg/l), Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

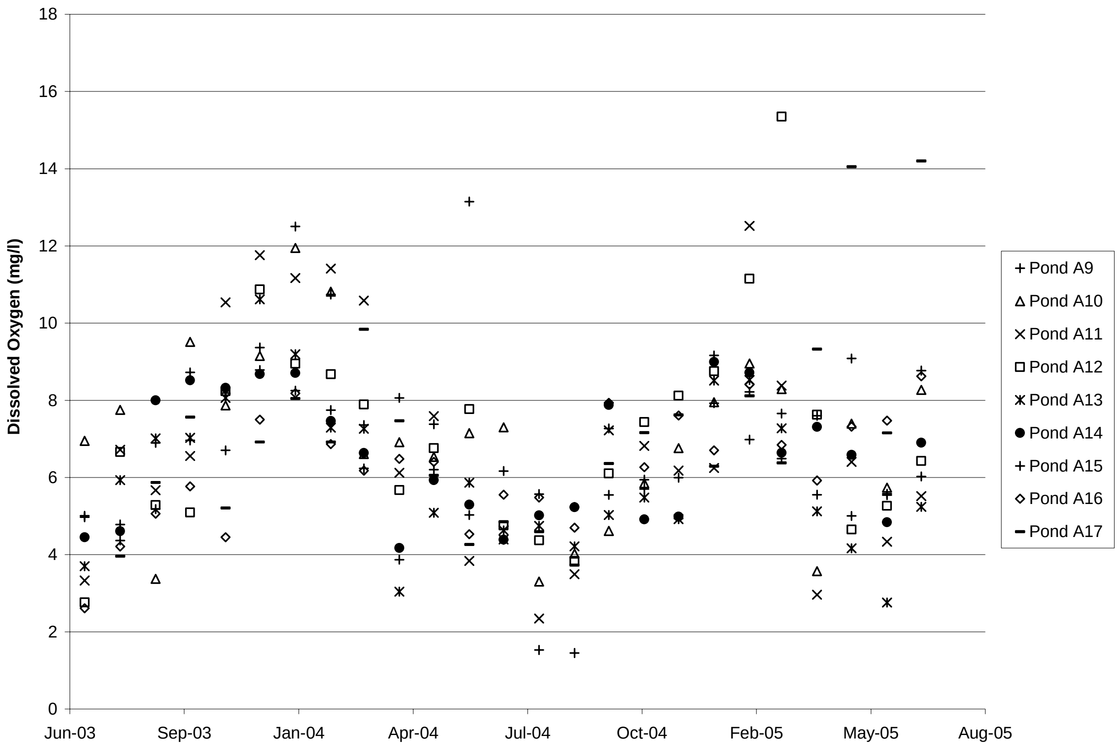


Figure 66b. Standard deviation of dissolved oxygen, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

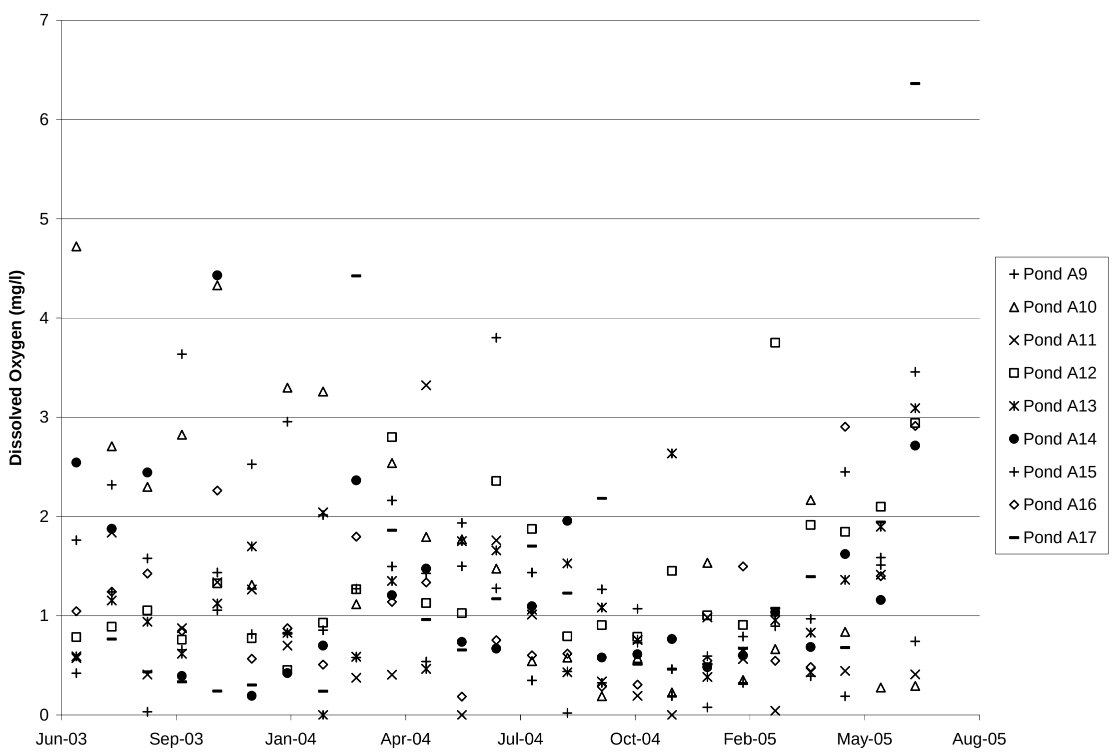


Figure 67a. Average water temperature (°C), Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

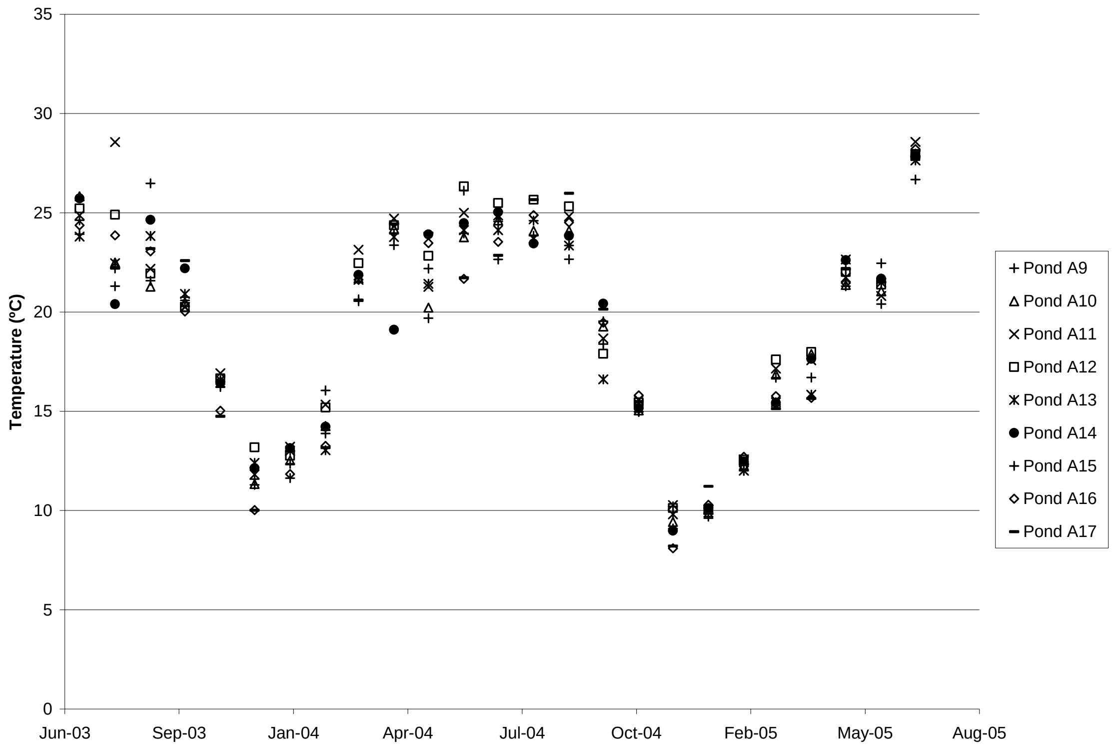


Figure 67b. Standard deviation of water temperature, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

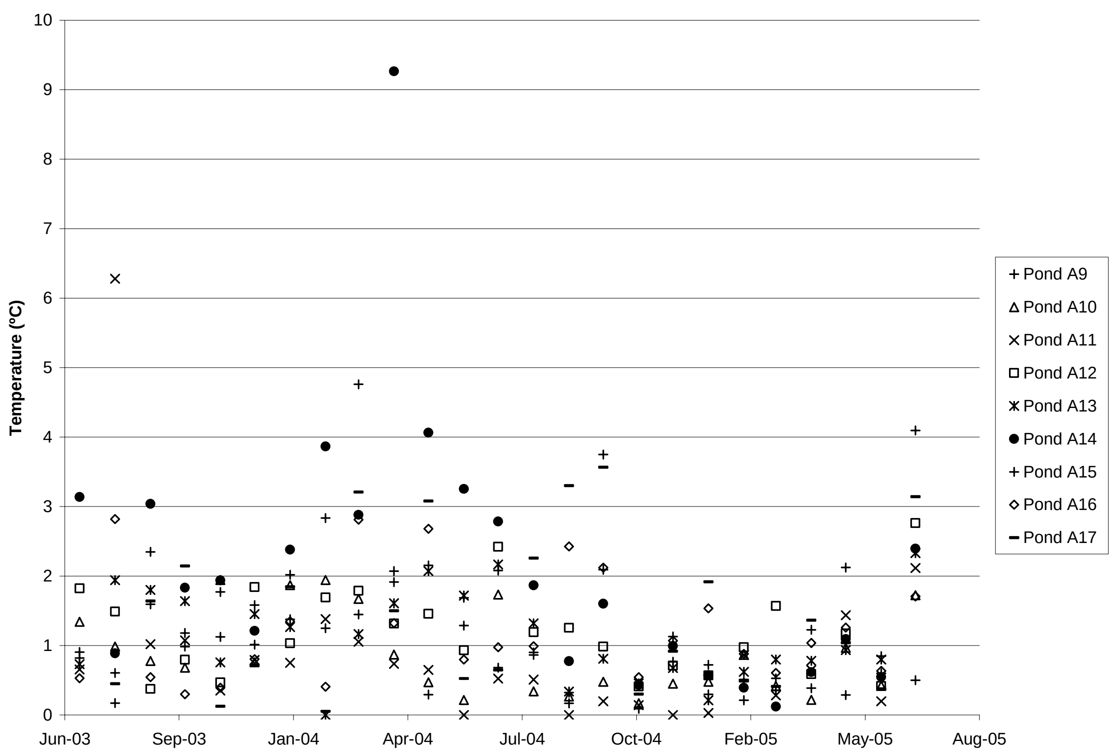


Figure 68a. Average pH, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

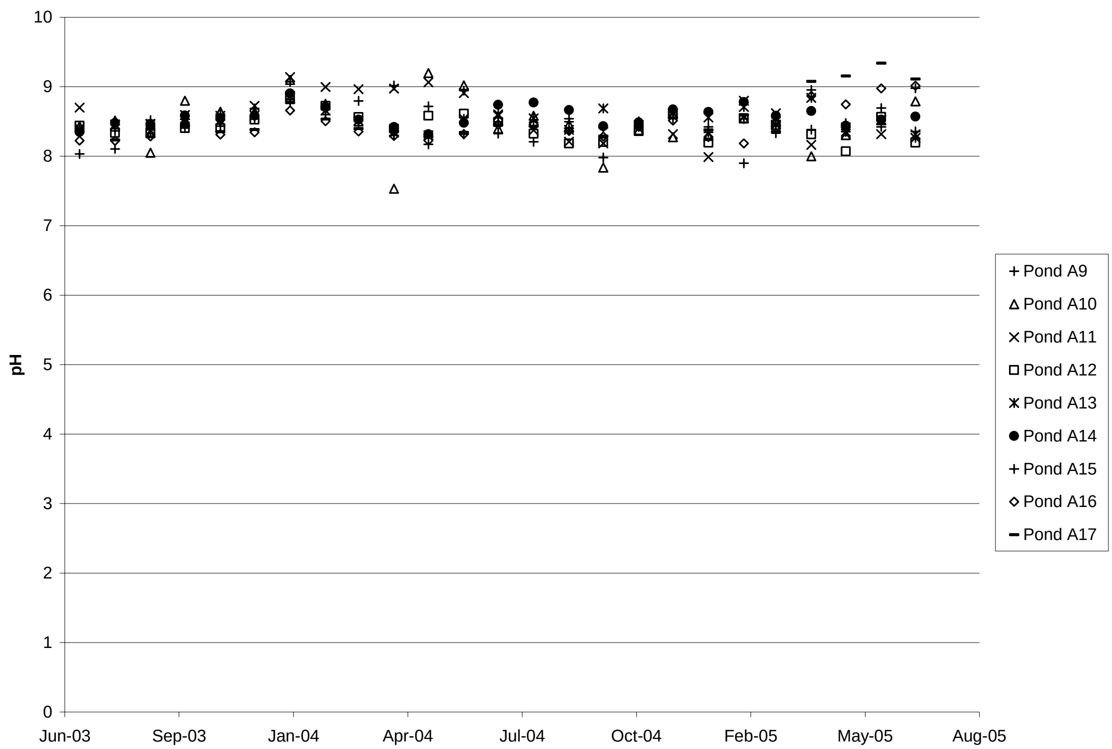


Figure 68b. Standard deviation of average pH, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

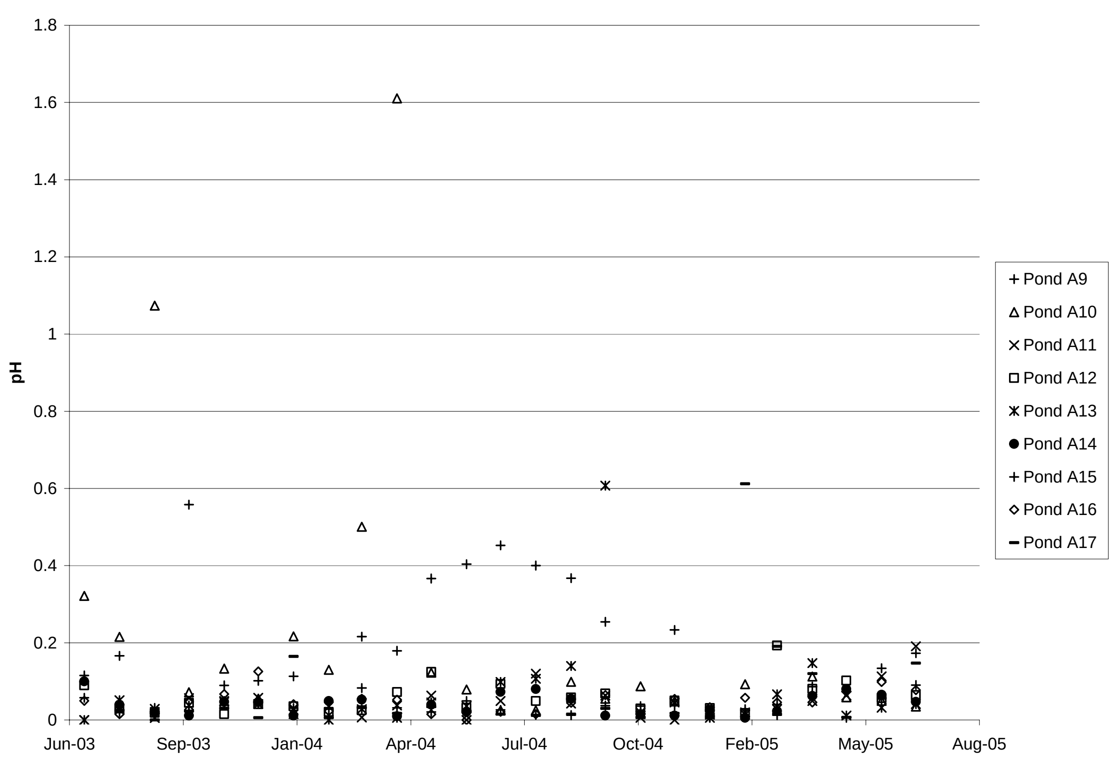


Figure 69a. Average turbidity (NTU), Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

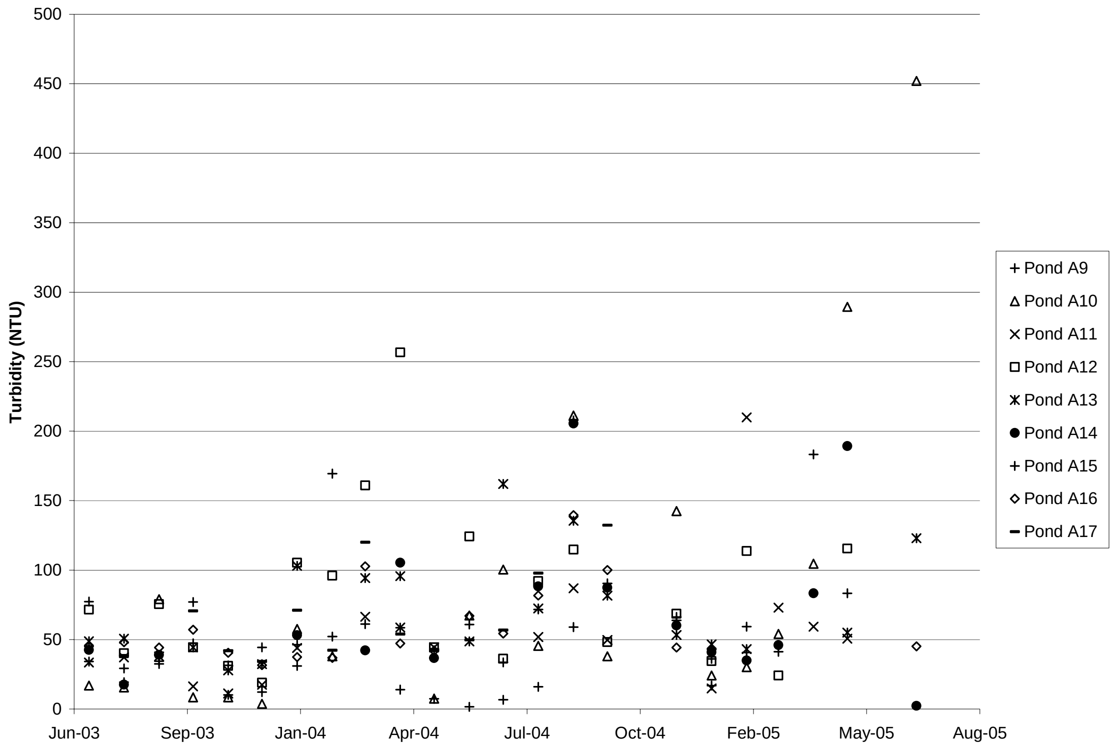


Figure 69b. Standard deviation of average turbidity, Marina ponds A9-A17, Alviso salt ponds, San Francisco Bay, CA.

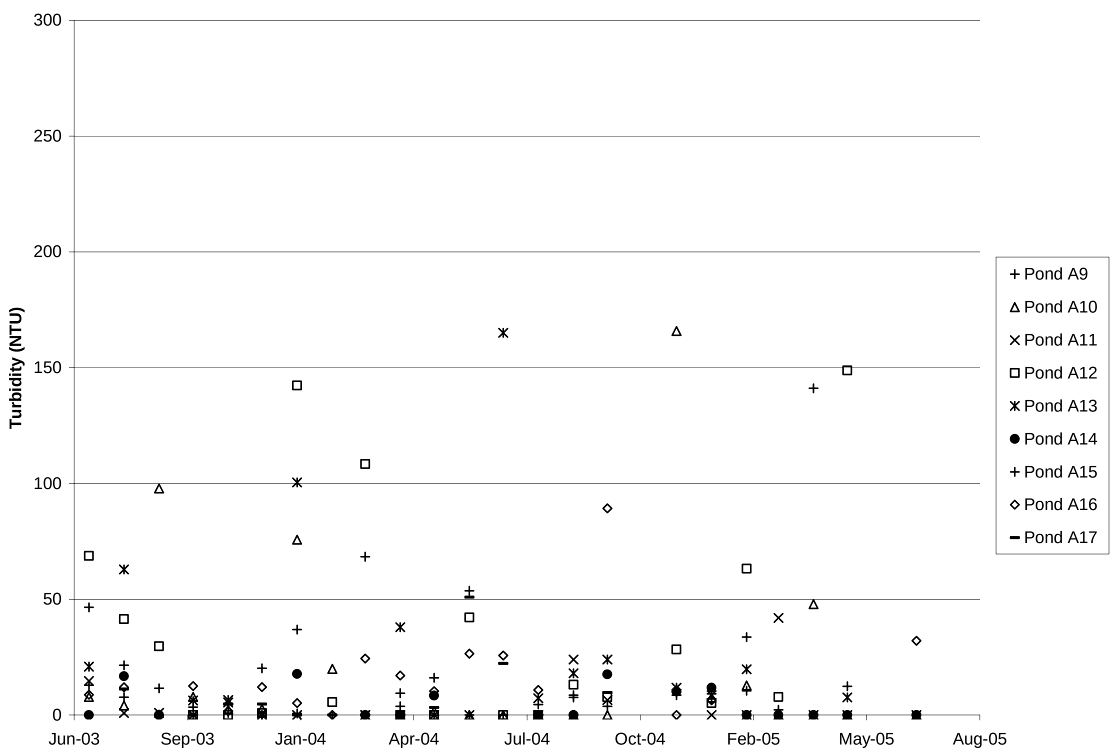


Figure 70a. Average salinity (ppt), ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

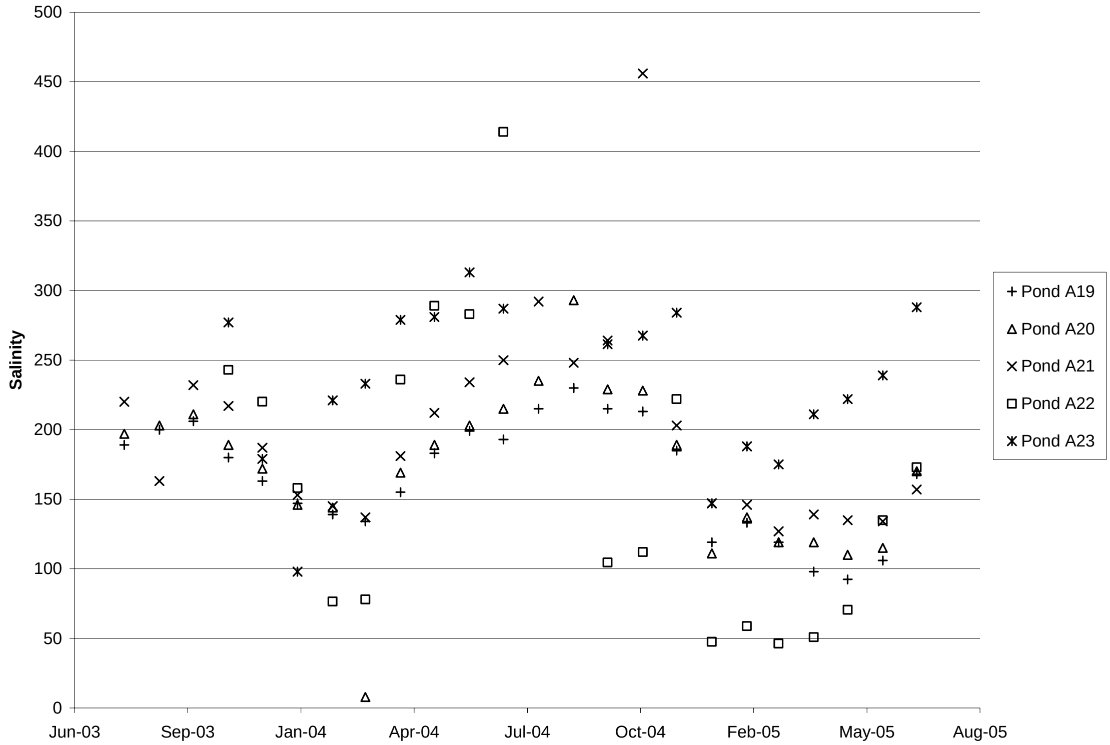


Figure 70b. Standard deviation of salinity, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

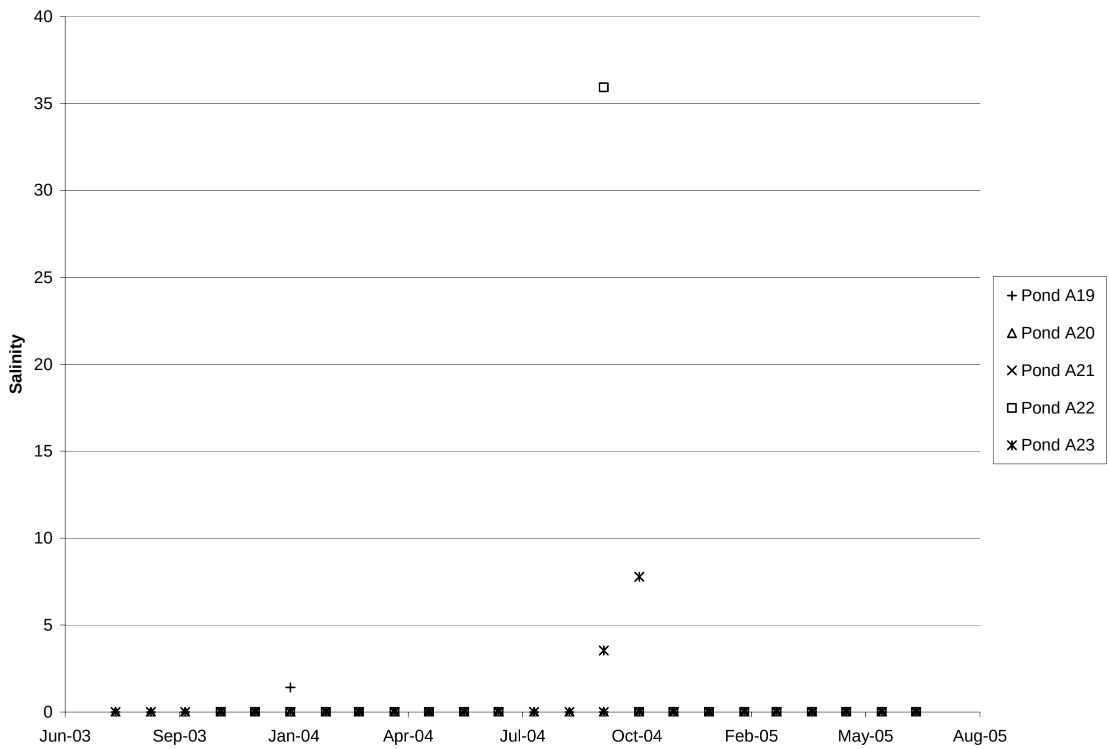


Figure 71a. Average dissolved oxygen (mg/l), ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

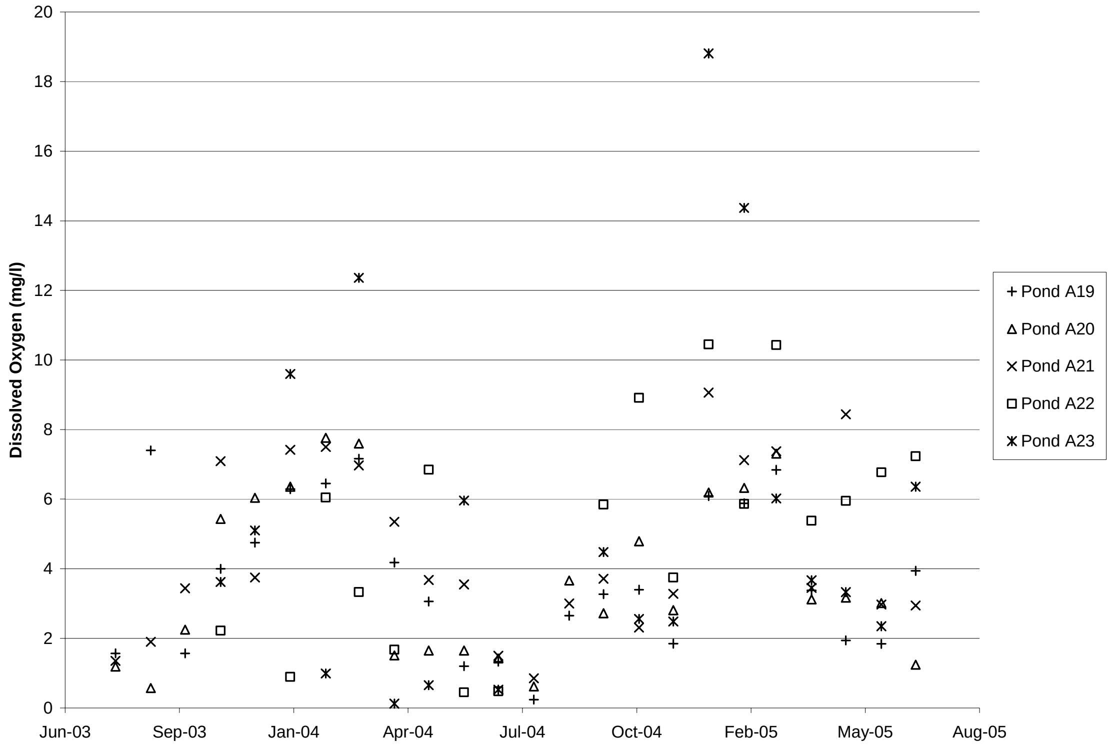


Figure 71b. Standard deviation of dissolved oxygen, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

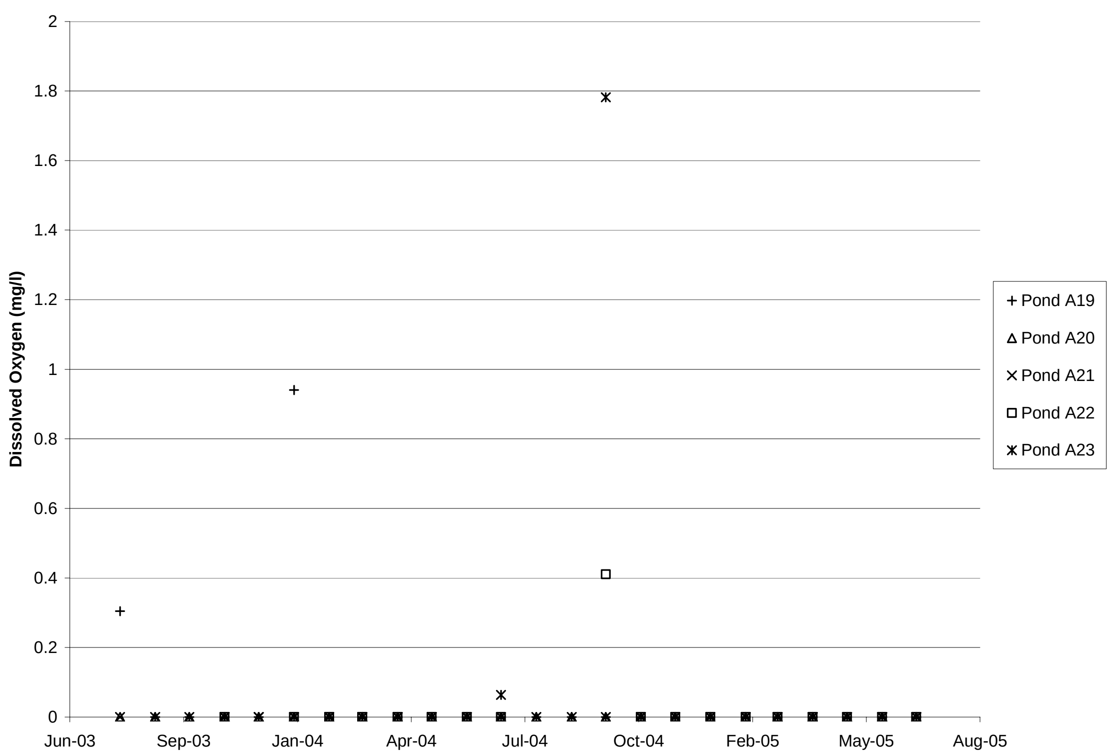


Figure 72a. Average water temperature (°C), ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

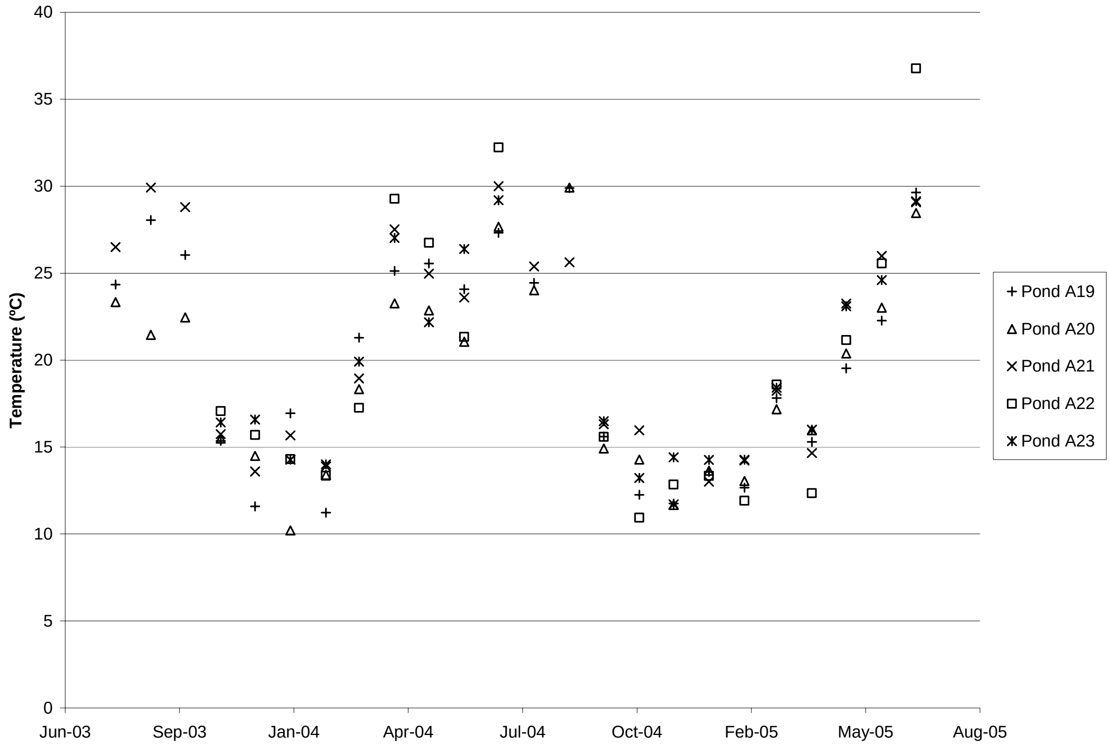


Figure 72b. Standard deviation of water temperature, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

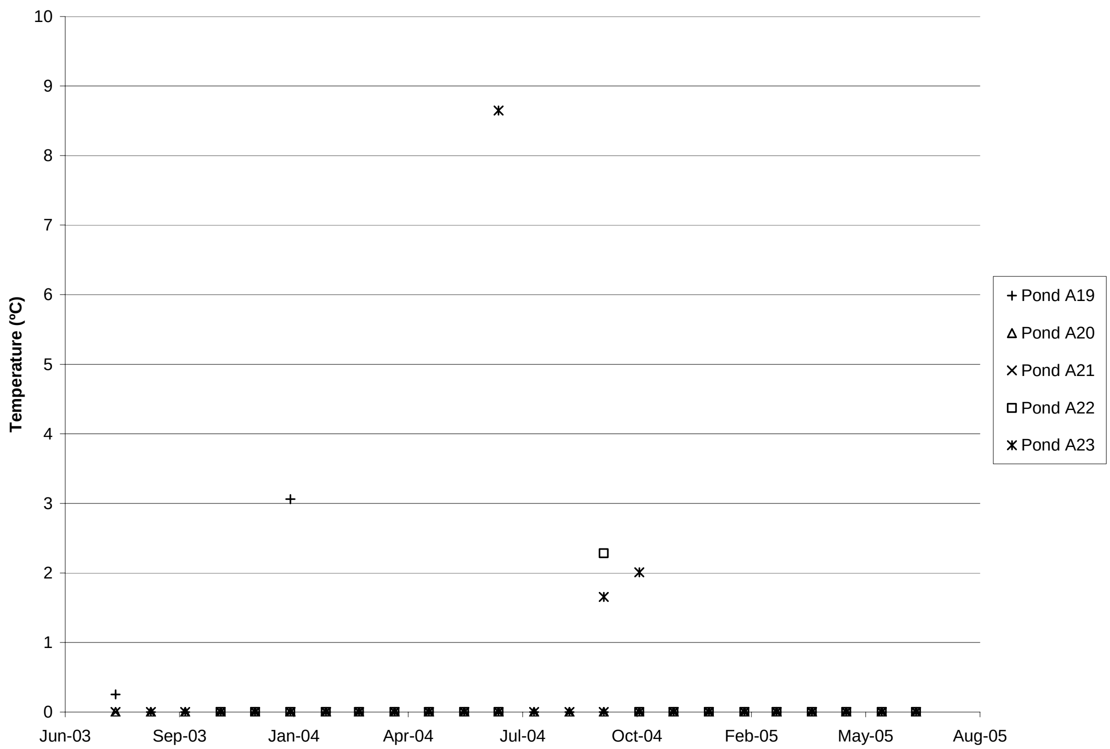


Figure 73a. Average pH, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

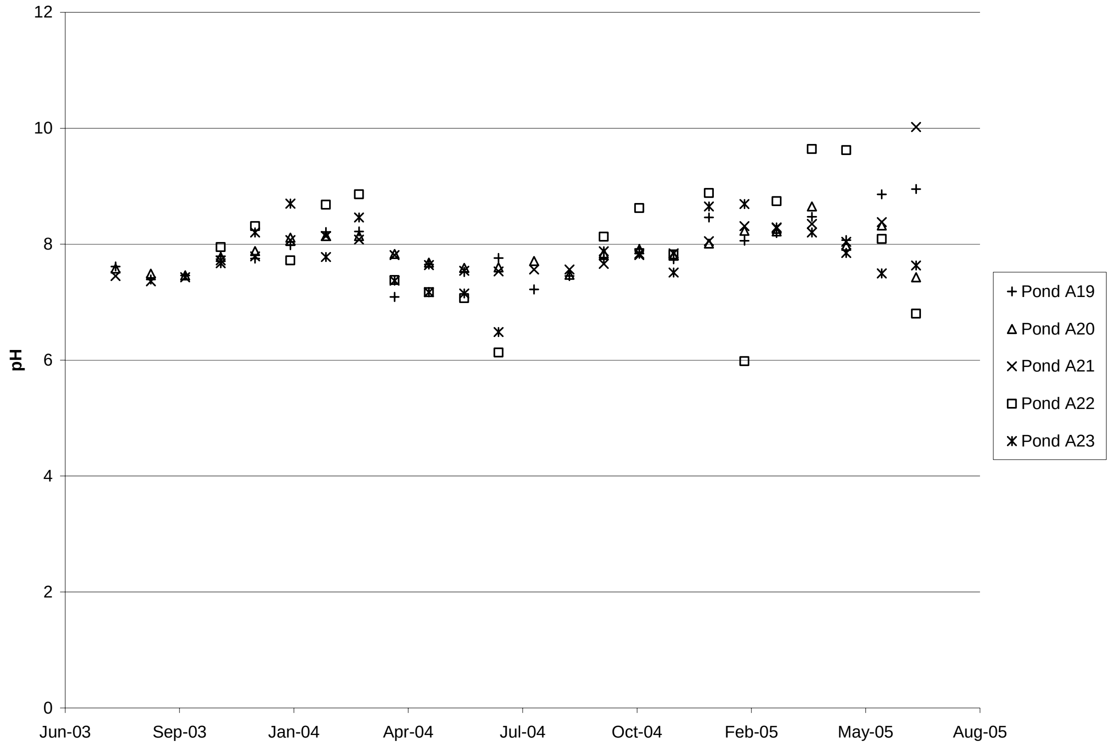


Figure 73b. Standard deviation of average pH, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

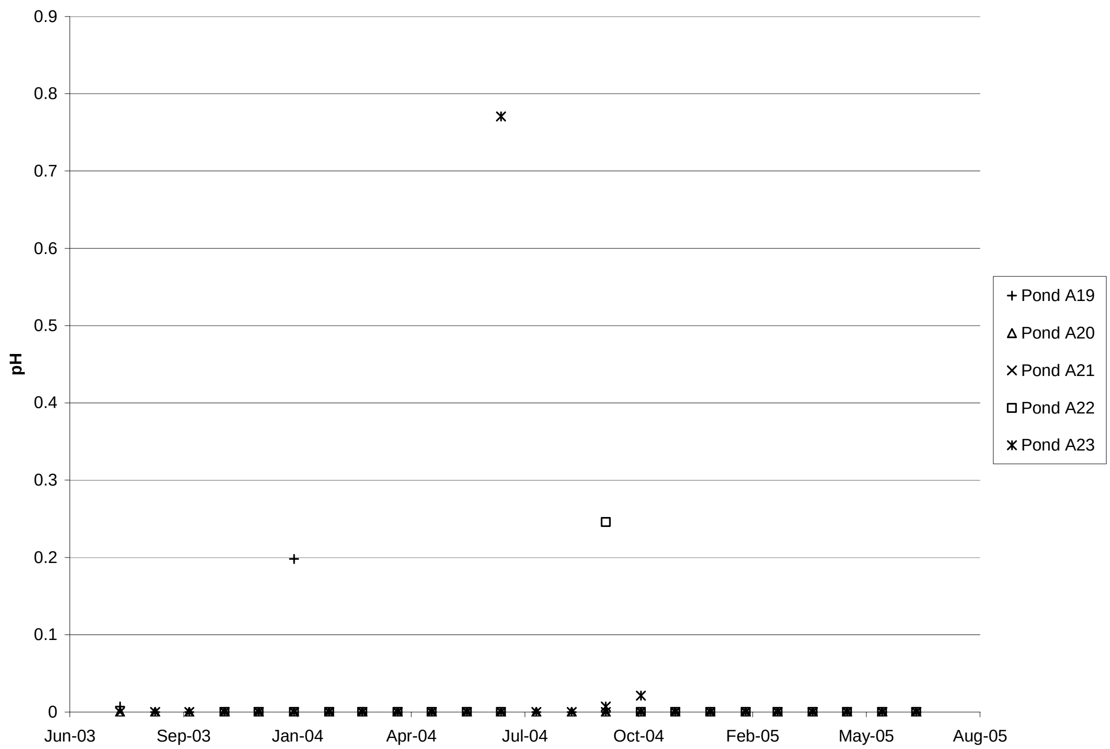


Figure 74a. Average turbidity (NTU), ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

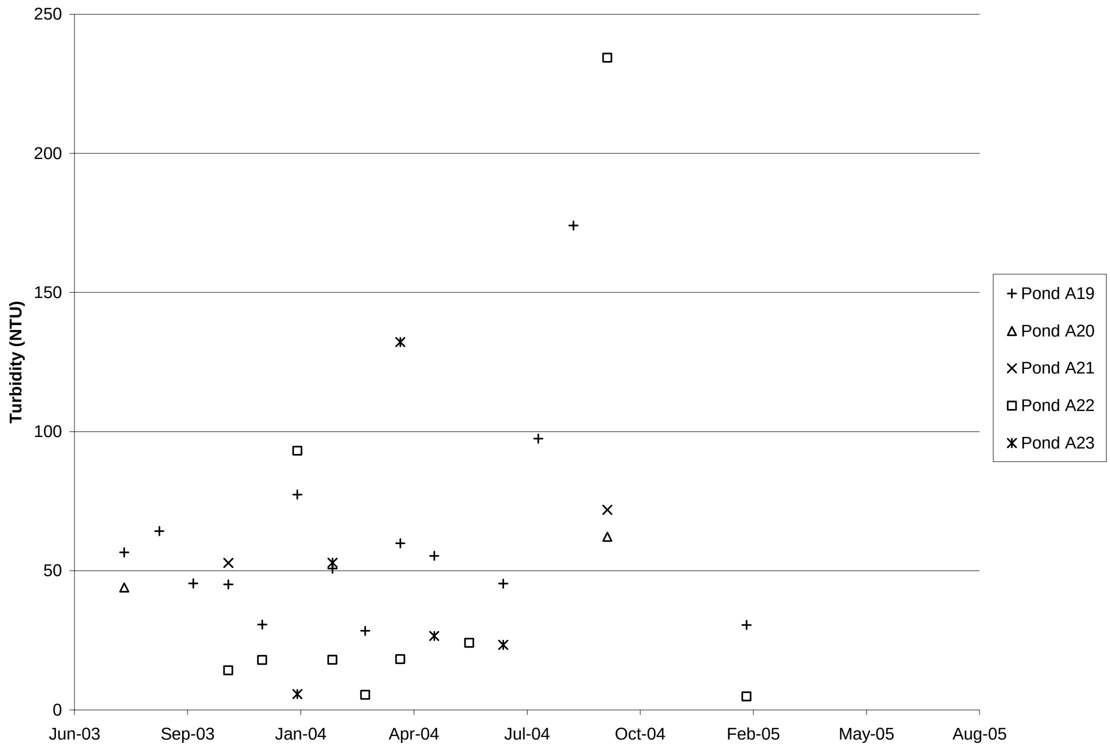


Figure 74b. Standard deviation of average turbidity, ponds A19-A23, Alviso salt ponds, San Francisco Bay, CA.

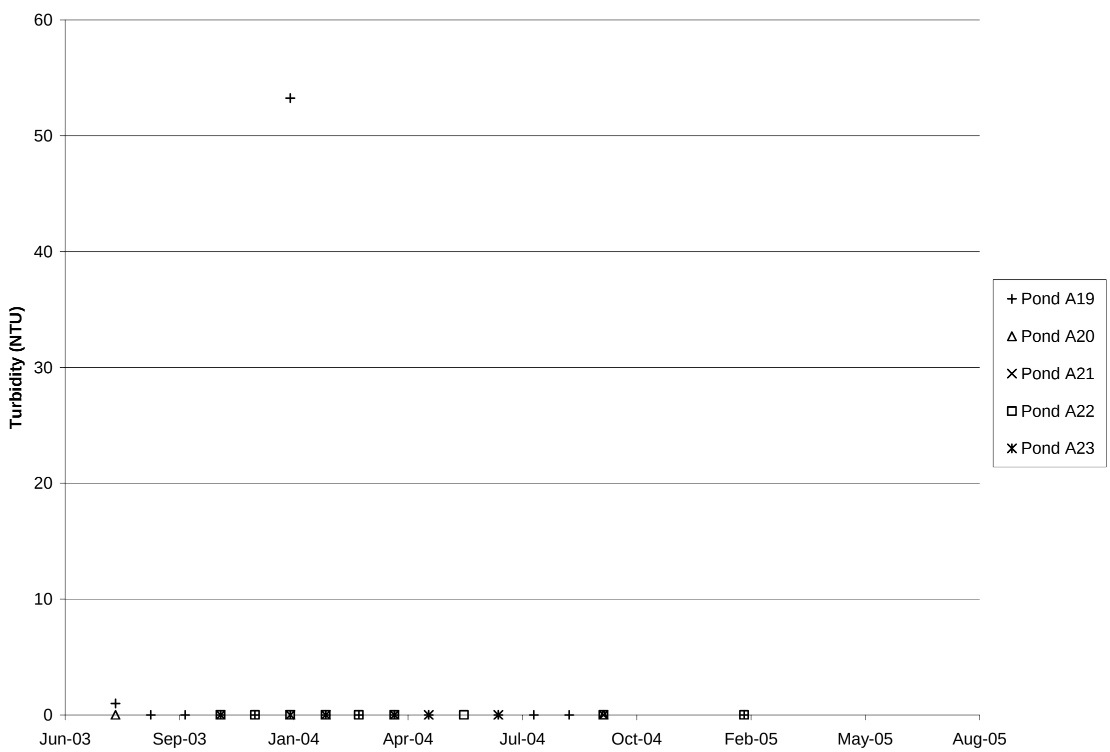


Figure 75a. Average salinity (ppt), Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

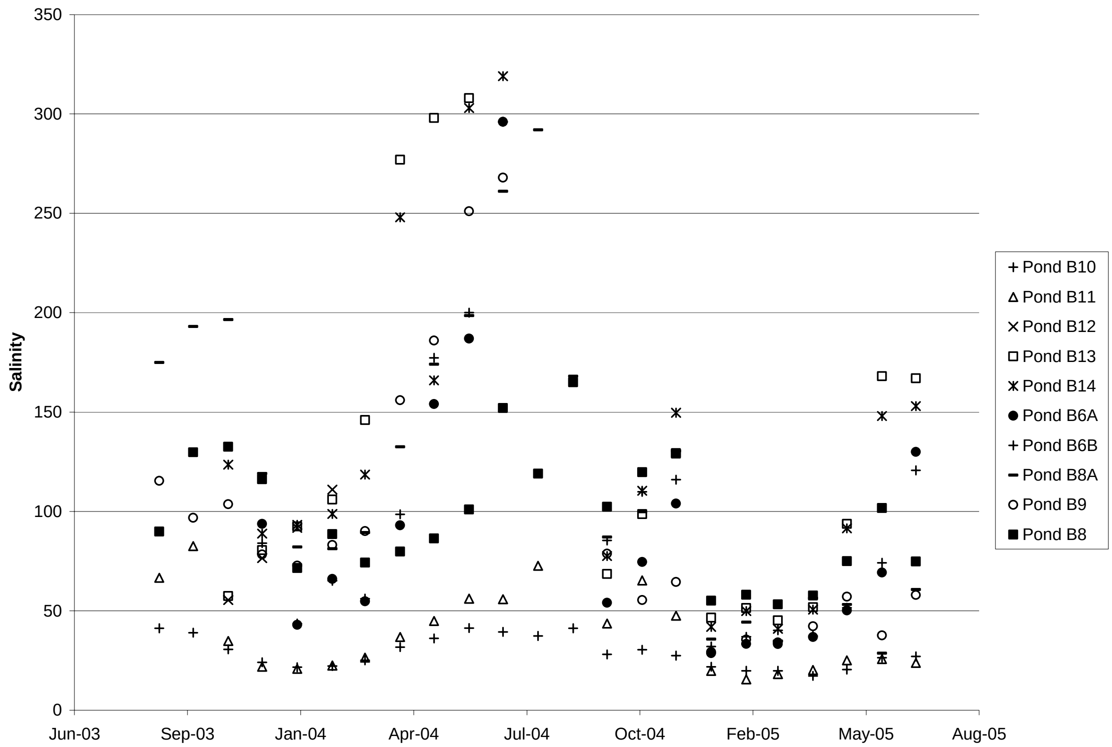


Figure 75b. Standard deviation of salinity, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

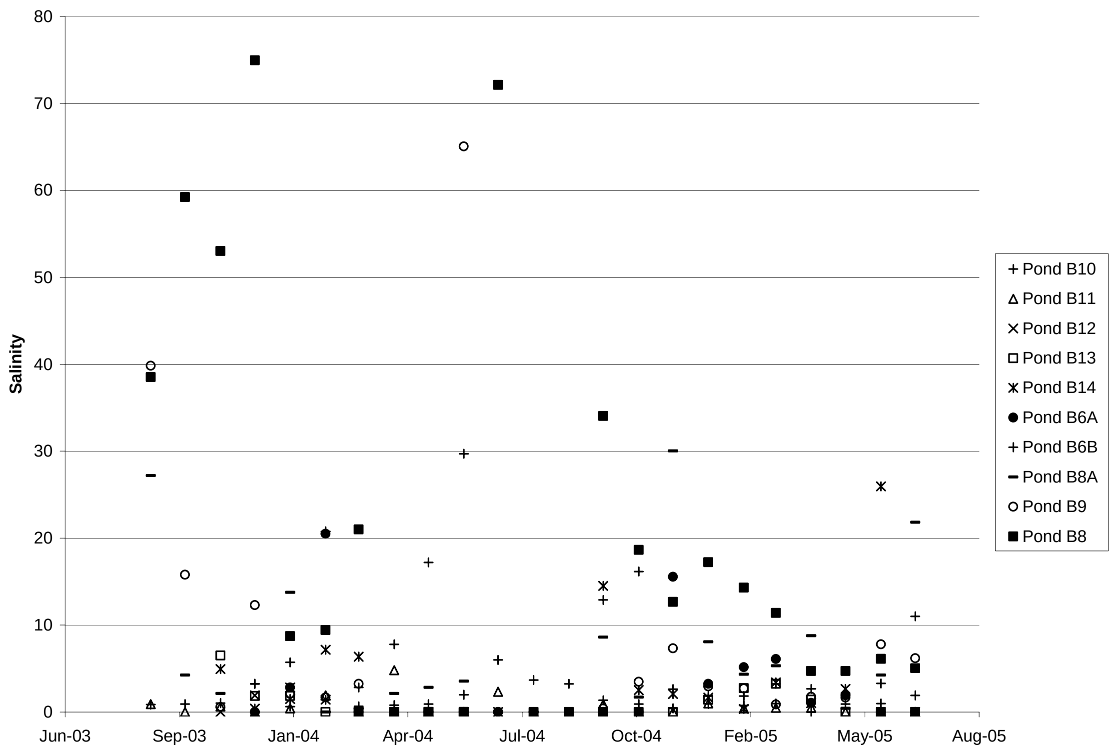


Figure 76a. Average dissolved oxygen (mg/l), Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

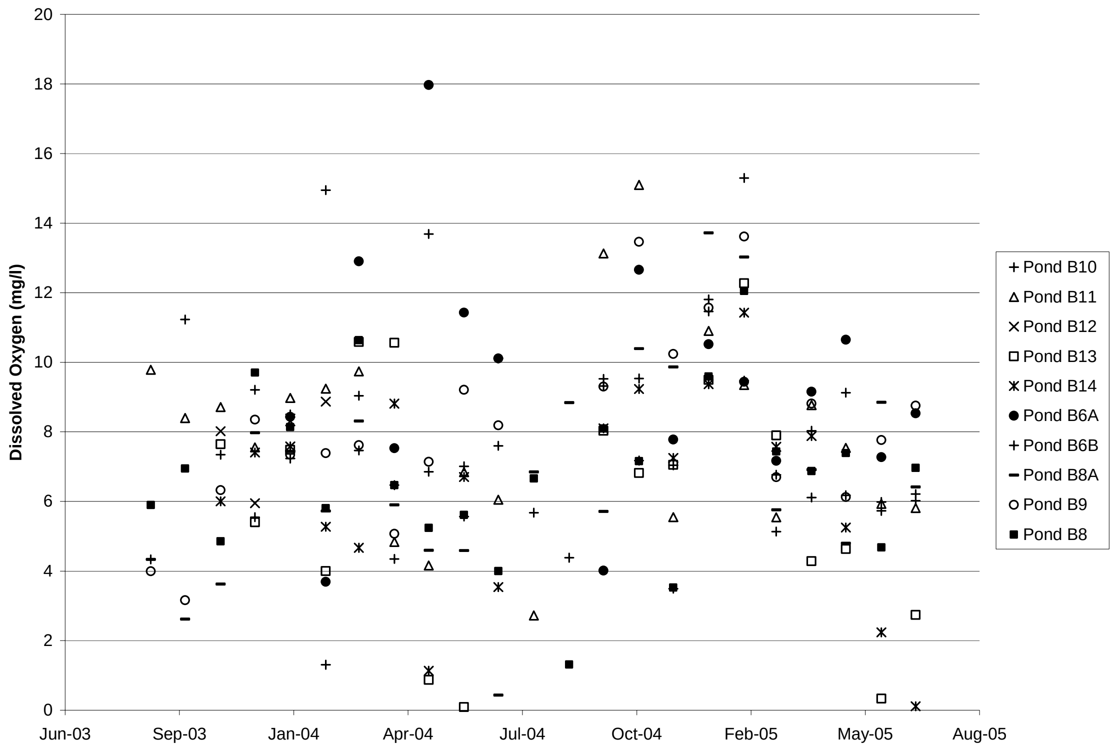


Figure 76b. Standard deviation of dissolved oxygen, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

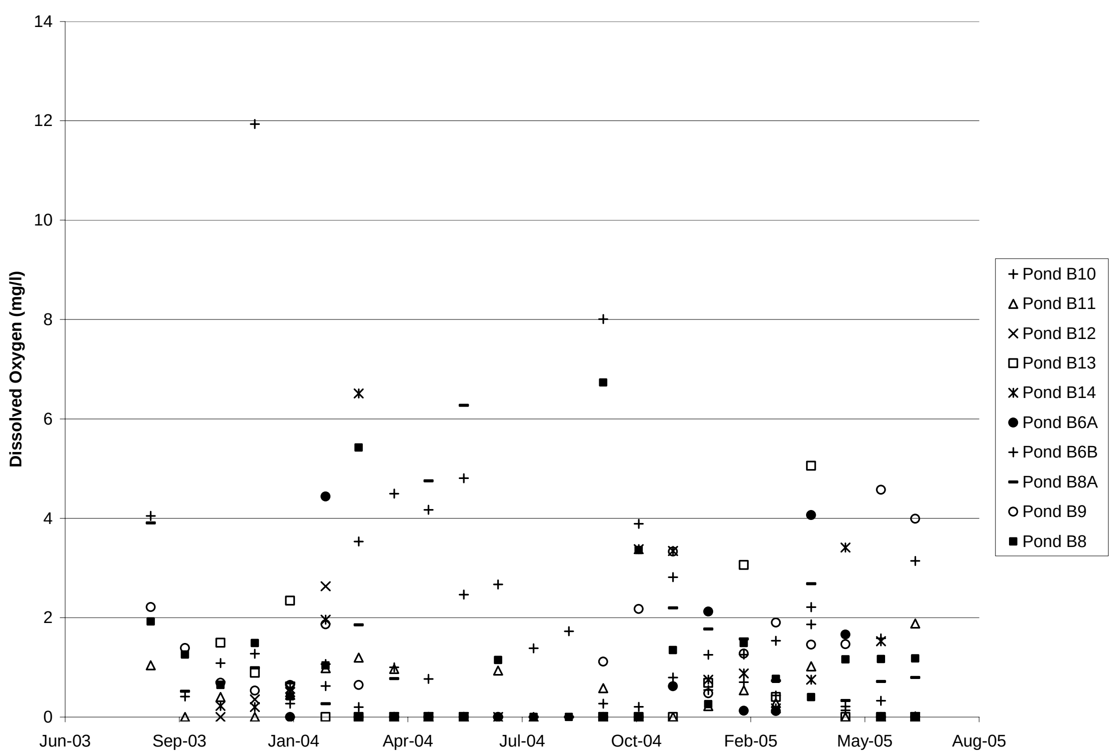


Figure 77a. Average water temperature (°C), Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

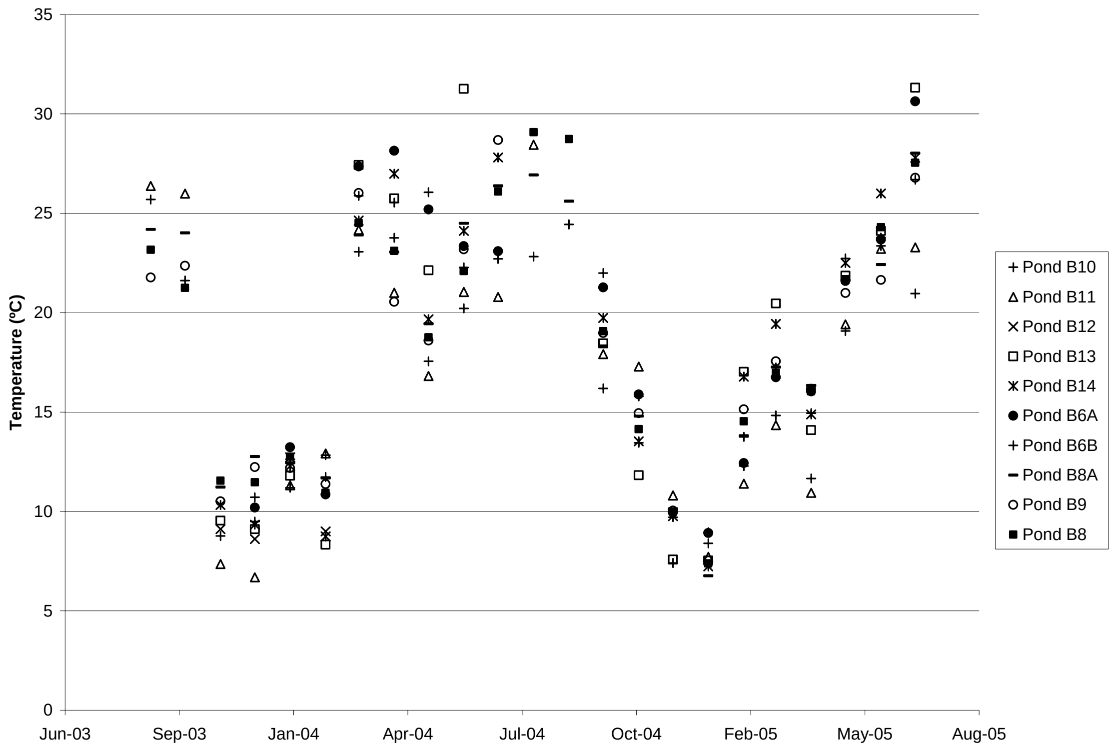


Figure 77b. Standard deviation of water temperature, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

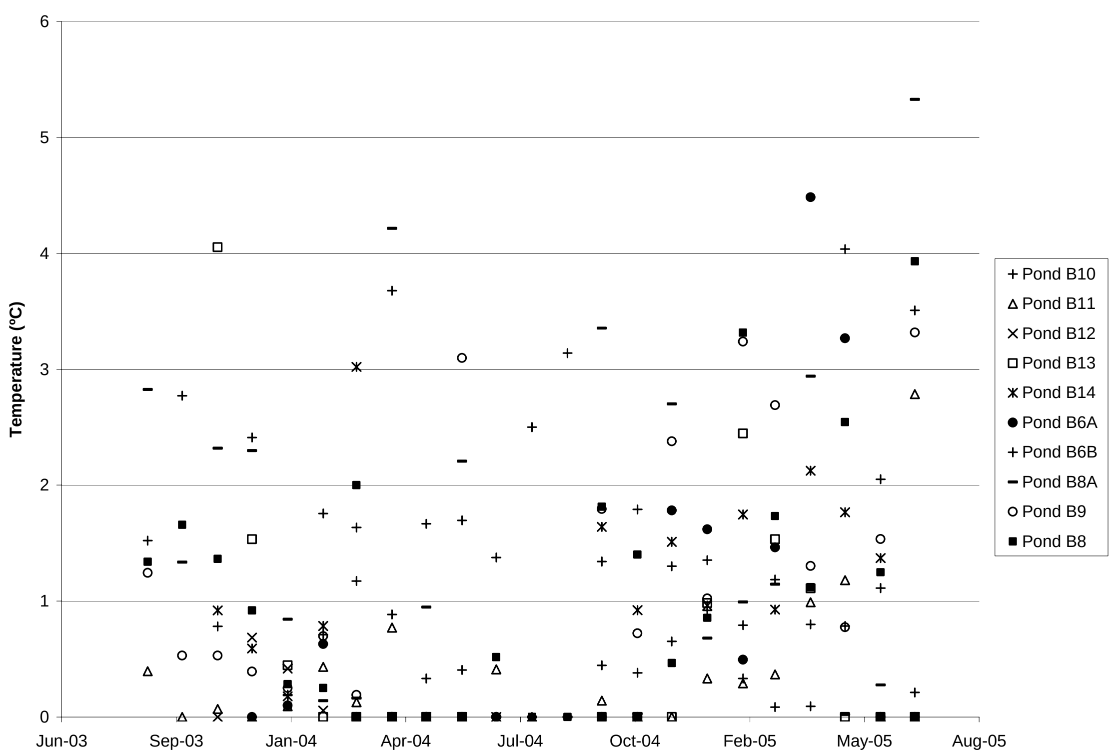


Figure 78a. Average pH, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

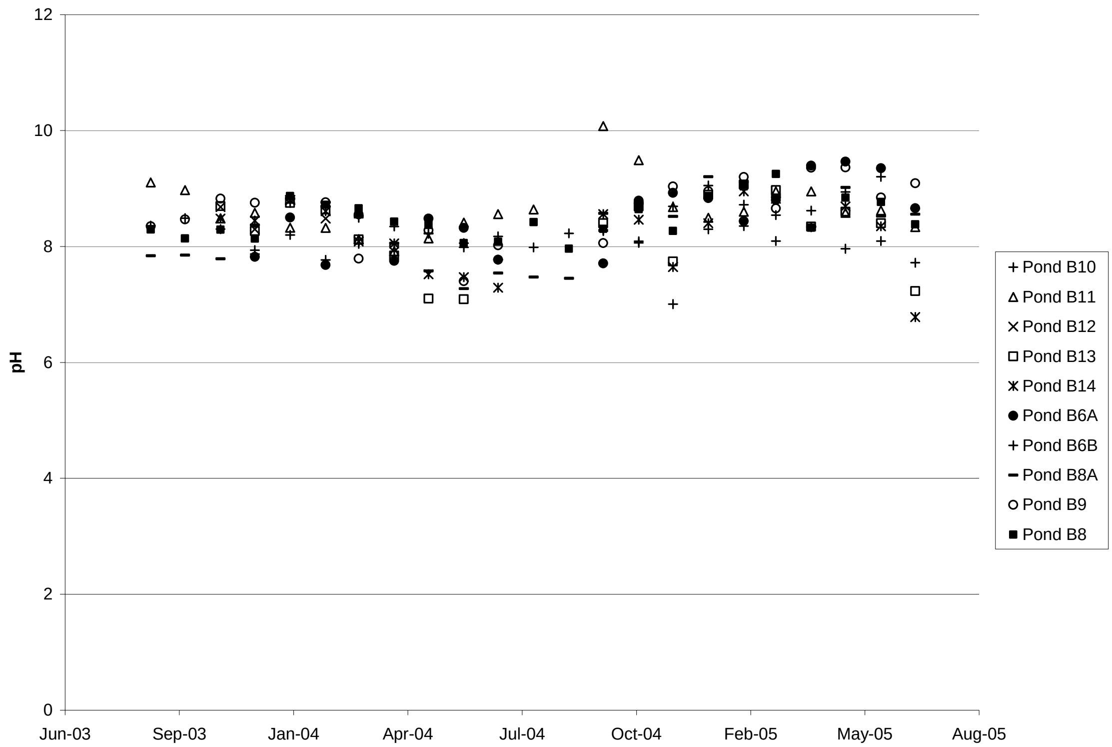


Figure 78b. Standard deviation of average pH, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

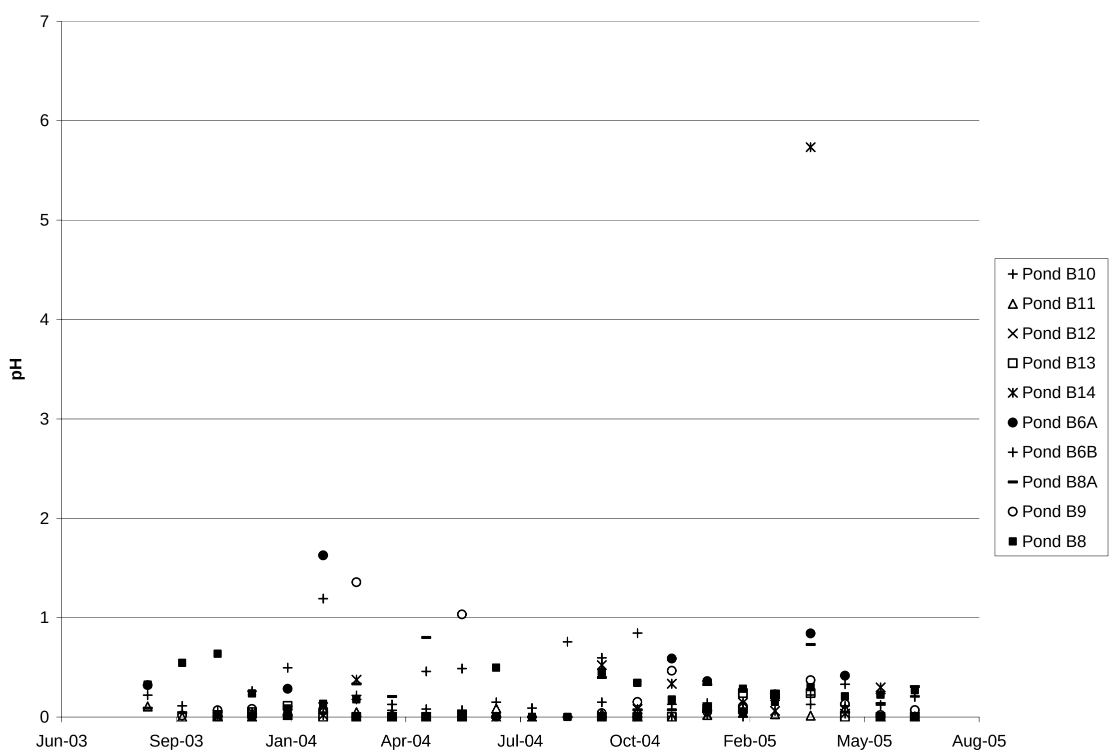


Figure 79a. Average turbidity (NTU), Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

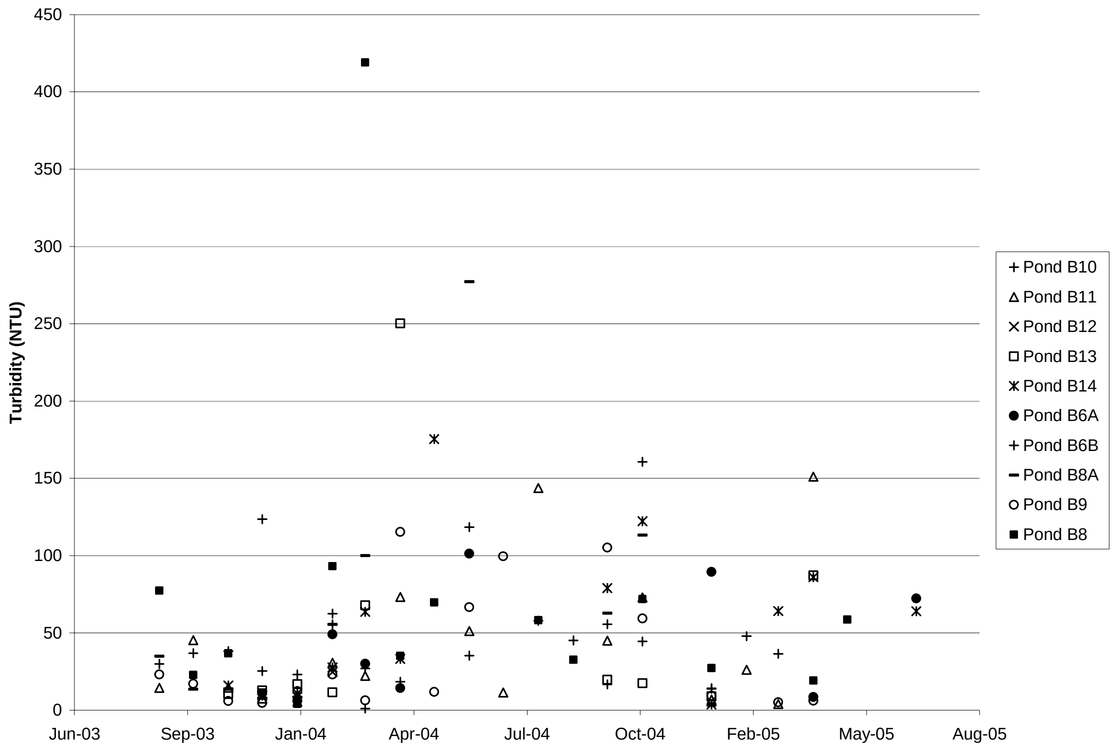


Figure 79b. Standard deviation of average turbidity, Upper Eden Landing ponds B6A, B6B, B8A B8-B14, Eden Landing salt ponds, San Francisco Bay, CA.

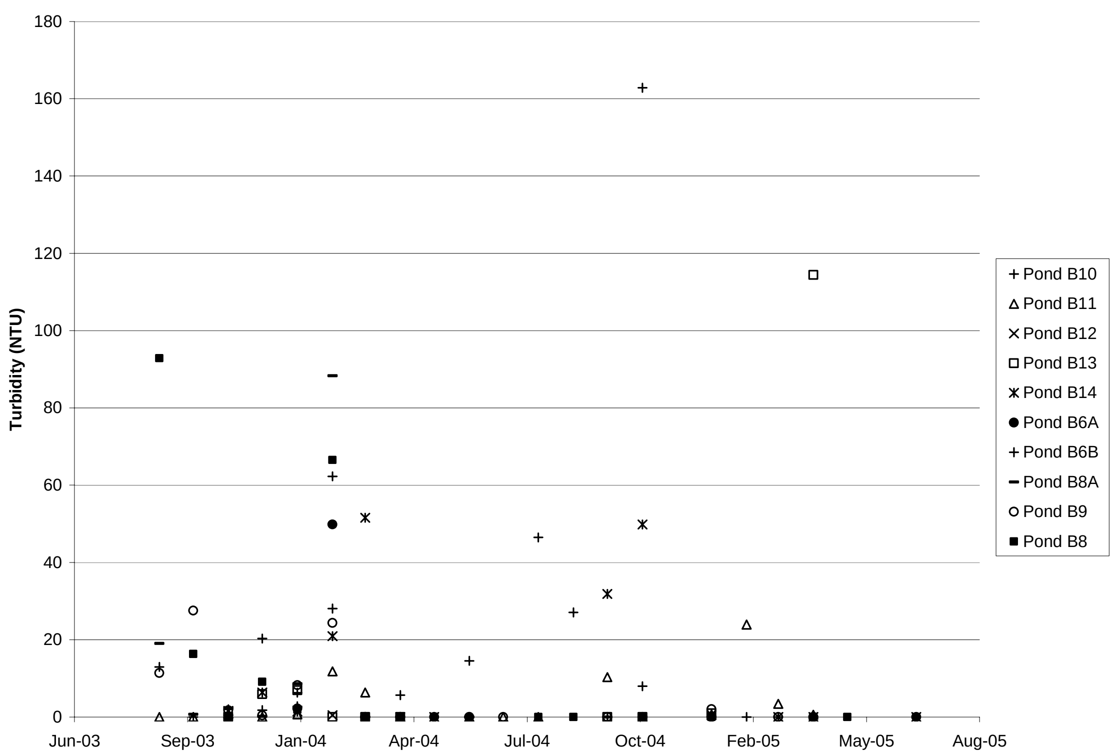


Figure 80a. Average salinity (ppt), Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

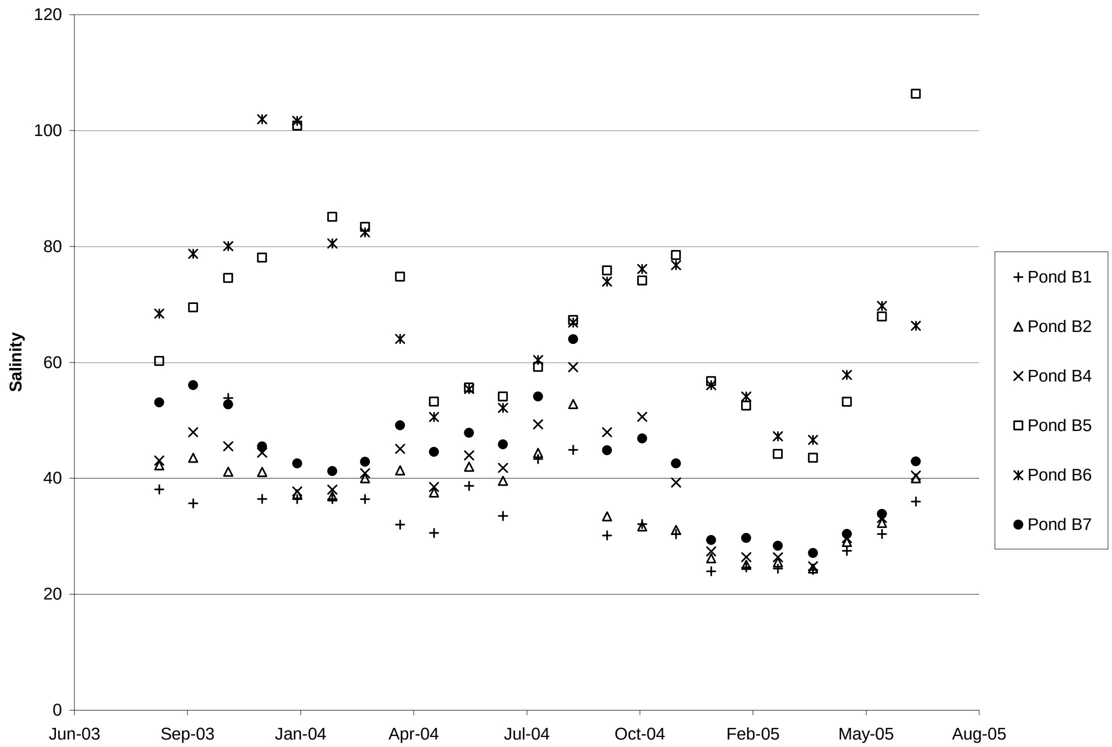


Figure 80b. Standard deviation of salinity, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

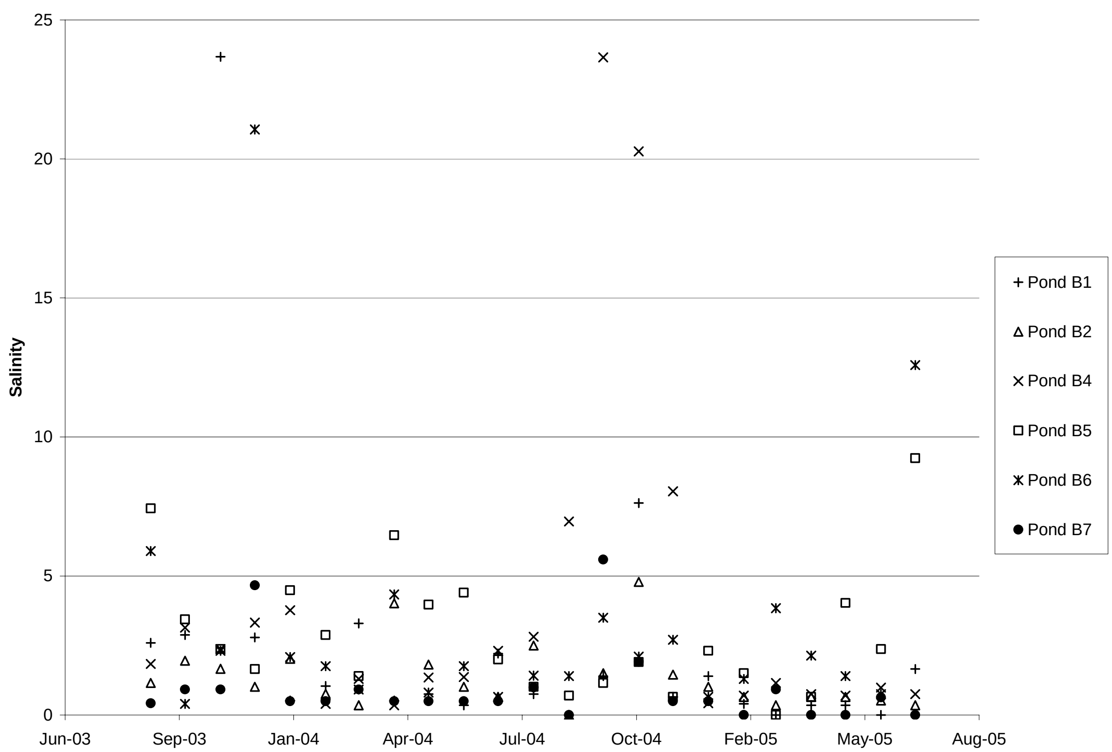


Figure 81a. Average dissolved oxygen (mg/l), Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

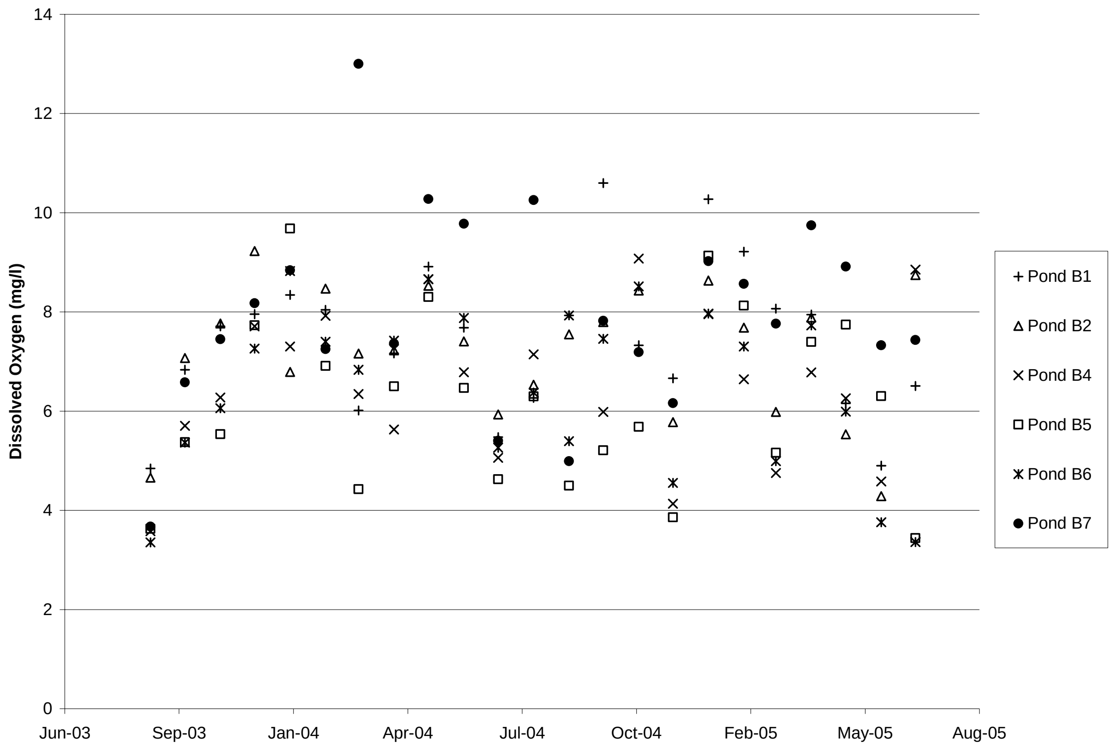


Figure 81b. Standard deviation of dissolved oxygen, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

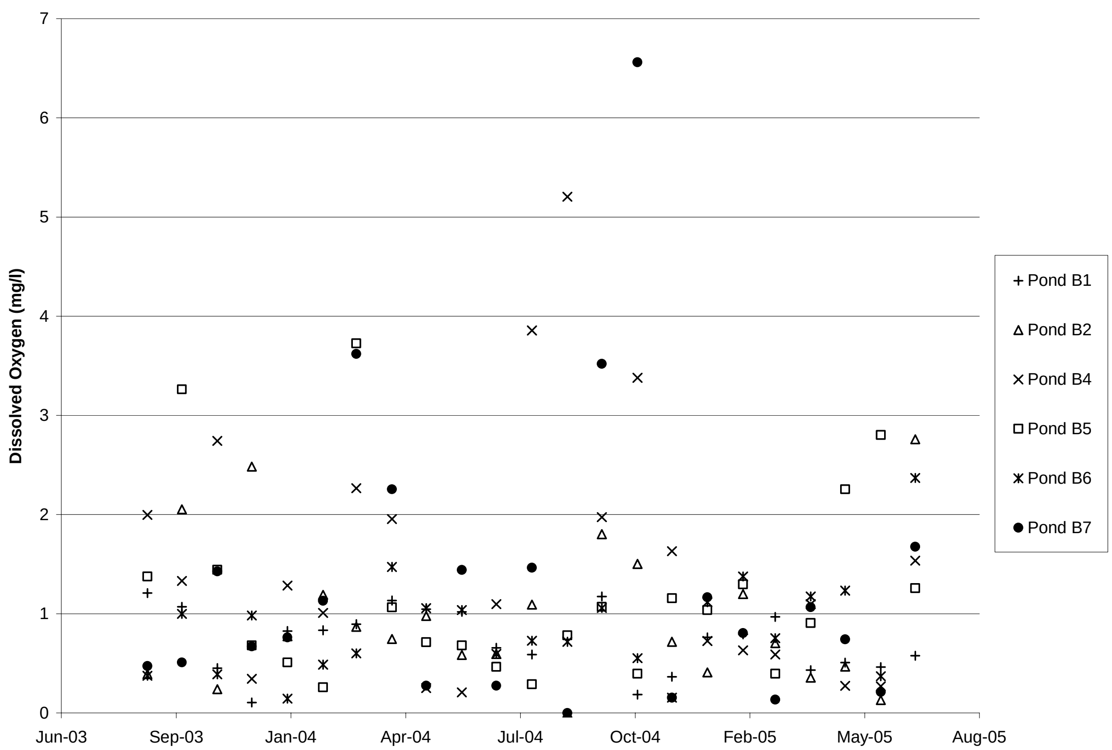


Figure 82a. Average water temperature (°C), Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

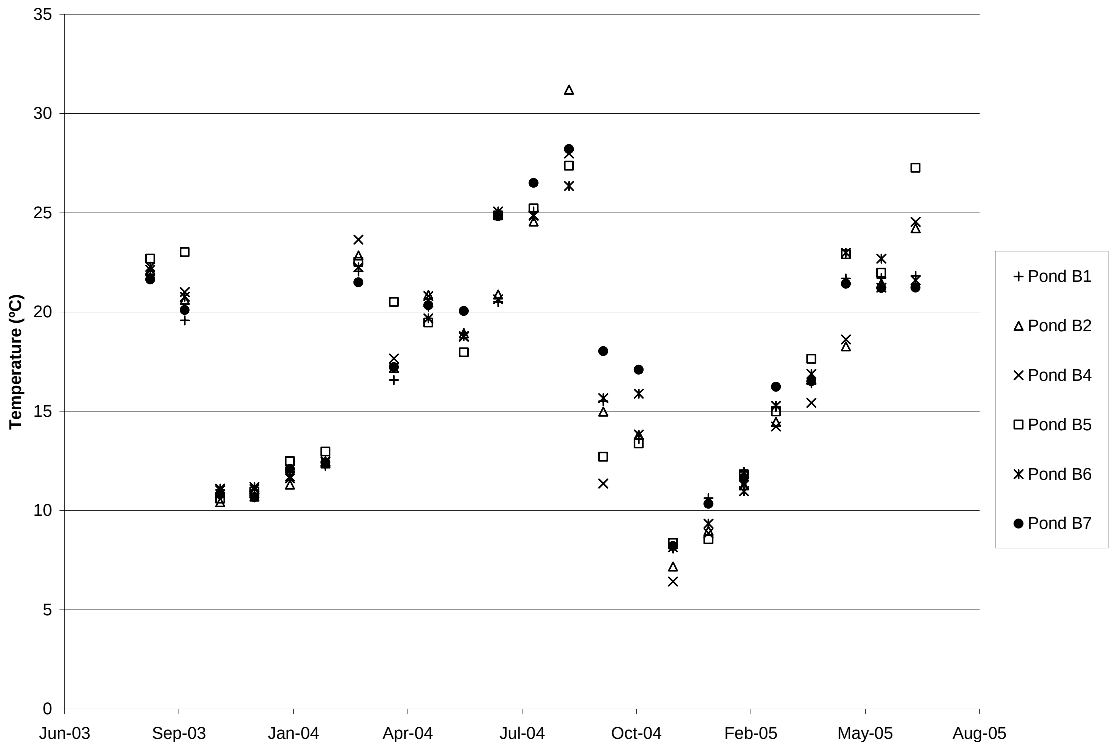


Figure 82b. Standard deviation of water temperature, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

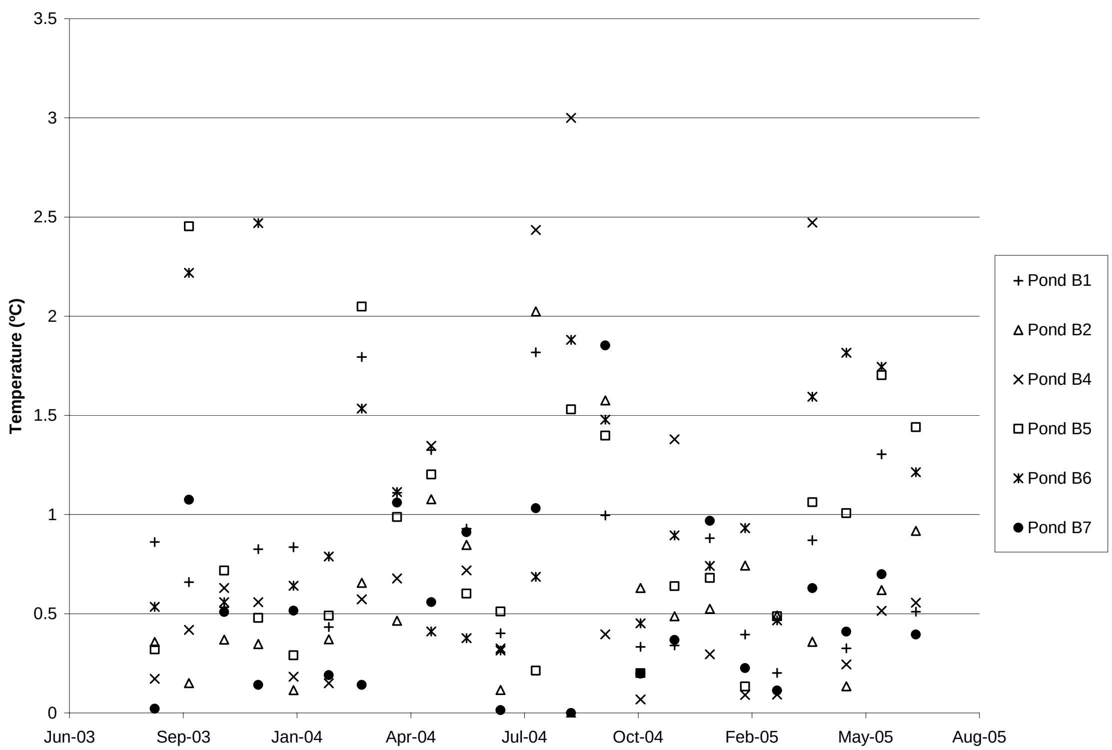


Figure 83a. Average pH, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

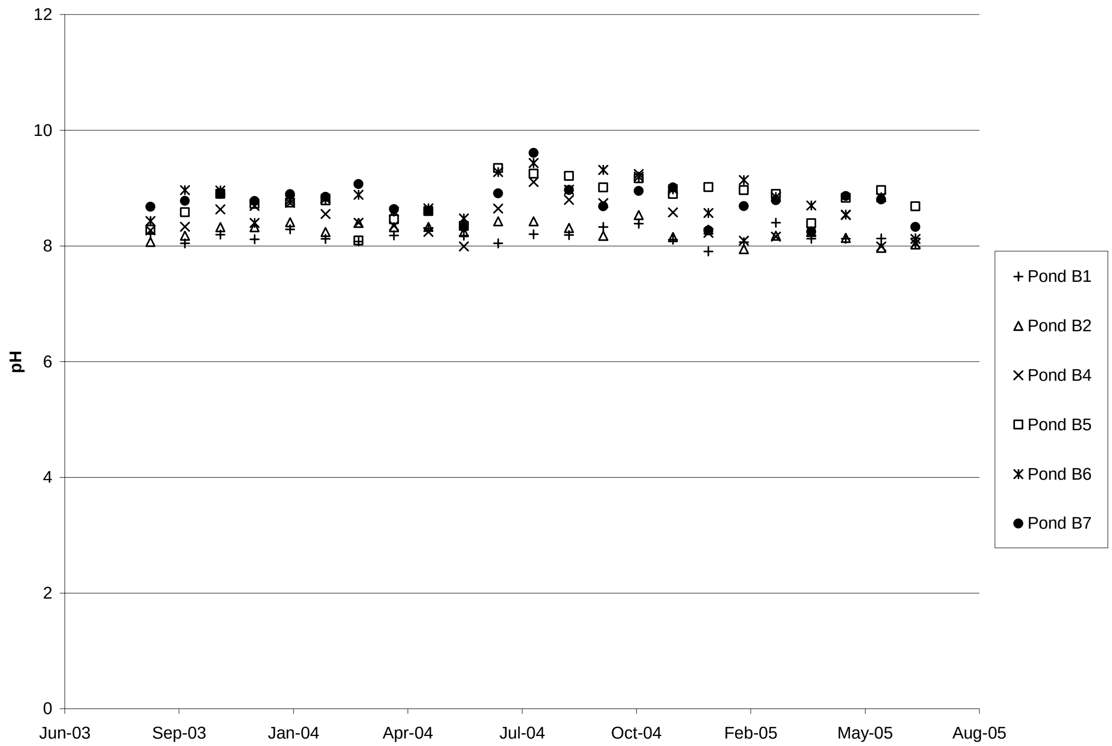


Figure 83b. Standard deviation of average pH, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

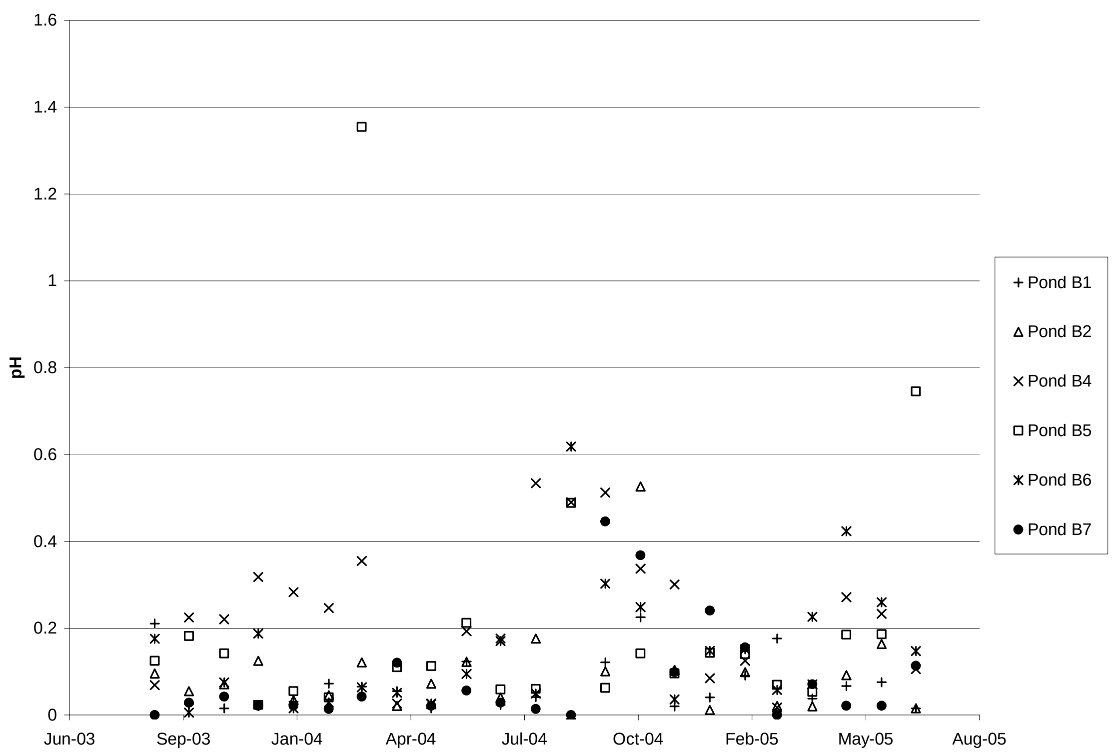


Figure 84a. Average turbidity (NTU), Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

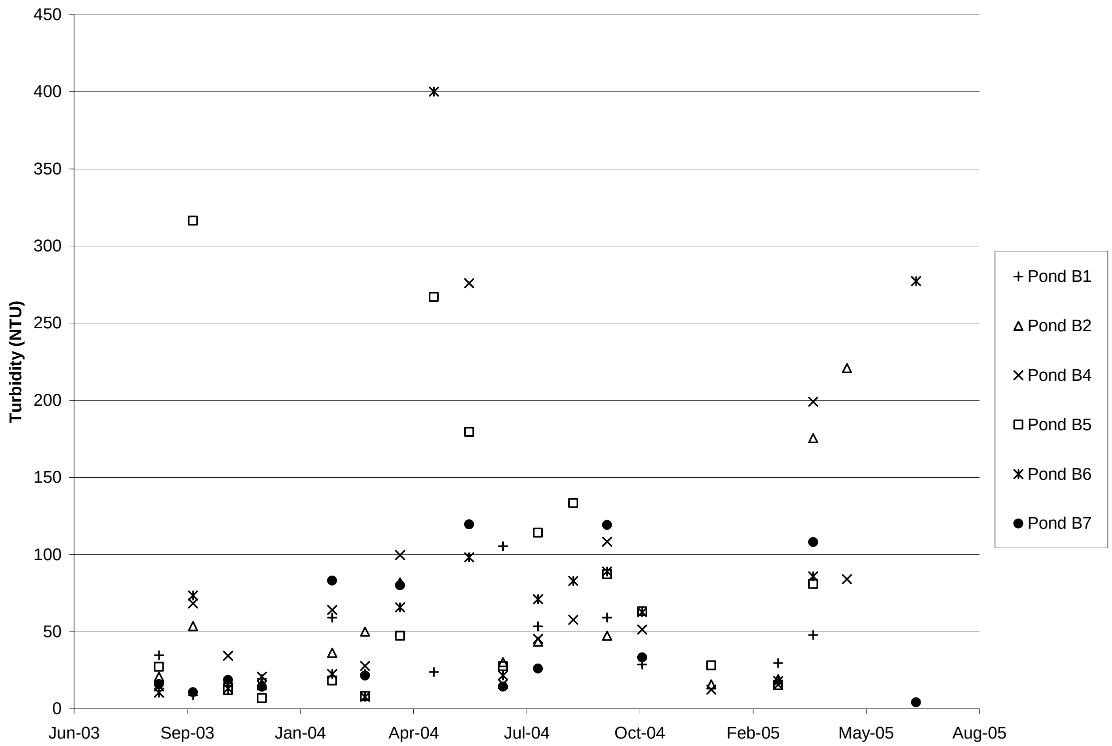


Figure 84b. Standard deviation of average turbidity, Middle Eden Landing ponds B1, B2, B4-B7, Eden Landing salt ponds, San Francisco Bay, CA.

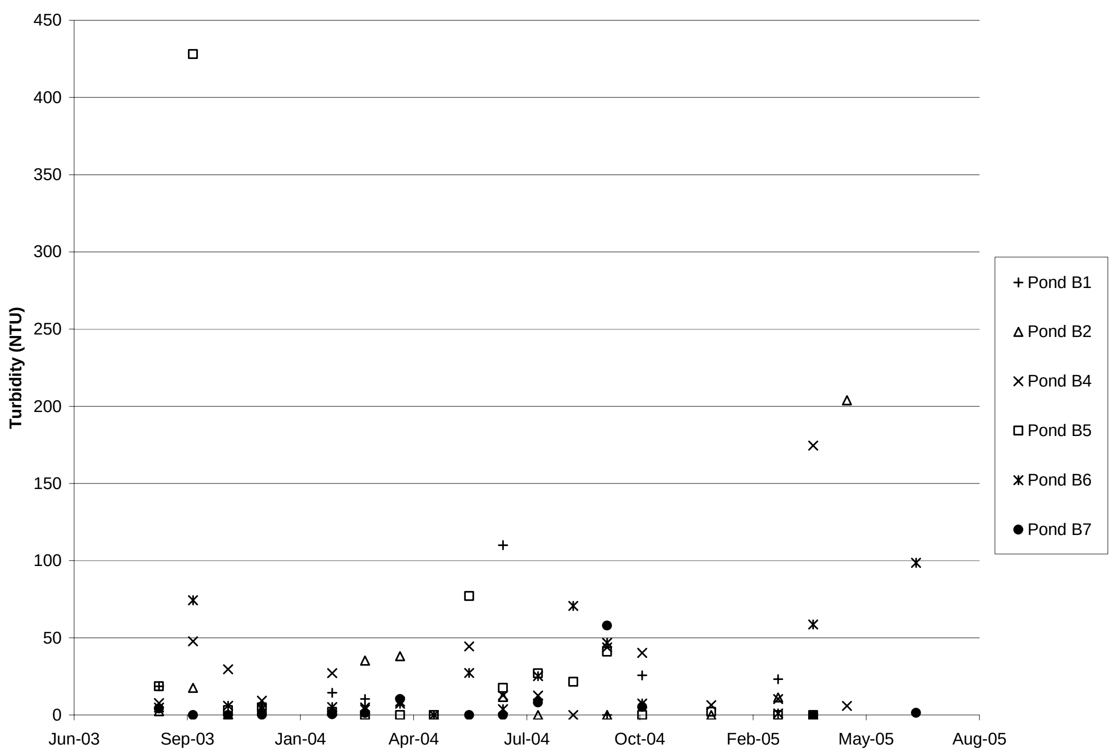


Figure 85a. Average salinity (ppt), Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

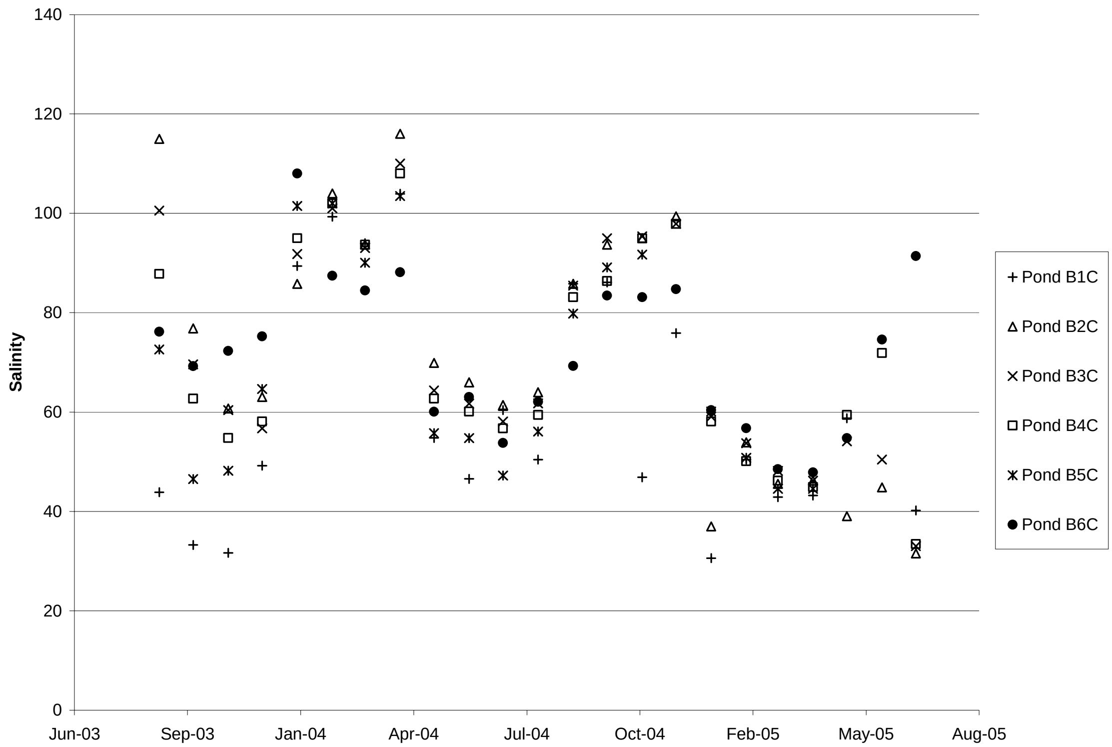


Figure 85b. Standard deviation of salinity, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

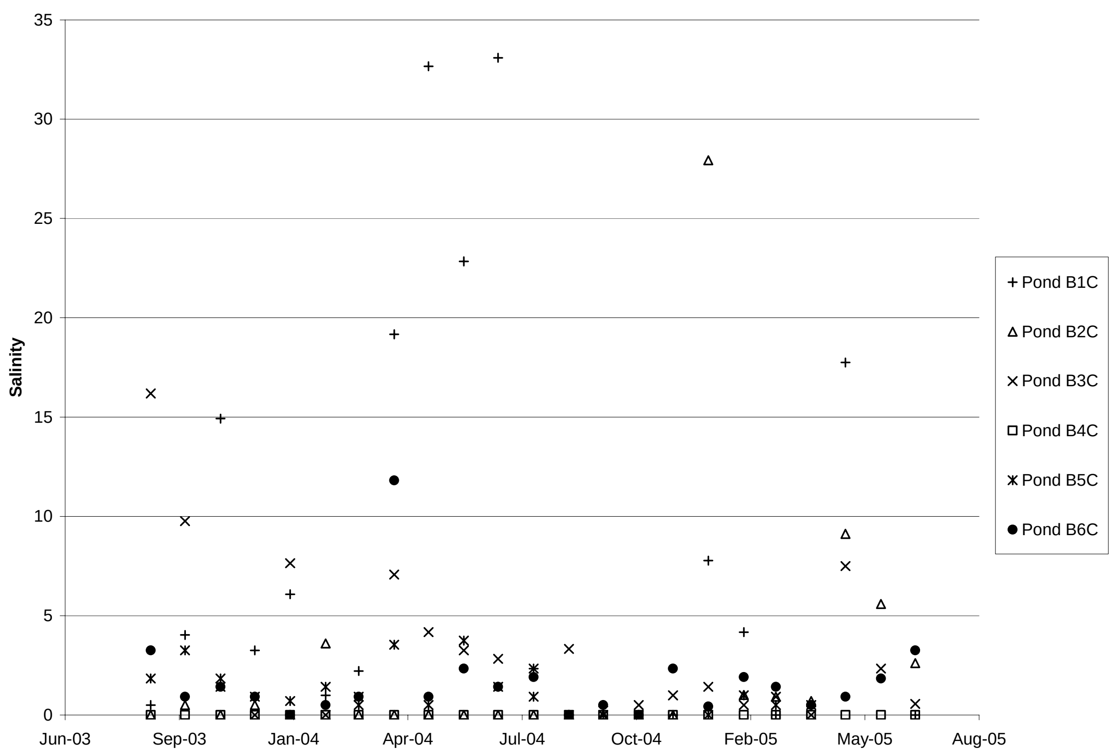


Figure 86a. Average dissolved oxygen (mg/l), Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

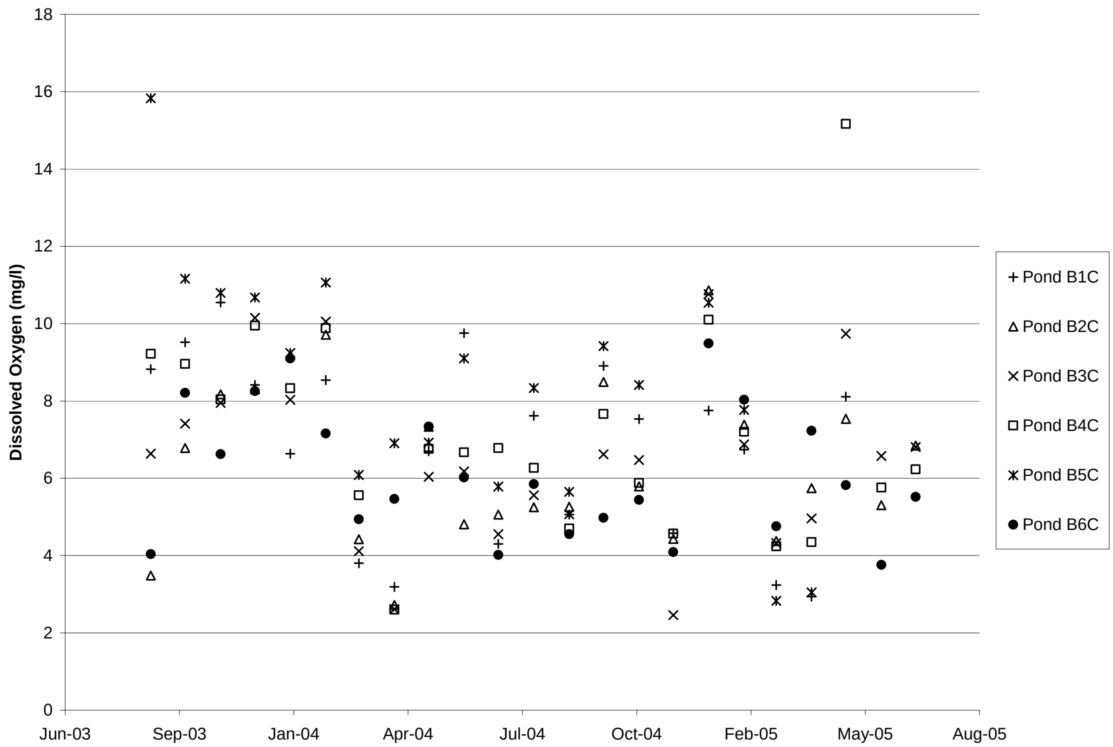


Figure 86b. Standard deviation of dissolved oxygen, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

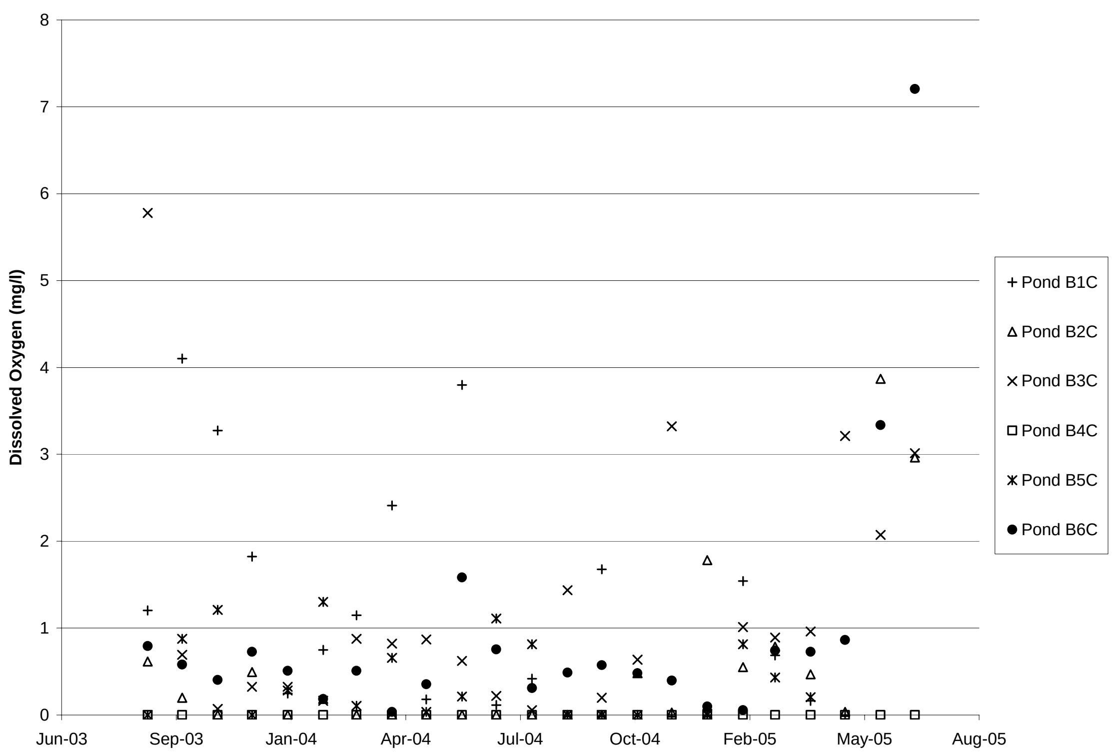


Figure 87a. Average water temperature (°C), Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

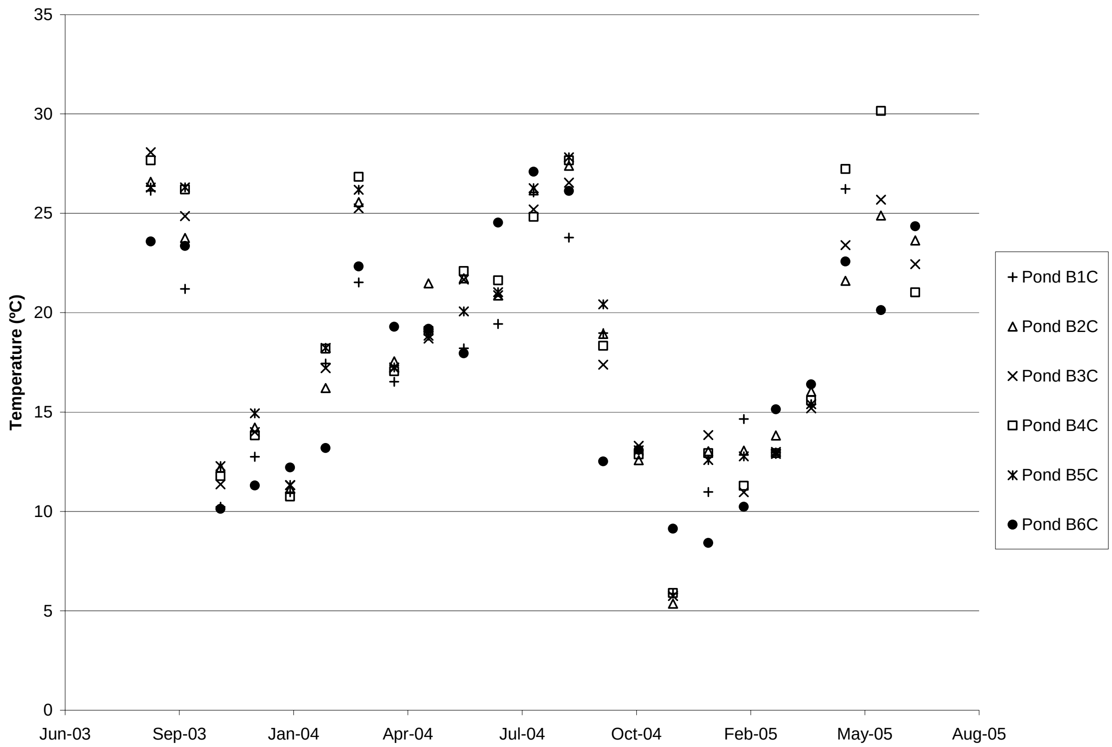


Figure 87b. Standard deviation of water temperature, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

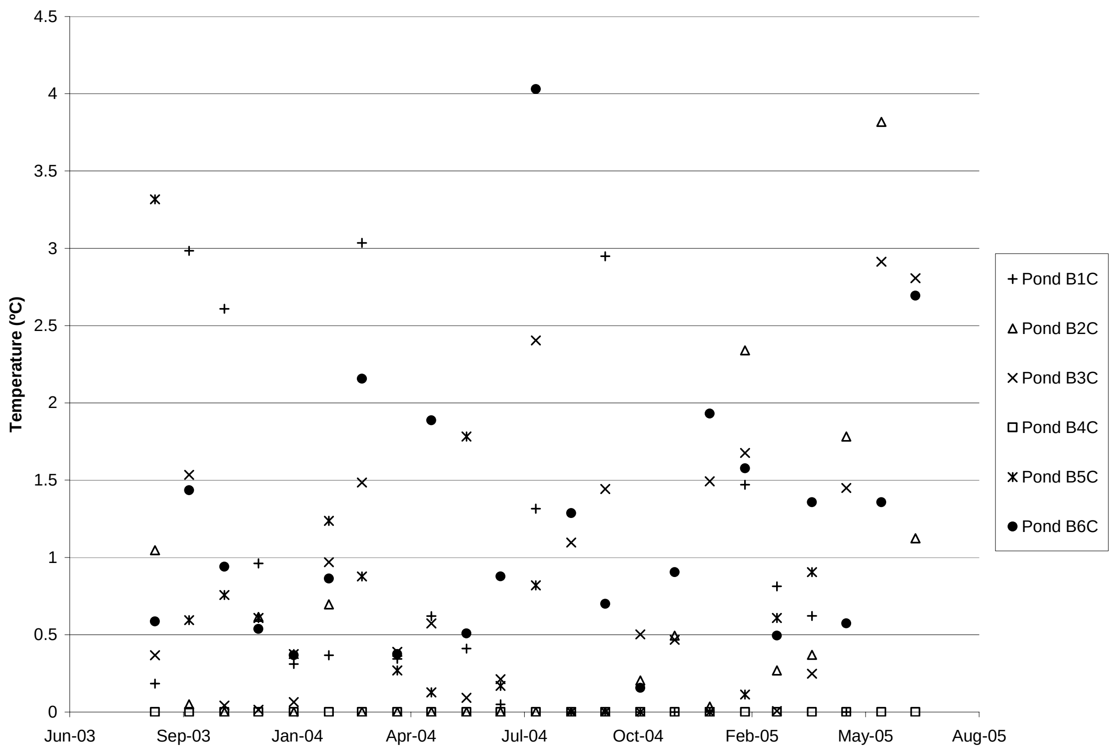


Figure 88a. Average pH, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

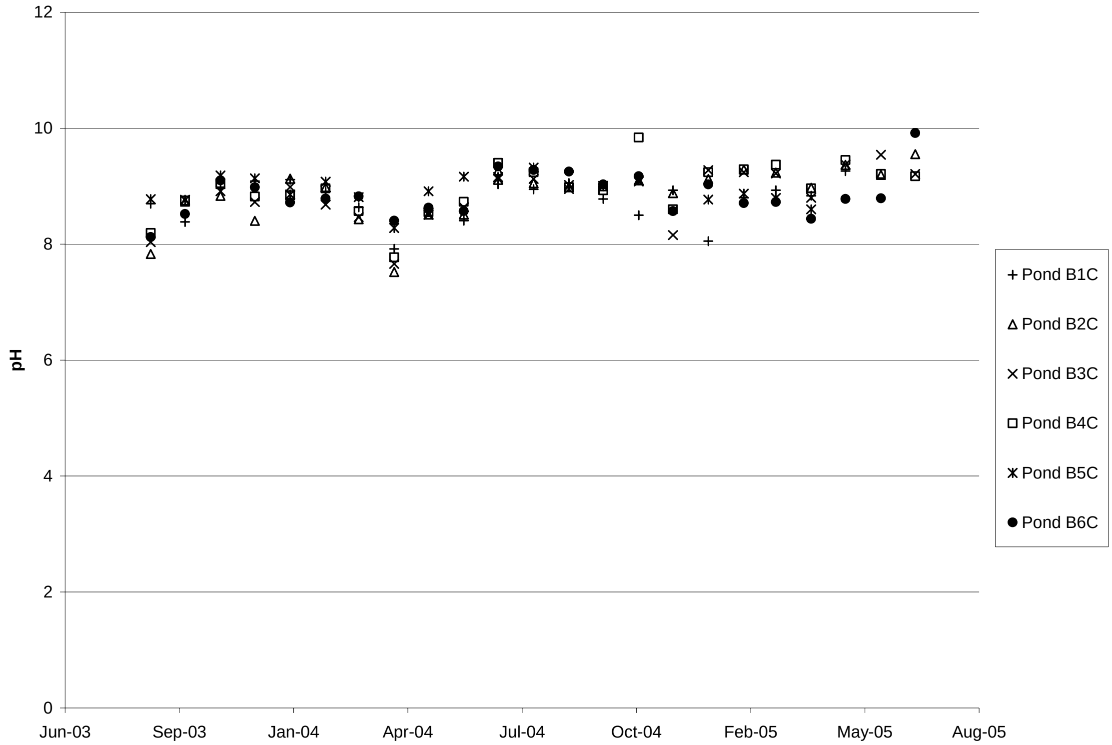


Figure 88b. Standard deviation of average pH, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

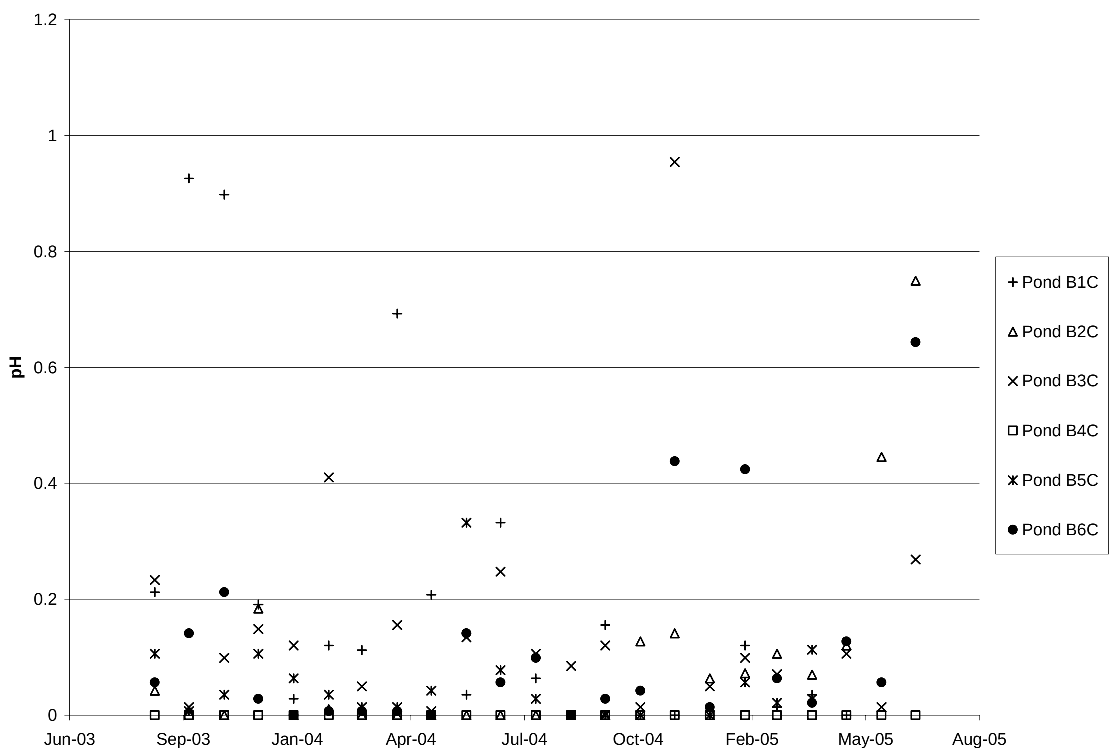


Figure 89a. Average turbidity (NTU), Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

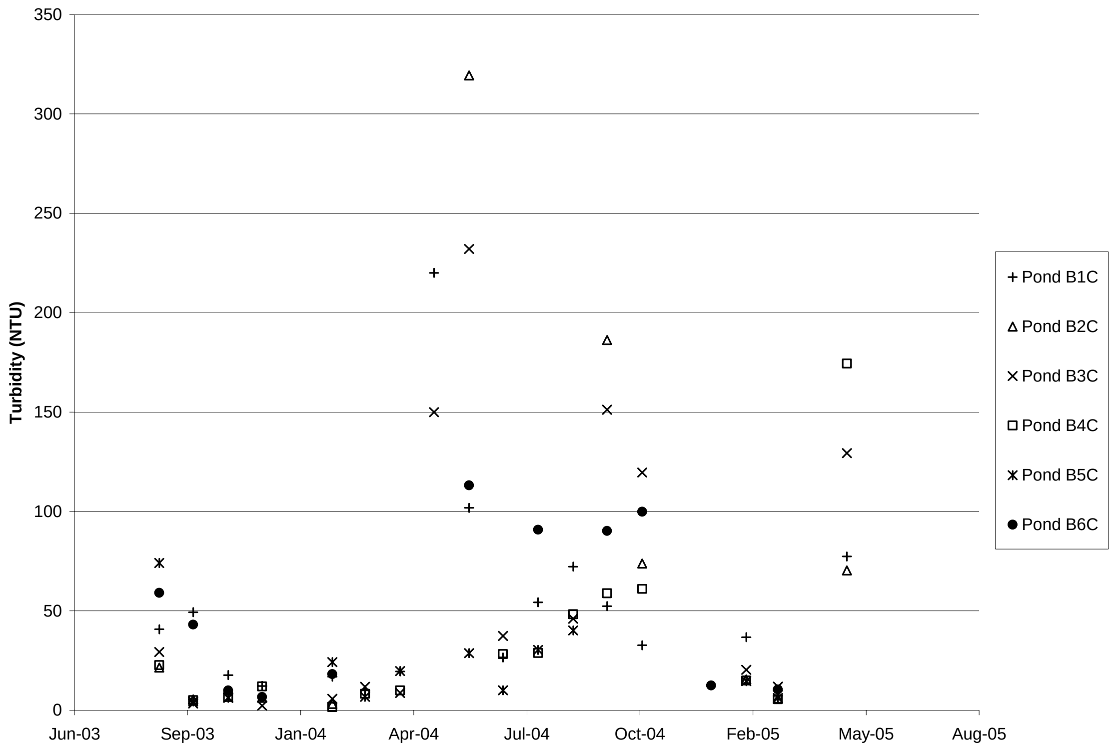


Figure 89b. Standard deviation of average turbidity, Lower Eden Landing ponds B1C-B6C, Eden Landing salt ponds, San Francisco Bay, CA.

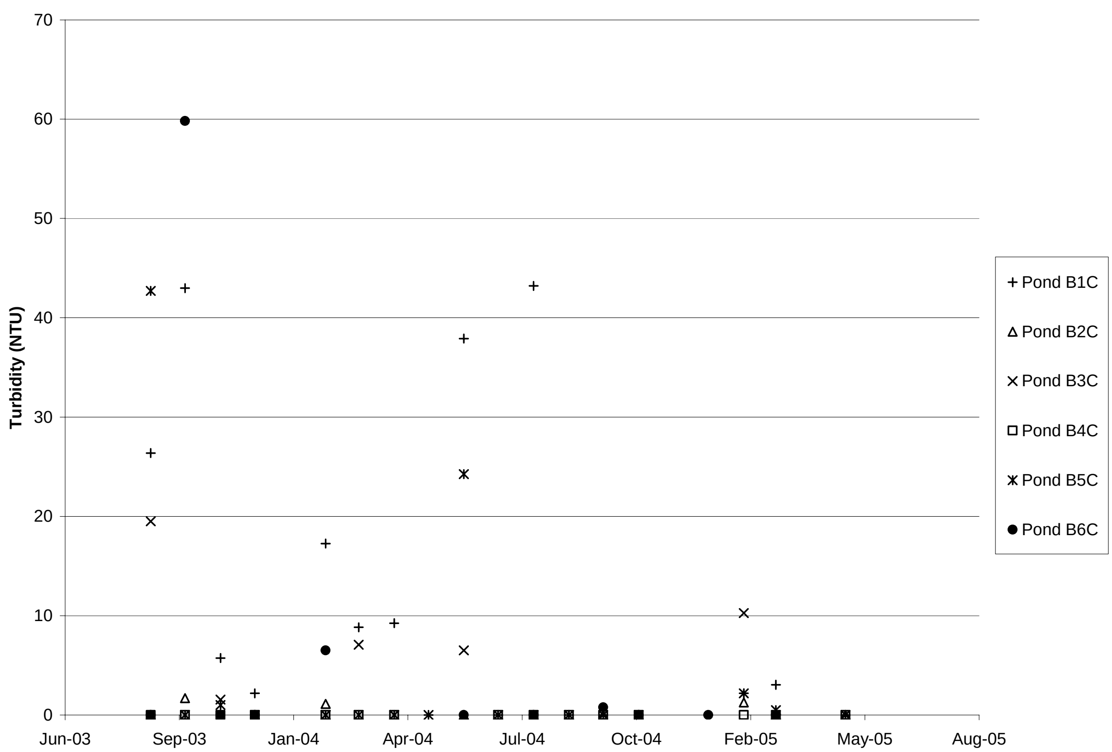


Figure 90a. Average salinity (ppt), Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

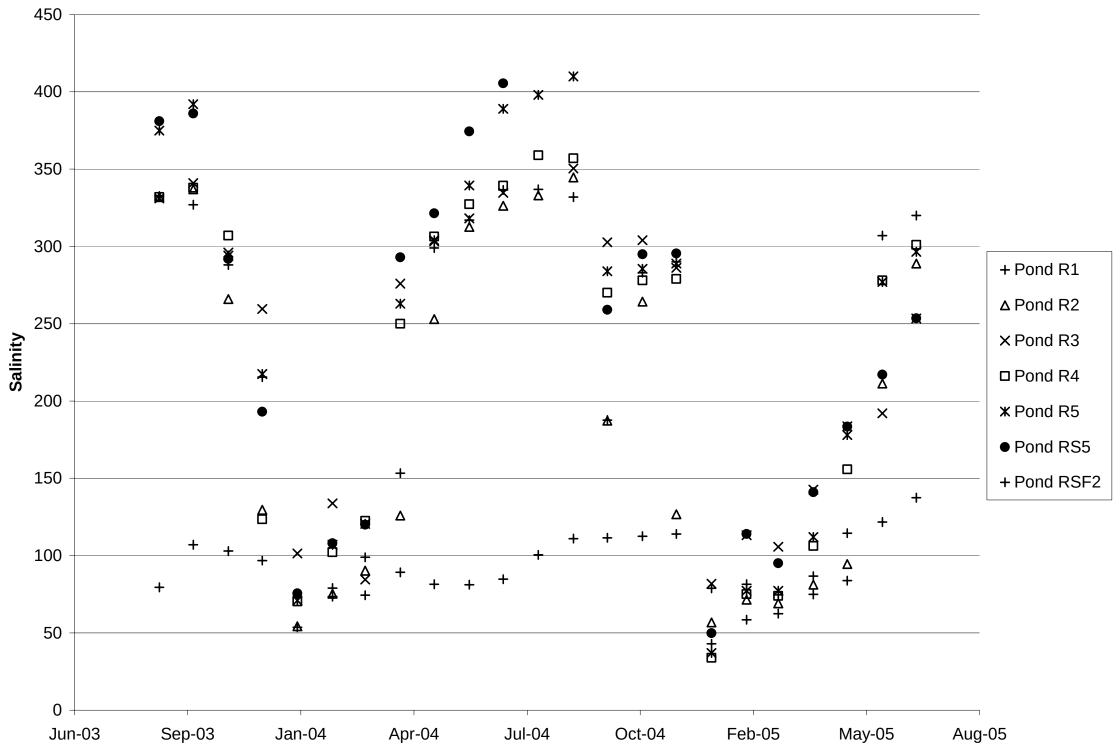


Figure 90b. Standard deviation of salinity, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

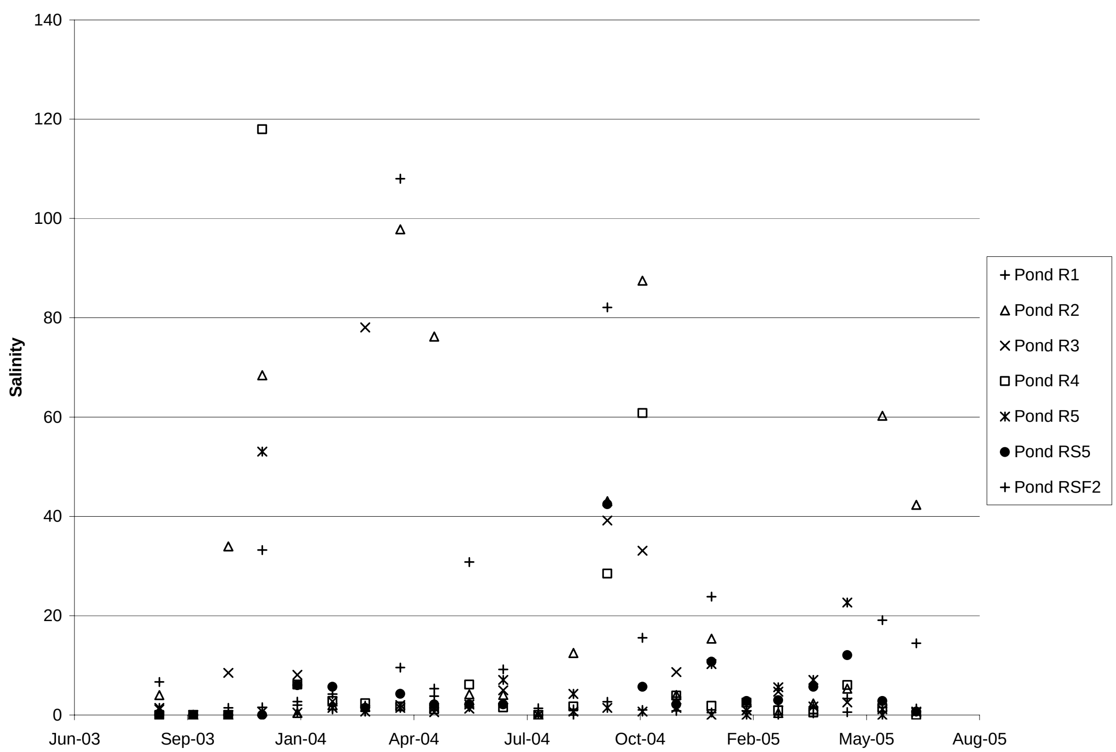


Figure 91a. Average dissolved oxygen (mg/l), Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

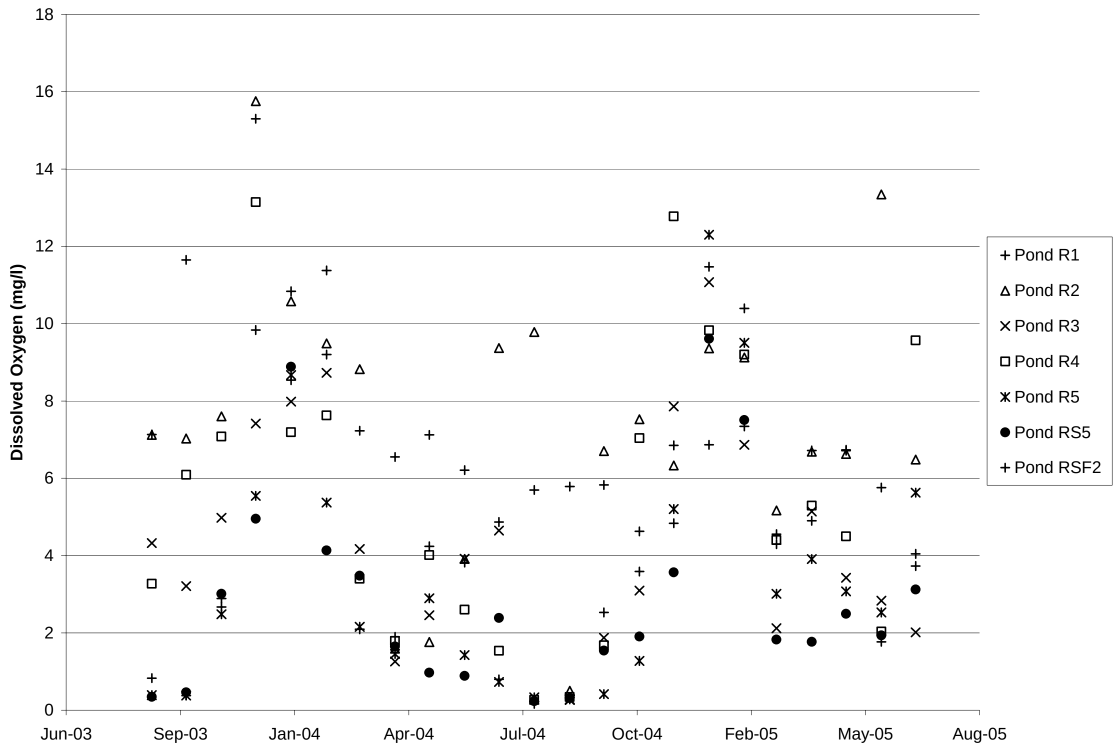


Figure 91b. Standard deviation of dissolved oxygen, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

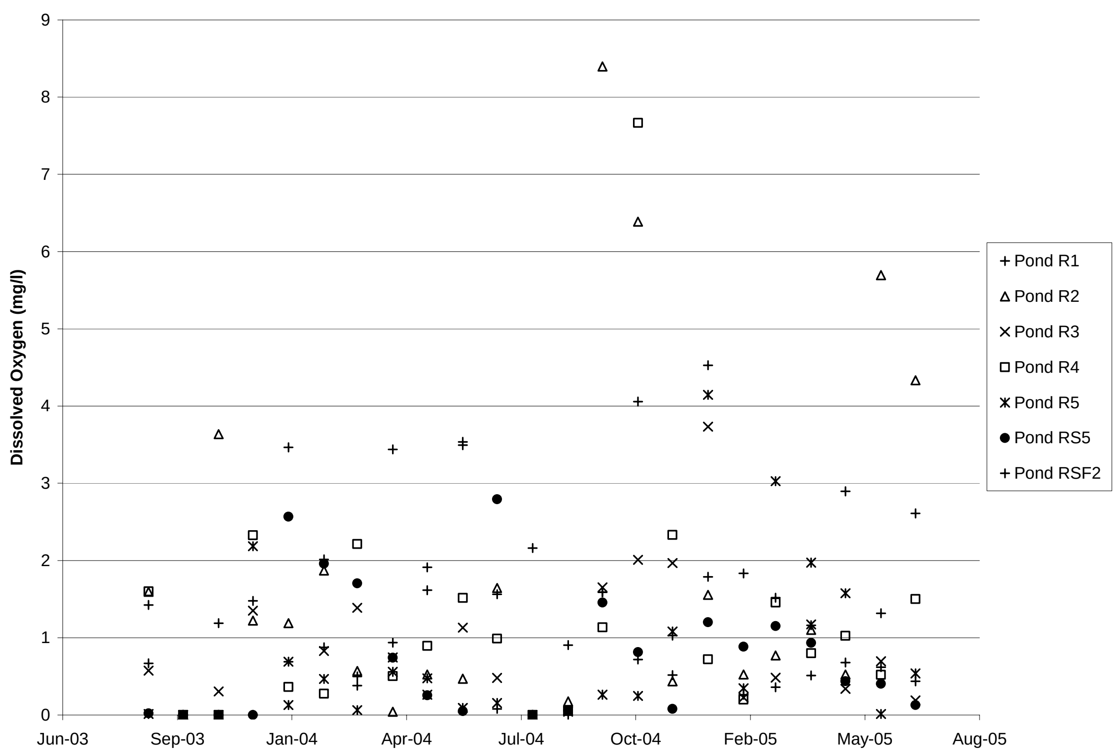


Figure 92a. Average water temperature (°C), Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

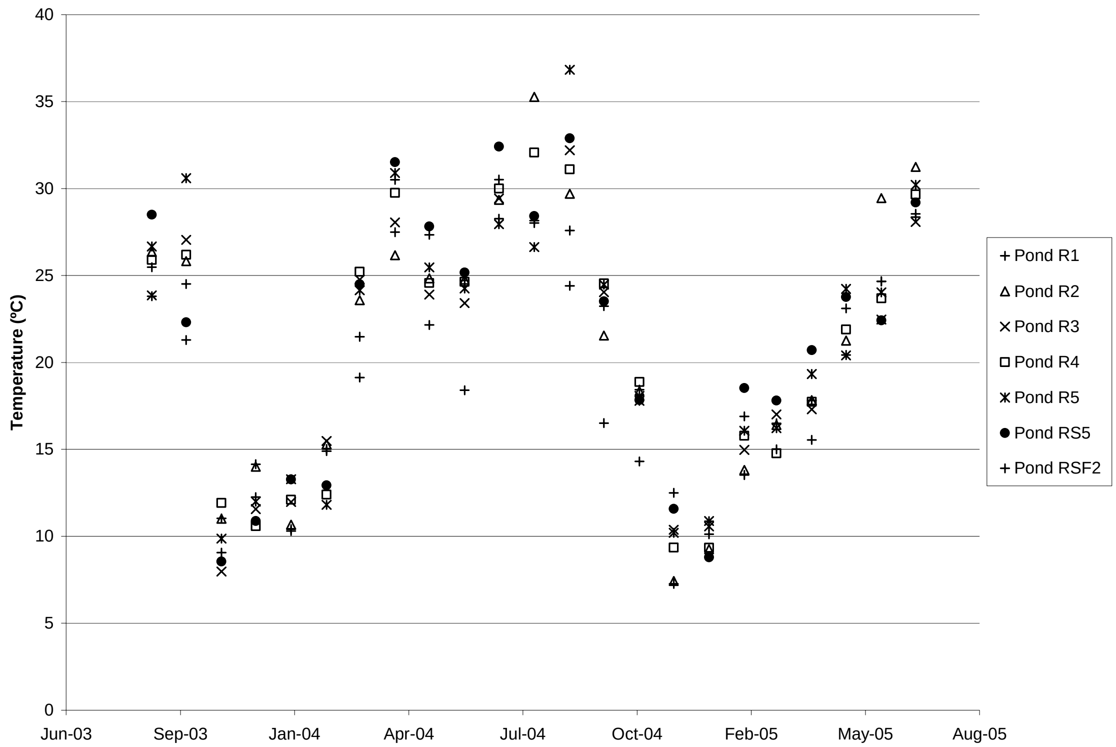


Figure 92b. Standard deviation of water temperature, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

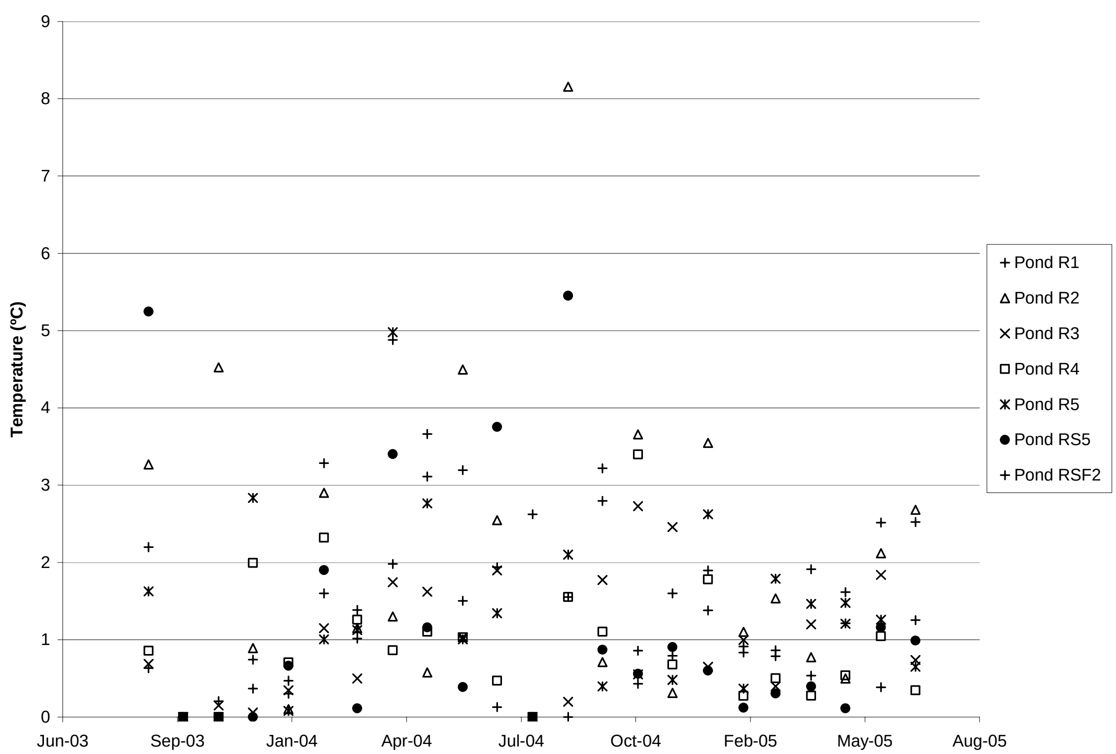


Figure 93a. Average pH, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

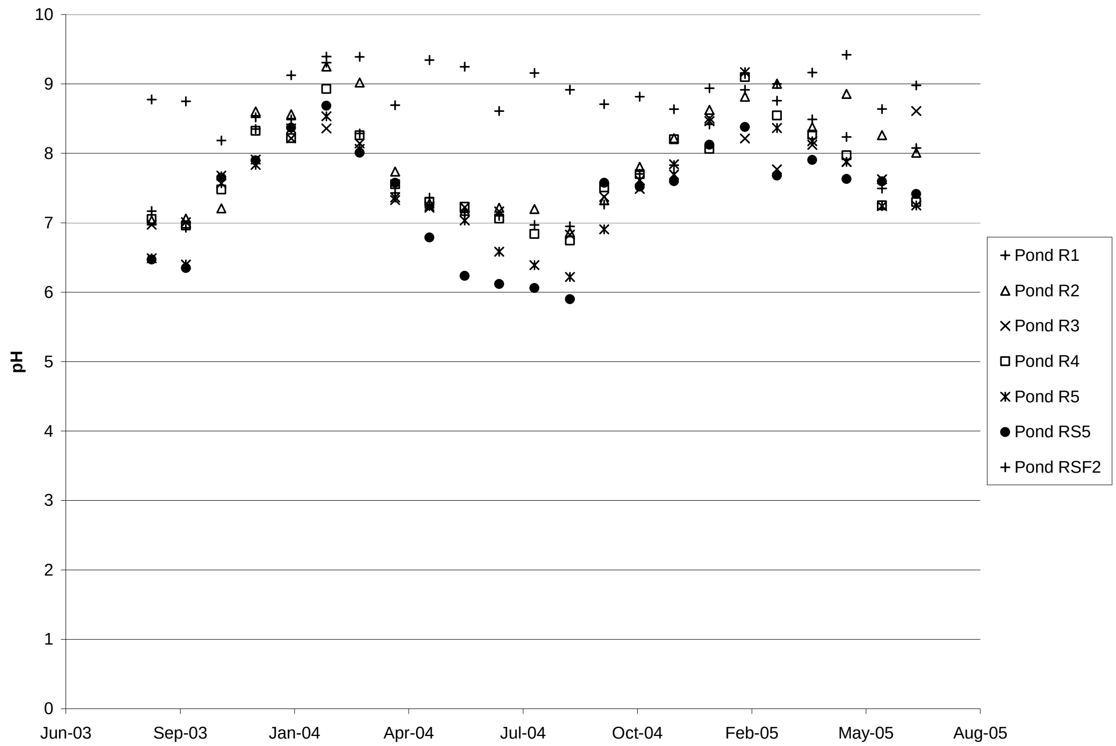


Figure 93b. Standard deviation of average pH, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

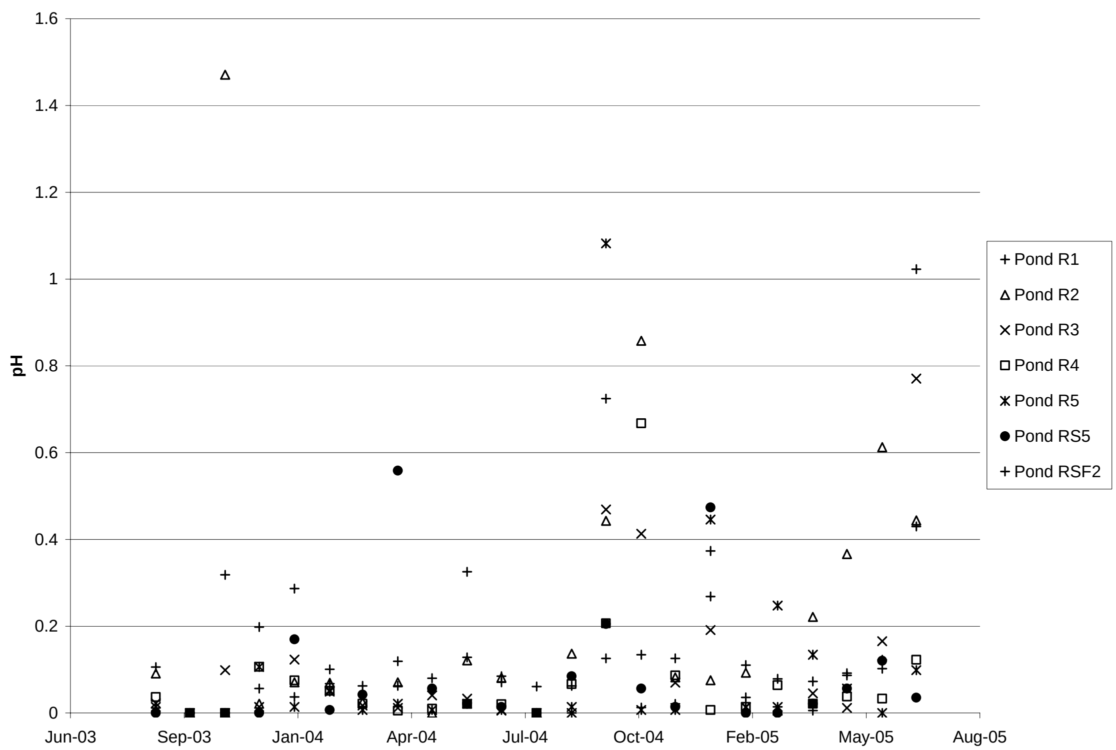


Figure 94a. Average turbidity (NTU), Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.

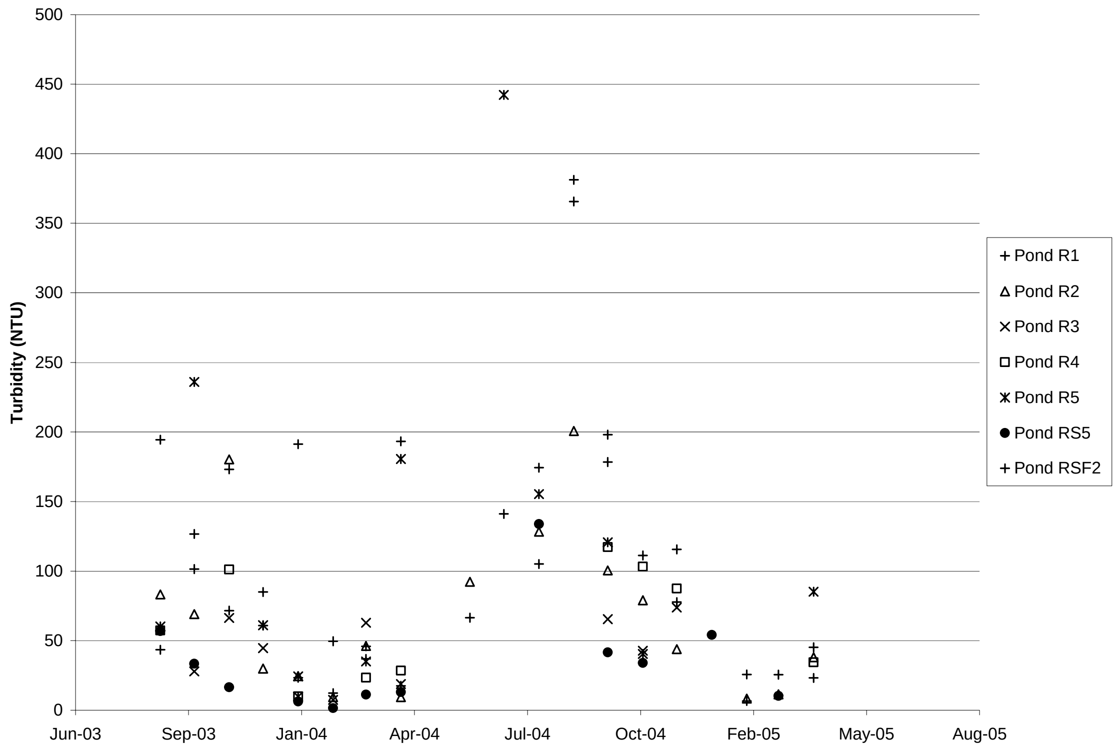
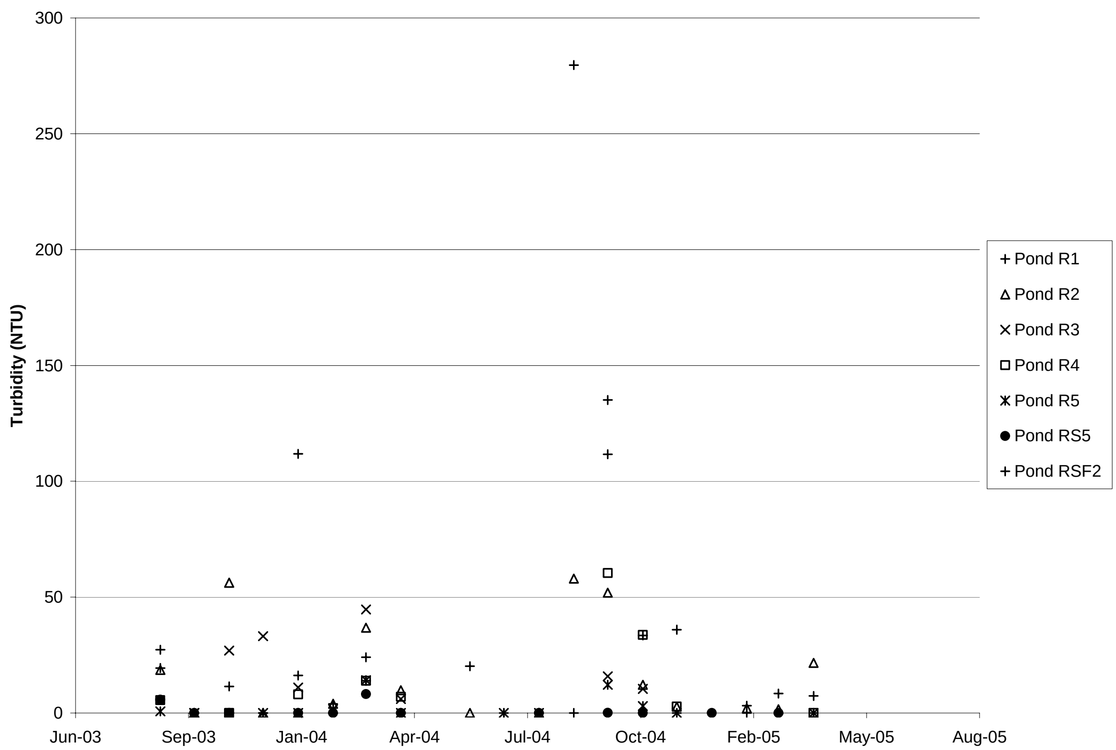


Figure 94b. Standard deviation of average turbidity, Ravenswood ponds R1-R5, RS5, and RSF2, Ravenswood salt ponds, San Francisco Bay, CA.



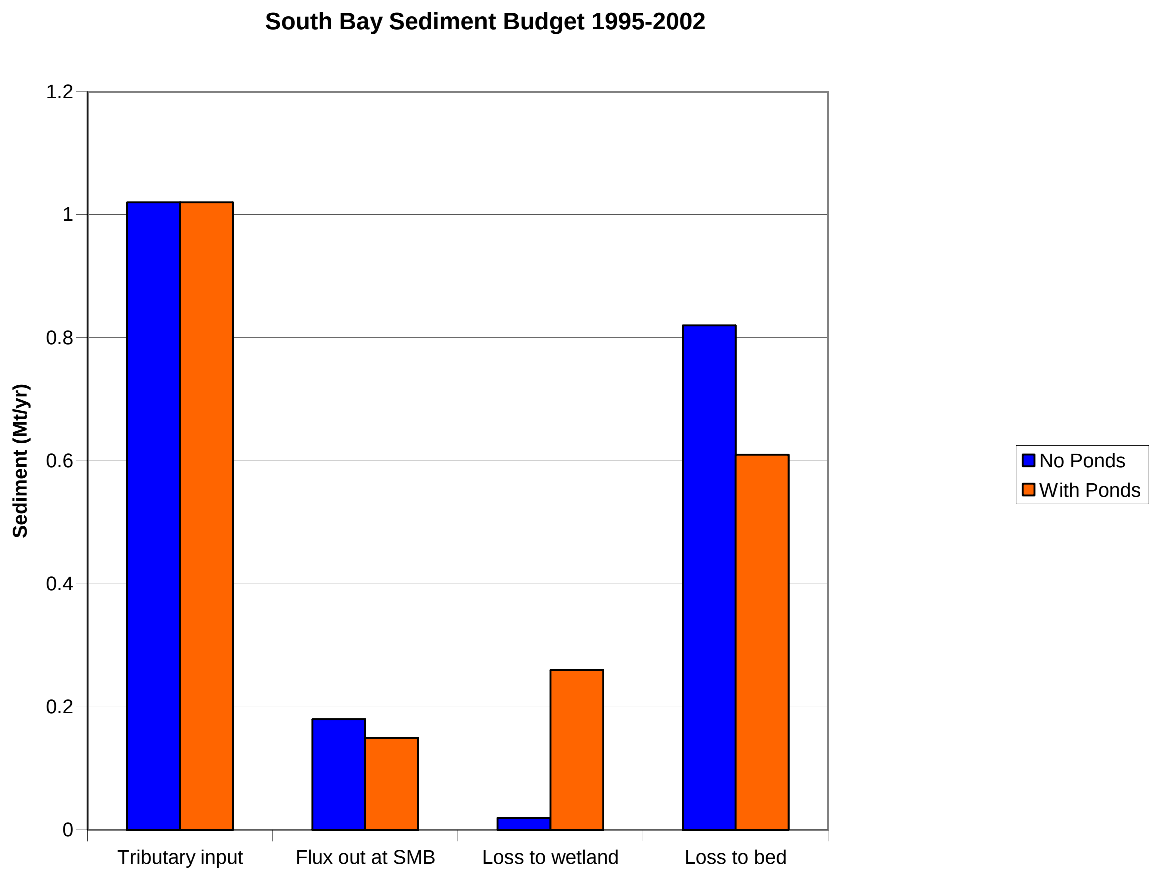


Figure 95. Results of the sediment budget for South San Francisco Bay for the years 1995-2002. These results reflect differences in the sediment budget that come from the opening of some of the Alviso salt ponds to tidal action. The South Bay averaged suspended-sediment concentration decreases from 106 mg/L to 100 mg/L from the new wetland sediment sink that is created by opening these ponds to tidal action.

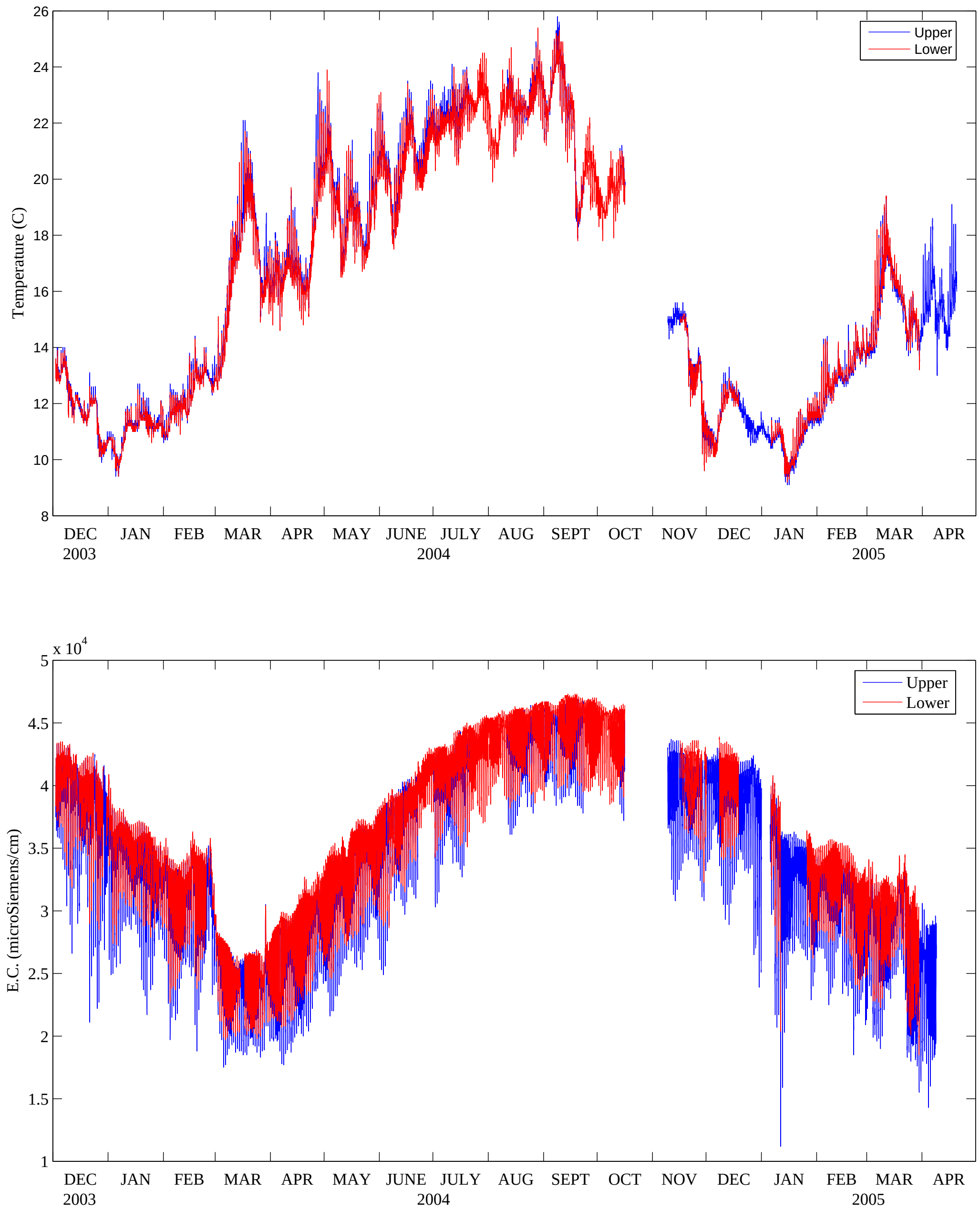


Figure 96. Top panel displays about 17 months of temperature data from Channel Marker 17 in South San Francisco Bay starting in December 2003. Bottom panel shows the electrical conductivity from Channel Marker 17 for the same period of record as the temperature data. Gaps in the datasets result from equipment malfunctions and biofouling.

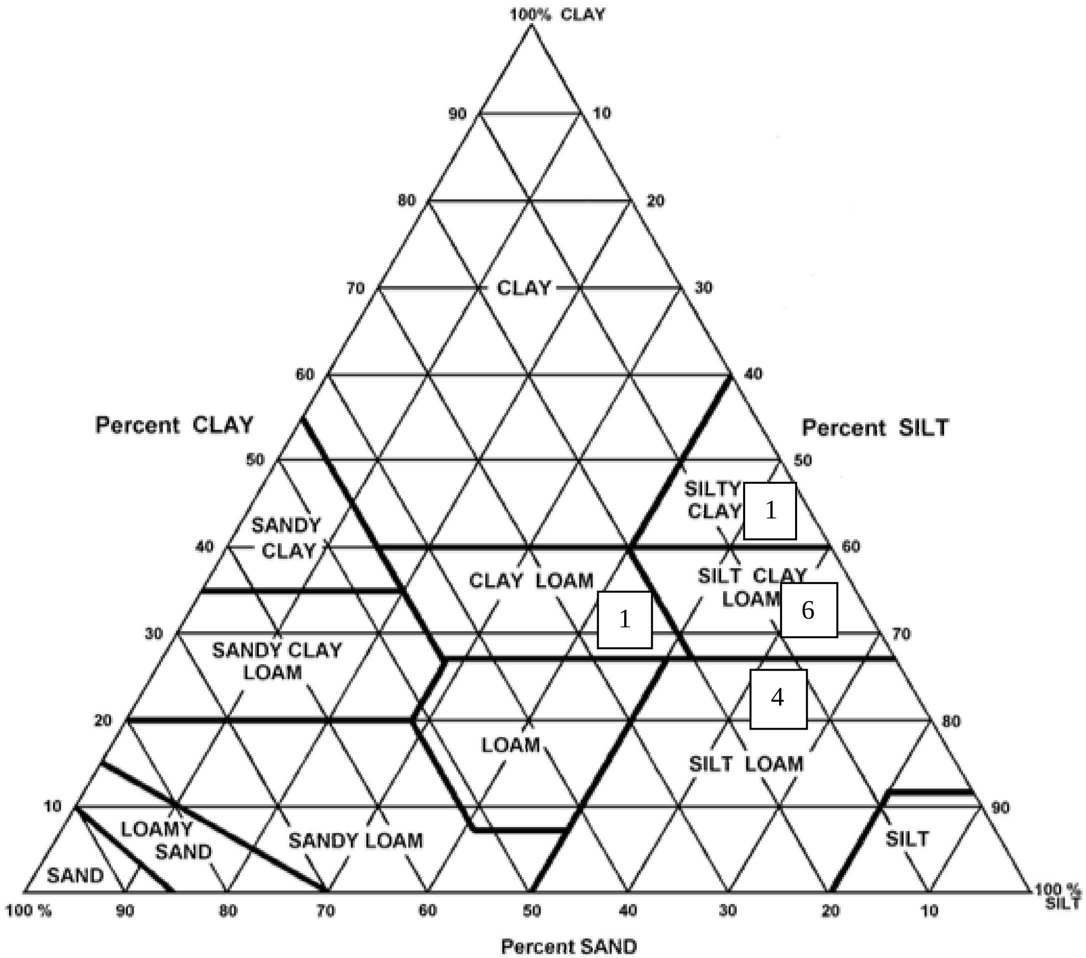


Figure 97. Soil Texture Triangle, numbers in boxes indicate number of slough samples with soil type, San Francisco Bay, CA.

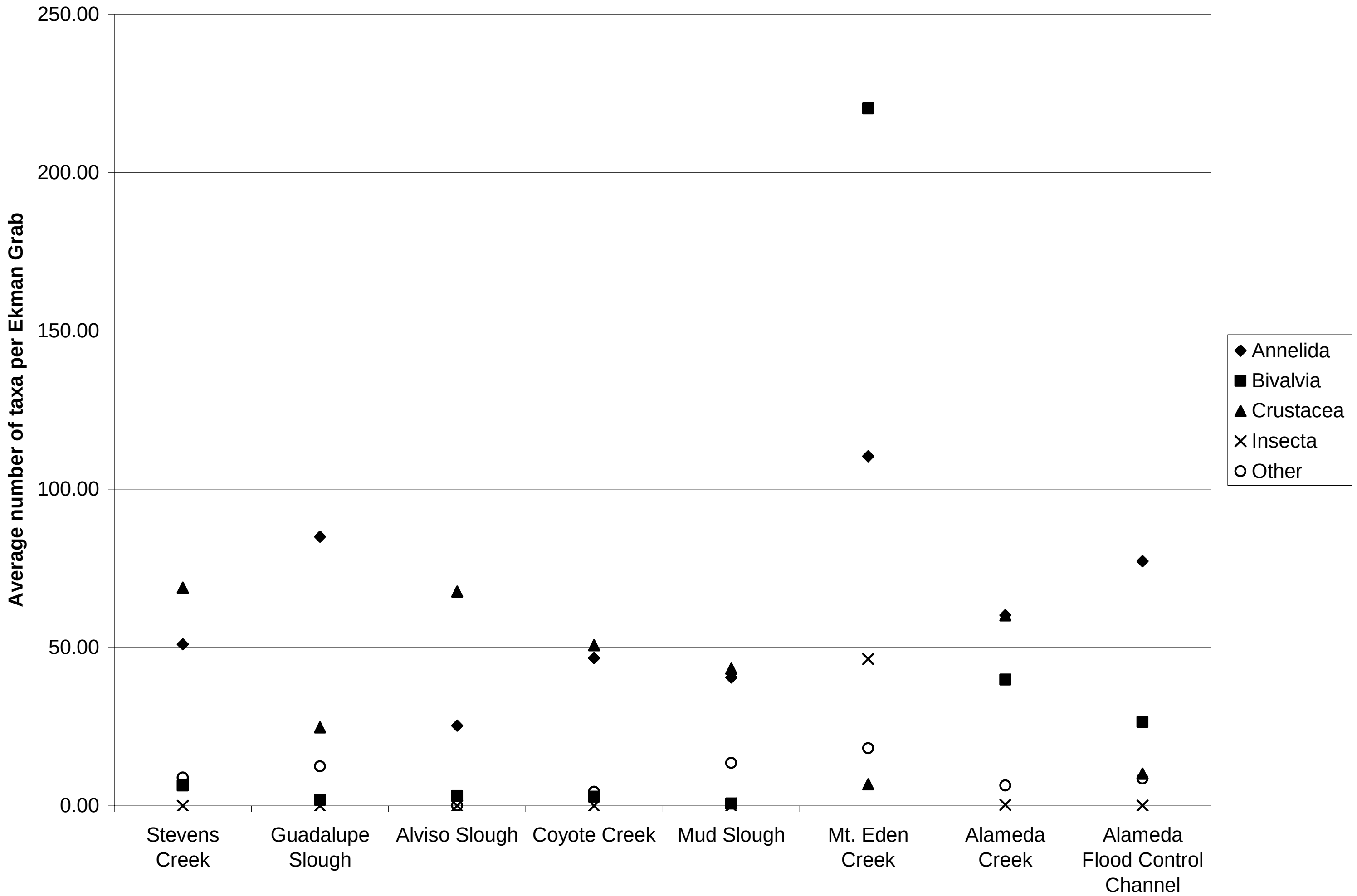


Figure 98. Mean number of invertebrates per benthic sample in each slough, San Francisco Bay, CA.

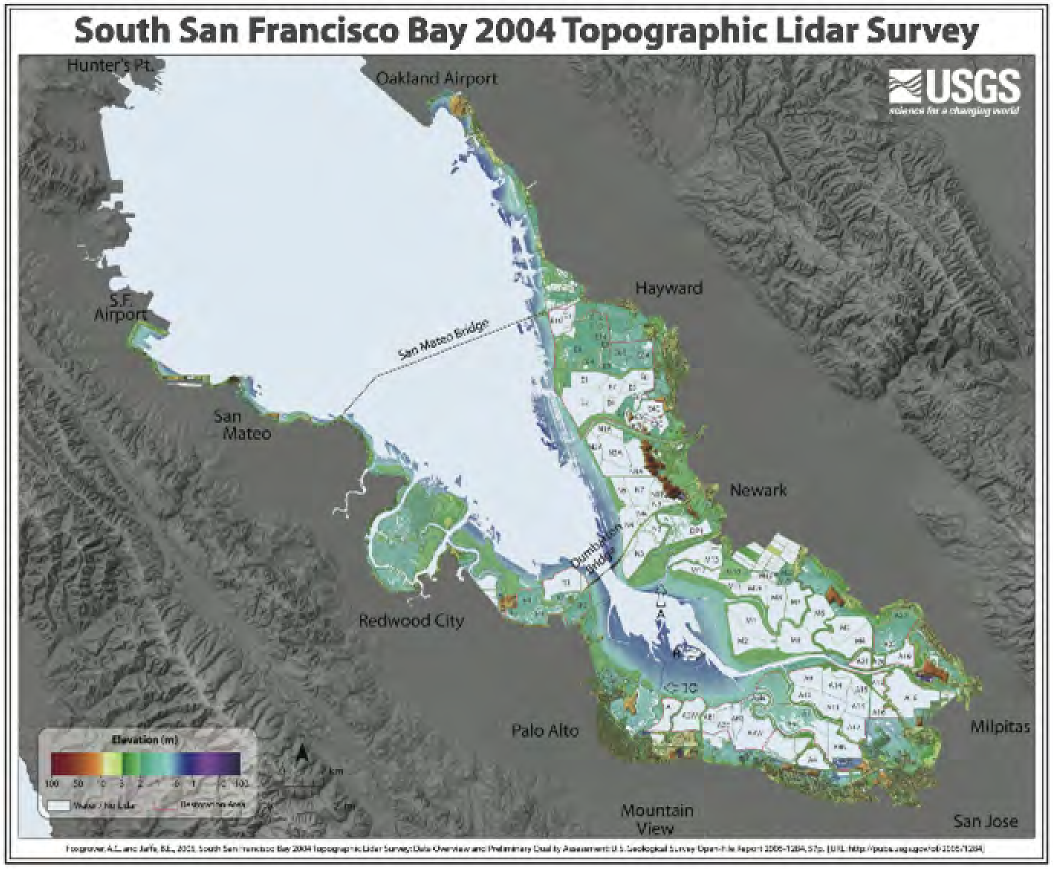


Figure 99. DEM of the South San Francisco Bay area. Full-feature LIDAR data gridded at 2m resolution and colored by elevation (over-water returns removed). Figure from Foxgrover and Jaffe (2005).

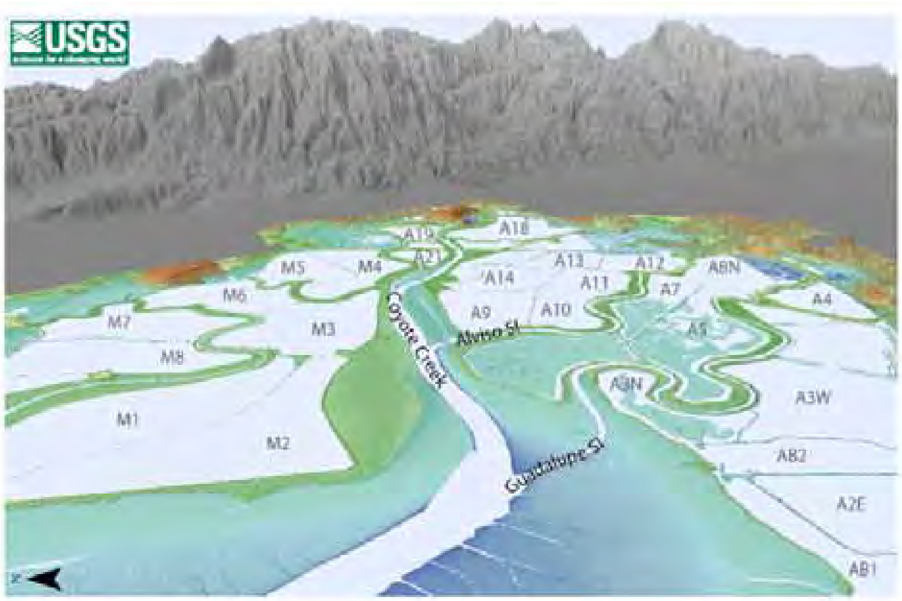


Figure 100. Shaded relief map of full feature LIDAR colored by elevation (vertical exaggeration 5x). Perspective view is looking east towards Coyote Creek. Figure from Foxgrover and Jaffe (2005).

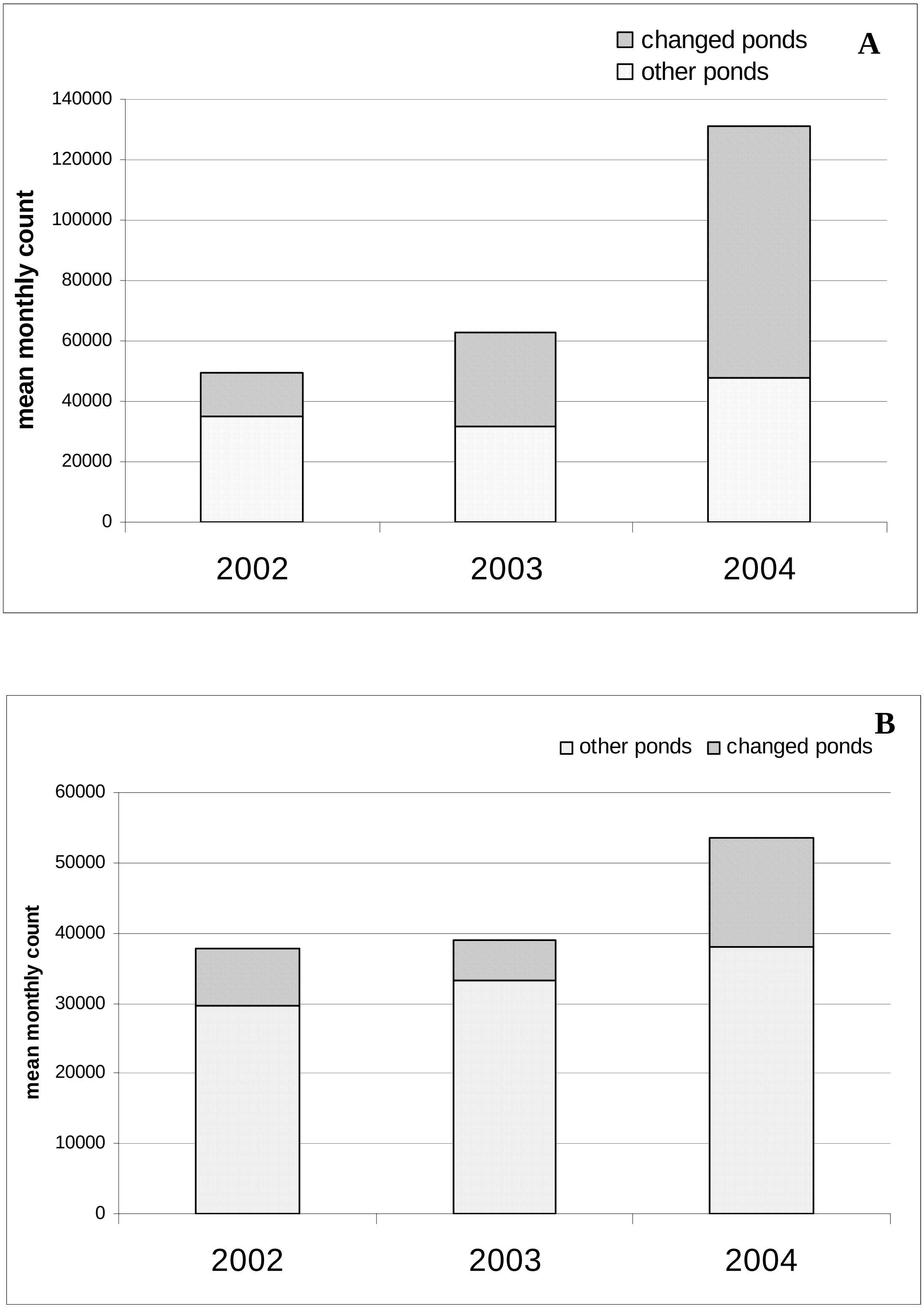


Figure 101. Mean monthly winter bird counts (November-February) at A) Alviso and B) Eden Landing salt ponds showing the overall effects of initial ISP actions prior to winter 2004, San Francisco Bay, CA

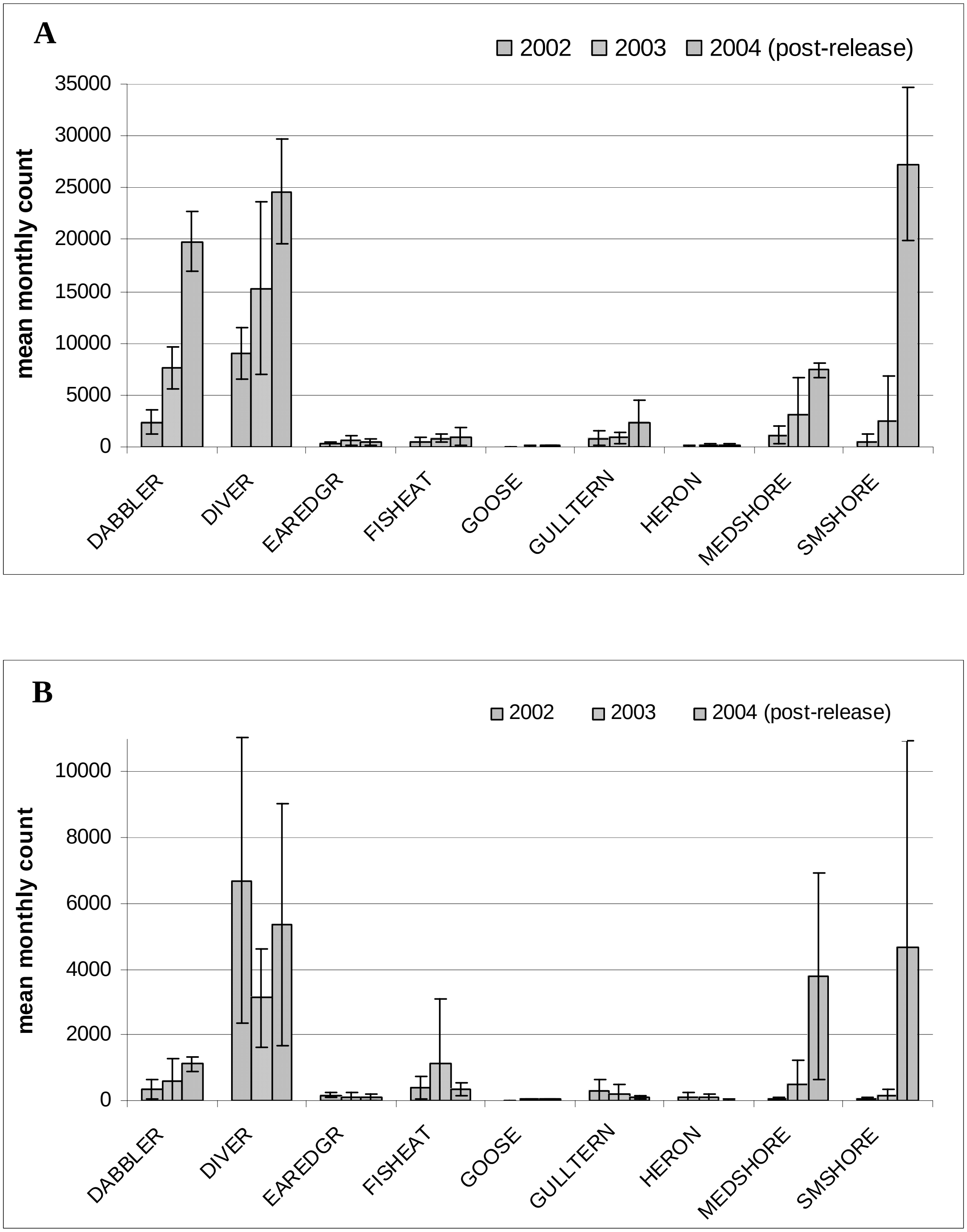


Figure 102. Mean (± SD) monthly winter bird counts (November-February) showing changes in guild composition at Alviso (A) and Eden Landing (B) salt ponds affected by initial ISP actions prior to winter 2004, San Francisco Bay, CA

APPENDICES

Appendix A. Examples of pond metadata files for ponds with staff gages surveyed by 1) USGS, San Francisco Bay Estuary Field Station (Alviso ponds A9-A16); 2) USGS from benchmark elevations provided by Moffat-Nichol (Alviso ponds A2W and A3W); and 3) Fremont Engineers, Inc. (remaining ponds).

A9_bathy_NAVD88.xls

Metadata:

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: Unpublished Material
Publication_Time: Unknown
Title: A9_bathy_NAVD88.xls
Edition: First
Geospatial_Data_Presentation_Form: n/a

Description:
Abstract:

A9_bathy_NAVD88.xls contains latitude, longitude, and elevation data for Alviso salt pond A9. The data were created using a shallow water sounding system comprised of a single beam echosounder (Navisound 210, Reson), differential global positioning system unit (AgGPS 124/132 Receiver DGPS, Trimble), and a laptop computer in a water-resistant case affixed to a Bass Hunter boat with a salt water trolling motor. Transects were run in parallel directions spaced approximately 100m apart. Water depths measured with this system were converted to NAVD88 by surveying the staff gauge at each pond and adjusting water depth to the water level of the pond during the survey.

This pond was surveyed on 3/3/2004 and 3/8/2004. The staff gauge reading was 3.21 ft on 3/3/2004 and 3.20 ft on 3/8/2004, measured at regular intervals during the survey, and did not change. The top of the staff gauge (reads 6 ft) was surveyed to be 4.64 ft NGVD29 by laser level rod from benchmark H555 (see below; 3.729 ft NGVD29, 9/25/1996) and was converted to 7.33 ft NAVD88 using the program CorpsCom (NAVD88 = NGVD29 + 2.69 ft). Depths, collected in meters, were converted to feet and then referenced to NAVD88 by subtracting water depth from NAVD88 water height (staff gauge reading 3.21 ft = 4.54 ft NAVD88; 3.20 = 4.53 ft NAVD88).

Elevation of National Coast and Geodetic benchmark “H555, 1956” (last verified by the National Geodetic Survey in 1967 to be 5.09’ NGVD but thought to have since subsided), was determined using two survey methods. In August 1995, we used differential leveling to determine the new elevation for H555 based on a recently surveyed benchmark (K555, surveyed in 1993 by Ray Thinggaard). Based on this benchmark, we used differential leveling to determine the new elevation for H555. We carried the elevation to H555 and closed the loop back to K555. In September 1996, the elevation was determined using a GPS total station relative to 4 local bedrock elevations (benchmarks 3001, 3002, 3005, and 3006, surveyor was John Pettley of Bestor Engineers, Inc.). The final elevation of H555 based on K555 was 3.85 ft NGVD29. The final elevation of H555 based on GPS total station was 3.729 ft NGVD29. We used 3.729 ft NGVD29 because we consider it to be the most reliable elevation of the benchmark.

Summary: NAVD88 min = -5.49 ft; max = 4.07 ft ; mean = 3.01 ft; mode = 3.48 ft; stdev = 0.77 ft.

Purpose:
The intended use of A9_bathy_NAVD88.xls is for a source to create a 50m bathymetric surface for the salt ponds.

Time_Period_of_Content:
Time_Period_Information: staff gauge surveyed August 2002, pond depth data collected across 2 days: 3/3/2004 and 3/8/2004.
Calendar_Date: Data processing completed July 2004
Time_of_Day: unknown
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.019787
East_Bounding_Coordinate: -122.001150
North_Bounding_Coordinate: 37.462811
South_Bounding_Coordinate: 37.452422
Keywords:

Theme:
Theme_Keyword_Thesaurus: ISO
Theme_Keyword: salt ponds
Theme_Keyword: bathymetry
Theme_Keyword: depth
Place:
Place_Keyword: San Francisco Bay
Access_Constraints: This is public data.
Use_Constraints:
This is public data. Please cite US Geological Survey if these data are used or included in developed products.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8 am to 5 pm Monday - Friday
Contact_Instructions: Email is preferred.
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: None
Native_Data_Set_Environment:
Microsoft Windows 2000 Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 8.3.0.800

Data_Quality_Information:
Logical_Consistency_Report:
Transect points were checked to ensure they were within the boundary polygon of the salt pond being surveyed. Boundary polygons used were digitized from aerial photos from San Francisco Estuary Institute's (SFEI) Ecoatlas and converted to UTM NAD83.

Depth values reading “0” were assumed to be erroneous and were removed from the data set.

Completeness_Report:
Some areas of the salt ponds were excluded from the transects due to shallow depth of the water and the inability to maneuver the boat into those areas. Islands and shallow areas are not represented in these data.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:

DPGS is assumed to be accurate within 1-2 meters. All DGPS data is referenced to WGS84 (NAD83).

Vertical_Positional_Accuracy:

Vertical_Positional_Accuracy_Report:

Depths are obtained from a single acoustic beam, precise to the nearest centimeter. 20 depth readings were collected for each DGPS location. The elevation data presented here are the average of 20 values.

Depths were converted to NAVD88 by subtracting them from the NAVD88 height of the water's surface. Water surface elevation was determined by reading the pond's staff gauge, which was by surveyed in August 2002 by laser level rod from benchmark H555 (3.729 ft, 9/25/1996). No estimate of staff gauge survey accuracy is provided here.

Lineage:

Source_Information:

Type_of_Source_Media: digital tape media

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: July 2004

Source_Currentness_Reference: ground condition

Source_Citation_Abbreviation: US Geological Survey

Spatial_Referance_Information:

Vertical_Coordinate_System_Definition:

Altitude_System_Definition:

Altitude_Datum_Name: North American Vertical Datum of 1988 (NAVD88)

Altitude_Distance_Units: feet

Entity_and_Attribute_Information:

Detailed_Description:

Entity_Type:

Attribute:

Attribute_Label: LAT

Attribute_Definition_Source: DGPS

Attribute:

Attribute_Label: LONG

Attribute_Definition_Source: DGPS

Attribute:

Attribute_Label: NAVD88

Attribute_Definition:

final depth value in feet = NAVD88 water height (ft) - depth (ft)

Attribute_Value_Accuracy_Information: Depends on accuracy of surveyed staff gauge and accuracy of echosounder.
Attribute_Value_Accuracy: Echosounder accuracy 0.03 feet, staff gauge survey accuracy unknown.

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: xls
File_Decompression_Technique: no compression applied
Transfer_Size:
Custom_Order_Process:
Email: william_perry@usgs.gov Submit request in writing.
Technical_Prerequisites:

Metadata_Reference_Information:
Metadata_Date: 20040707
Metadata_Future_Review_Date: Undetermined
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: William Perry
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address: 6924 Tremont Road
City: Dixon
State_or_Province: Ca
Postal_Code: 95620
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8am to 5pm
Contact_Instructions: Email
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

Generated by mp version 2.7.33 on Thu Jun 24 10:41:31 2004

A2W_bathy_NAVD88.xls

Metadata:

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: Unpublished Material
Publication_Time: Unknown
Title: A2W_bathy_NAVD88.xls
Edition: First
Geospatial_Data_Presentation_Form: n/a

Description:
Abstract:

A2W_bathy_NAVD88.xls contains latitude, longitude, and elevation data for Alviso salt pond A2W. The data were created using a shallow water sounding system comprised of a single beam echosounder (Navisound 210, Reson), differential global positioning system unit (AgGPS 124/132 Receiver DGPS, Trimble), and a laptop computer in a water-resistant case affixed to a Bass Hunter boat with a salt water trolling motor. Transects were run in parallel directions spaced approximately 100m apart. Water depths measured with this system were converted to NAVD88 by surveying the staff gauge at each pond and adjusting water depth to the water level of the pond during the survey.

This pond was surveyed on 10/28/2003 and 10/29/2003. There was no staff gauge. A temporary water level marker was installed and was surveyed by laser level and rod from a temporary levee benchmark surveyed by Moffat and Nichol (January 2004). The top of the temporary marker was surveyed to be 2.64 ft NGVD29 and was converted to 5.33 ft NAVD88 using the program CorpsCom (NAVD88 = NGVD29 + 2.69 ft). Depths, collected in meters, were converted to feet and then referenced to NAVD88 by subtracting water depth from NAVD88 water height (water

level 2.19 ft from top of marker to water is 0.45 ft NGVD29 = 3.14 ft NAVD88).

Summary: NAVD88 min = -1.10 ft; max = 2.75 ft; mean = 0.42 ft; mode = 0.32 ft; stdev = 0.50 ft.

Purpose:
The intended use of A2W_bathy_NAVD88.xls is for a source to create a 50m bathymetric surface for the salt ponds.
Time_Period_of_Content:
Time_Period_Information: water level marker surveyed January 2004, pond depth data collected across 2 days: 10/28/2003 and 10/29/2003.
Calendar_Date: Data processing completed July 2004
Time_of_Day: unknown
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.084248
East_Bounding_Coordinate: -122.065679
North_Bounding_Coordinate: 37.450092
South_Bounding_Coordinate: 37.435187
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO
Theme_Keyword: salt ponds
Theme_Keyword: bathymetry
Theme_Keyword: depth
Place:
Place_Keyword: San Francisco Bay
Access_Constraints: This is public data.
Use_Constraints:
This is public data. Please cite US Geological Survey if these data are used or included in developed products.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8 am to 5 pm Monday - Friday

Contact_Instructions: Email is preferred.

Security_Information:

Security_Classification_System: None

Security_Classification: Unclassified

Security_Handling_Description: None

Native_Data_Set_Environment:

Microsoft Windows 2000 Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 8.3.0.800

Data_Quality_Information:

Logical_Consistency_Report:

Transect points were checked to ensure they were within the boundary polygon of the salt pond being surveyed. Boundary polygons used were digitized from aerial photos from San Francisco Estuary Institute's (SFEI) Ecoatlas and converted to UTM NAD83.

Depth values reading “0” were assumed to be erroneous and were removed from the data set.

Completeness_Report:

Some areas of the salt ponds were excluded from the transects due to shallow depth of the water and the inability to maneuver the boat into those areas. Islands and shallow areas are not represented in these data.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report:

DPGS is assumed to be accurate within 1-2 meters. All DGPS data is referenced to WGS84 (NAD83).

Vertical_Positional_Accuracy:

Vertical_Positional_Accuracy_Report:

Depths are obtained from a single acoustic beam, precise to the nearest centimeter. 20 depth readings were collected for each DGPS location. The elevation data presented here are the average of 20 values.

Depths were converted to NAVD88 by subtracting them from the NAVD88 height of the water’s surface. Water surface elevation was determined by reading the temporary water level marker, which we surveyed by laser level and rod from a temporary benchmark surveyed by Moffat and Nichol. No estimate of staff gauge survey accuracy is provided here.

Lineage:

Source_Information:

Type_of_Source_Media: digital tape media

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:
Calendar_Date: July 2004
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: US Geological Survey

Spatial_Referance_Information:
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: North American Vertical Datum of 1988 (NAVD88)
Altitude_Distance_Units: feet

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Attribute:
Attribute_Label: LAT
Attribute_Definition_Source: DGPS
Attribute:
Attribute_Label: LONG
Attribute_Definition_Source: DGPS
Attribute:
Attribute_Label: NAVD88
Attribute_Definition:
final depth value in feet = NAVD88 water height (ft) - depth (ft)
Attribute_Value_Accuracy_Information: Depends on accuracy of surveyed staff gauge and accuracy of echosounder.
Attribute_Value_Accuracy: Echosounder accuracy 0.03 feet, staff gauge survey accuracy unknown.

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: xls
File_Decompression_Technique: no compression applied
Transfer_Size:
Custom_Order_Process:
Email: william_perry@usgs.gov Submit request in writing.
Technical_Prerequisites:

Metadata_Reference_Information:
Metadata_Date: 20040707
Metadata_Future_Review_Date: Undetermined
Metadata_Contact:

Contact_Information:
Contact_Person_Primary:
Contact_Person: William Perry
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address: 6924 Tremont Road
City: Dixon
State_or_Province: Ca
Postal_Code: 95620
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8am to 5pm
Contact_Instructions: Email
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

Generated by mp version 2.7.33 on Thu Jun 24 10:41:31 2004

A8_bathy_NAVD88b.xls

Metadata:

Identification_Information:

Citation:

Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: Unpublished Material
Publication_Time: Unknown
Title: A8_bathy_NAVD88b.xls
Edition: First
Geospatial_Data_Presentation_Form: n/a

Description:

Abstract:

A8_bathy_NAVD88b.xls contains latitude, longitude, and elevation data for Alviso salt pond A8. The data were created using a shallow water sounding system comprised of a single beam echosounder (Navisound 210, Reson), differential global positioning system unit (AgGPS 124/132 Receiver DGPS, Trimble), and a laptop computer in a water-resistant case affixed to a Bass Hunter boat with a salt water trolling motor. Transects were run in parallel directions spaced approximately 100m apart. Water depths measured with this system were converted to NAVD88 by surveying the staff gauge at each pond and adjusting water depth to the water level of the pond during the survey.

This pond was surveyed on 2/15/2004, 2/22/2004, and 3/13/2004. The staff gauge reading on 2/15/2004 and 2/22/2004 was 0.65 ft and on 3/13/2004 was 0.70 ft, measured at regular intervals during the survey, and did not change. The physical top of the staff gauge (0.99 feet from the top line which reads 2 ft) was surveyed to be 1.44 ft NGVD29 (Fremont Engineers, 05/17/1999, Job # 4459) and was converted to 4.14 ft NAVD88 using the program CorpsCom (NAVD88 = NGVD29 + 2.70 ft). Depths, collected in meters, were converted to feet and then referenced to

NAVD88 by subtracting water depth from NAVD88 water height (staff gauge reading 0.65 ft = 1.80 ft NAVD88; 0.70 ft = 1.85 ft NAVD88).

Summary: NAVD88   min = -12.24 ft; max = 1.36 ft ;mean = -1.55 ft; mode = -1.19 ft; stdev = 1.89 ft.

Purpose:
The intended use of A8_bathy_NAVD88b.xls is for a source to create a 50m bathymetric surface for the salt ponds.
Time_Period_of_Content:
Time_Period_Information: staff gauge surveyed 05/17/1999, pond depth data collected across 3 days: 2/15/2004, 2/22/2004, and 3/13/2004.
Calendar_Date: Data processing completed July 2004
Time_of_Day: unknown
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -121.998734
East_Bounding_Coordinate: -121.980801
North_Bounding_Coordinate: 37.438775
South_Bounding_Coordinate: 37.423053
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO
Theme_Keyword: salt ponds
Theme_Keyword: bathymetry
Theme_Keyword: depth
Place:
Place_Keyword: San Francisco Bay
Access_Constraints: This is public data.
Use_Constraints:
This is public data. Please cite US Geological Survey if these data are used or included in developed products.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8 am to 5 pm Monday - Friday

Contact_Instructions: Email is preferred.
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: None
Native_Data_Set_Environment:
Microsoft Windows 2000 Version 5.1 (Build 2600) Service Pack 1; ESRI ArcCatalog 8.3.0.800

Data_Quality_Information:
Logical_Consistency_Report:
Transect points were checked to ensure they were within the boundary polygon of the salt pond being surveyed. Boundary polygons used were digitized from aerial photos from San Francisco Estuary Institute's (SFEI) Ecoatlas and converted to UTM NAD83.

Depth values reading “0” were assumed to be erroneous and were removed from the data set.

Completeness_Report:
Some areas of the salt ponds were excluded from the transects due to shallow depth of the water and the inability to maneuver the boat into those areas. Islands and shallow areas are not represented in these data.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
DPGS is assumed to be accurate within 1-2 meters. All DGPS data is referenced to WGS84 (NAD83).
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report:
Depths are obtained from a single acoustic beam, precise to the nearest centimeter. 20 depth readings were collected for each DGPS location. The elevation data presented here are the average of 20 values.

Depths were converted to NAVD88 by subtracting them from the NAVD88 height of the water’s surface. Water surface elevation was determined by reading the pond’s staff gauge, which was surveyed by Fremont Engineers (05/17/1999, Job # 4459). No estimate of staff gauge survey accuracy is provided here.
Lineage:
Source_Information:
Type_of_Source_Media: digital tape media
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:

Calendar_Date: July 2004
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Source_Citation_Abbreviation: US Geological Survey

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Altitude_Distance_Units: feet

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Attribute_Definition:
final depth value in feet = NAVD88 water height (ft) - depth (ft)
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Format_Name: xls
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Email: william_perry@usgs.gov Submit request in writing.
Technical_Prerequisites:

Metadata_Reference_Information:
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Metadata_Future_Review_Date: Undetermined
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Contact_Information:

Contact_Person_Primary:
Contact_Person: William Perry
Contact_Organization: US Geological Survey
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address: 6924 Tremont Road
City: Dixon
State_or_Province: Ca
Postal_Code: 95620
Contact_Voice_Telephone: 707-678-0682
Contact_Facsimile_Telephone: 707-678-5039
Contact_Electronic_Mail_Address: william_perry@usgs.gov
Hours_of_Service: 8am to 5pm
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Appendix B. Mudflat invertebrate report.

A Summary of our Knowledge of South San Francisco Bay Infaunal Invertebrate Community

J. K. Thompson & M.K. Shouse
U. S. Geological Survey
Menlo Park, CA
June 2004

Introduction

The benthic invertebrate community in south San Francisco Bay is an important component of the ecosystem as a controlling consumer of phytoplankton biomass in a potentially eutrophic system (Cloern 1982, Thompson 1999), as an accumulator of contaminants (Hornberger et al 2000), a contributor to nutrient and contaminant recycling (Caffrey et al 1996, Grenz, et al 2000), and as a source of prey for other invertebrates and resident and migratory birds and fish. Our knowledge of this community will help us understand the dynamics of benthic invertebrates within and outside of the restored salt pond areas and help us understand what invertebrate recruits might be seasonally available for recruitment into breached salt pond areas. The following report is a description of what we know about the species composition, community dynamics and secondary production of the benthic community in South Bay based on two studies:

1. The primary study will be that of a mudflat community that has been sampled since 1974 in an area adjacent to the Palo Alto Water Quality Control Plant (Figure 1).
2. Reference will be made to a study of the spatial and temporal distribution of bivalves throughout the southern bay, south of San Mateo Bridge, from 1991-1995 (Thompson 1999) that will be used to inform our understanding of the seasonal cycle of these important members of the benthic community (Figure 2).

Reference will be made to all geographic-specific literature that the authors feel is relevant to our understanding of this community. As will be noted, there is a collection of benthic samples, which have been partially processed at most, that are in storage at the USGS that are available for further processing should it become prudent for us to do so. A listing of these samples is shown in Appendix A, B, C.

Study Locations

The Palo Alto study was begun in 1974 with samples being collected at monthly intervals in 1974 at three stations arranged on a transect perpendicular to the shoreline south of Sand Point (Sta. 45: 12 m from the 1974 marsh shoreline and 110 cm above mean lower low water (MLLW), Sta. 46: 28 m offshore from the nearshore station and 90 cm above MLLW, and Sta. 47 142 m from the nearshore station and 80 cm above MLLW). The same stations were sampled at a near-monthly to quarterly intervals until 1986 when Sta. 47 was discontinued (see Appendix for A for chronology). The two nearshore stations were collected until 1990, when sampling ceased until mid-1998 when monthly sampling recommenced at the two near shore stations. Sampling at St. 46 stopped in mid-2000 but monthly sampling at the nearshore station (Sta. 45) continues today. Three replicate samples are collected with a 8.5cm diameter core (20 cm long). Six rectangular cores (16.5 cm x 10 cm by 23 cm deep) were collected at Sta. 45 in 1983-1985 to examine larger scale patterns with the larger species. Samples are sieved through a 0.5mm screen, preserved in 10% buffered formalin for at least 1 week, transferred to 70% ethyl alcohol stained with Rose Bengal, and sorted at the USGS.

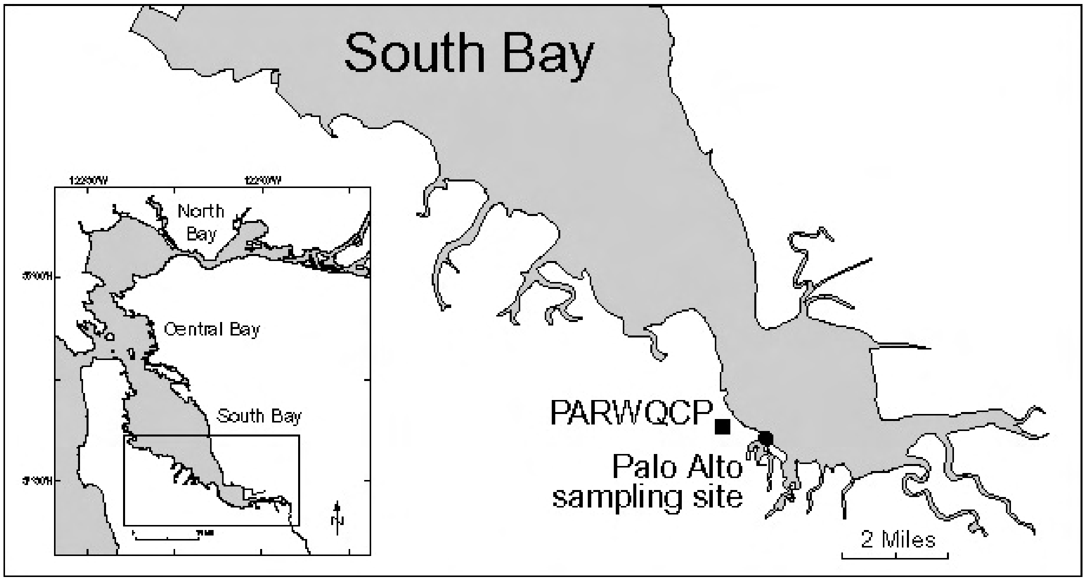


Figure 1. Location of three mudflat stations (Sta. 45, 46, and 47) near Palo Alto Water Quality Control Plant.

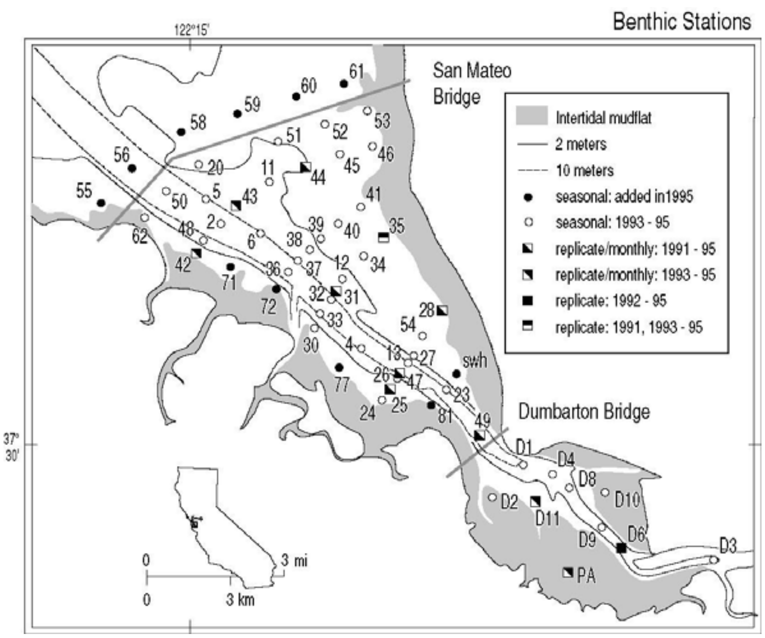


Figure 2. Station locations for temporal/spatial study of bivalves in South Bay.

Taxonomy is done at the USGS for all but the difficult groups which are sent to Susan McCormick, a locally known private contractor who is familiar with San Francisco Bay taxa.

Monthly sampling for the study of south bay bivalves was done at high tide from a boat using a 0.05 m^2 van Veen Grab. Samples were processed as described above. Three replicate samples were taken at 6-7 stations in 1991-1993 and at 13 stations in 1993-1996 (Figure 2, Appendix B). A large scale spatial distribution study of bivalves was done in spring, summer, and fall in 1993 and 1994 at 49 stations and at 59 stations in 1995 (Figure 2) when one sample was collected per station. Samples were processed as above, but only 5 species of bivalves (*Potamocorbula amurensis, Venerupis japonica, Musculista senhousia, Mya arenaria*,and *Macoma balthica*) were removed from the samples, measured and counted. The data are summarized in Thompson (1999).

<u>*A comment on changes to the mudflat site since the inception of the study*</u>

There have been four prominent changes to this mudflat since the beginning of the study in 1974. The first change, presumably due to a gradual increase in sedimentation on the mudflat, has resulted in the burial of what was a seasonally visible shell bank at Station 46. In the summer, following the increased wind wave resuspension of the fine sediments, the sediment would significantly coarsen and the percent sand would increase (Thompson 1979). Coincident with this erosion period, a shell bank would surface at the middle elevation station such that it would be possible to stand on the sediment and sink no more than a few centimeters into the sediment. That is no longer the case and the shell bank is no longer perceptible at depths of over 30 cm. This sedimentation may be due to long term sedimentation patterns in south bay that have been recently described by Foxgrover et al (2004) or may be due to episodic pulses of sediment that have accumulated on this mudflat coincident with the El Nino storms that occurred in the 1980's and 1990's. It is also possible that the introduction of the Chinese Mitten Crab (*Eriocheir sinensis*) in the early 1990's (Cohen and Carlton 1995) has increased the sedimentation rate at this mudflat. The relatively rapid erosion of the salt marsh bank at this site over the last 10 years is the second major alteration of the physiography of this site. Although unproven, it may be that the Mitten Crab burrows, which are ubiquitous here, possibly due to the proximity of San Francisquito Creek, are increasing the erosion rate of the bank. The bank appearance and salt marsh extent into

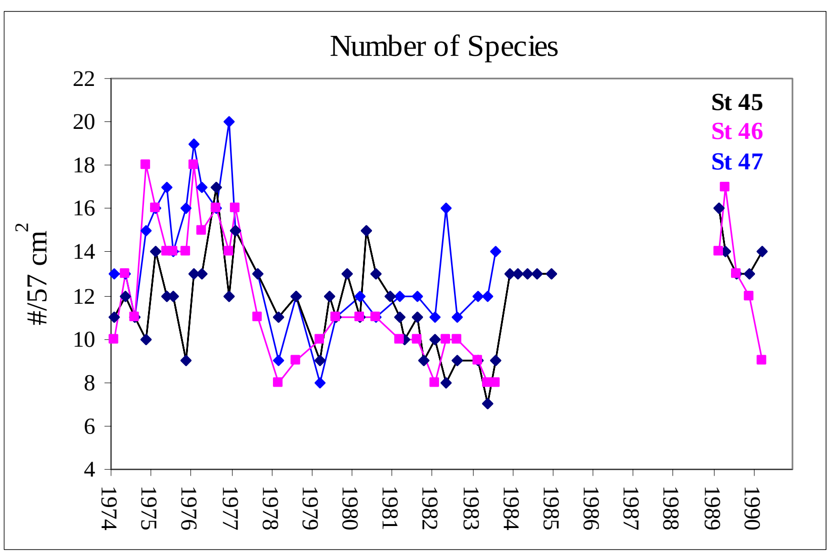


Figure 3. Maximum number of species in three replicate cores at three stations from 1974-1985 and for the two nearshore stations in 1989-1990.

the mudflat has changed dramatically in the last ten years. These two physiographic changes have most likely changed the elevation and distance to shore of the stations which were surveyed in 1974.

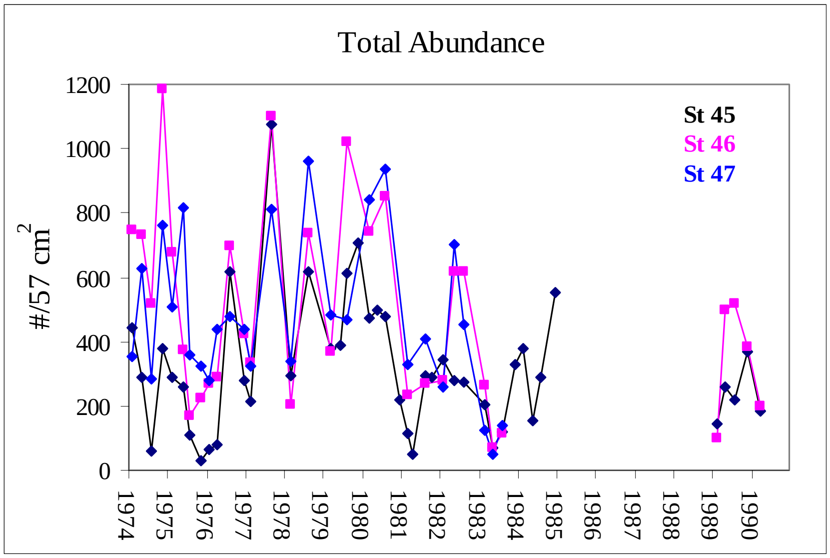
Human activities have also resulted in changes to the benthic community structure and to the contaminant loading into the system. The continual introduction of exotic species into the San Francisco Bay and Delta has been well documented (Cohen and Carlton 1998). Since the inception of this study we have seen four species that may have influenced the structure and dynamics of the benthic community. (1) *Potamocorbula amurensis*, an exotic filter feeding bivalve that invaded in 1986, has dramatically changed the northern bay pelagic ecosystem but not the southern system (Thompson in press). This bivalve has been seen at this site but infrequently and never in large numbers. (2) *Philine auriformis*, a carnivorous opisthobranch that invaded in 1982, can occur in very large numbers in bottom trawls in South Bay (personal communication Marine Sciences Institute) but is not collected in our sampling because it is most frequently found in the deeper water at low tide. It is possible however, that *P. auriformis* has increased the predation on small bivalves, especially *G. gemma*, in our field area during high tide periods. (3) The European Green Crab (*Carcinus maenas*), a predator on benthic organisms and on benthic bivalves in particular, is considered to be a common inhabitant in South Bay since its introduction in 1989. (4) As stated above the Chinese Mitten crab (*Eriocheir sinensis*) is another exotic species that is likely to have changed the physical nature of the mudflat.

Finally, the reduction in trace element loading at the adjacent water quality treatment plant in the mid-1980's has resulted in a large decline in metal accumulation in *Macoma balthica* and a concomitant increase in the reproductive activity of that species (Hornberger et al 2000). More recent work by Shouse (2002) has shown that the benthic community may now be responding to the decrease in metal accumulation in the sediment; there has been a decrease in the abundance of surface dwelling, brooding species and an increase in the number of individuals that lay their eggs in the sediment and are subsurface deposit feeders.

Results

<u>Three Mudflat Stations – Are They Different?</u>

A comparison of the benthic community at the three Palo Alto mudflat sites is possible for the first 10 years of the study. Samples have been collected but not processed for other years (Appendix A). A comparison of the mudflat community at the three elevations shows the species found at the three sites to be similar and to be primarily exotic or cryptogenic species (Nichols 1977, Nichols and Thompson 1985a). These species and their functional ecology are listed in Table 1 (from Shouse 2002). The number of species at each site is similar and was usually in the range of 10-16 prior to 1978 and in the 10-13 range thereafter (Figure 3). Although total abundance of species at the sites varies with season and year, the abundances track well between stations. With a few exceptions, the mid-elevation station (46) has the most organisms and the near-shore station (45) has the least (Figure 4). The discrepancy in abundance of organisms between stations is mostly due to the higher number of the most abundant organism (*G. gemma*) at the two deeper stations (Figures 4 and 5). The other highly abundant species (the polychaete *Streblopsio benedicti* and the amphipod *Ampelisca abdita*, Figure 5) are also variably abundant between stations but do not maintain a relative order of abundance between stations as consistently as does *G. gemma*.



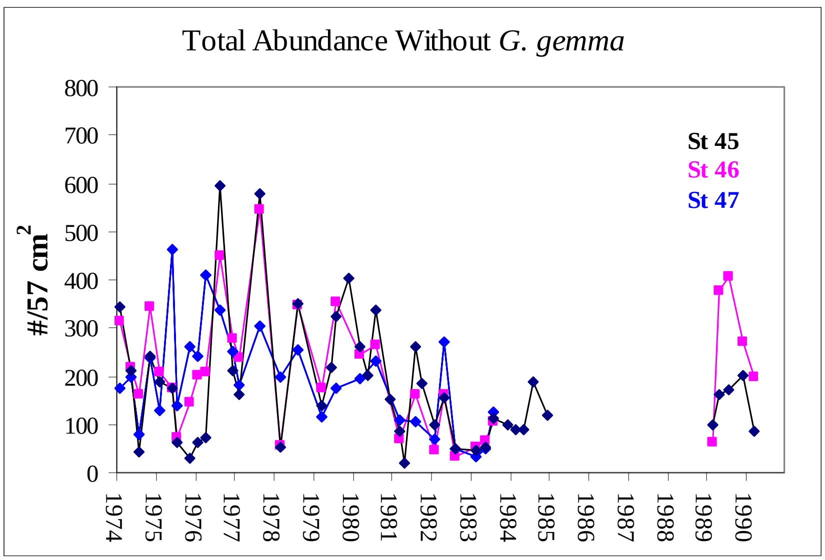


Figure 4. Total abundance of organisms at the three mudflat stations between 1974 and 1985 and at the two near stations in 1989-1990. The second plot shows the total number of organisms at each stations with the most common organism, *Gemma gemma*, removed.

Although *G. gemma*, *A. abdita* and *S. benedicti* were consistently the most dominant species during this study through 1990 there were also other species which were present at all three stations. Three of these species are shown in Figure 6 because of their importance as prey for birds (the bivalves *Macoma petalum* and *Mya arenaria*) and their clear trend over the period of the study. Seasonality of *M. petalum* is very coherent between stations and this species is consistently most abundant at the nearshore station (45). The second species, the bivalve *Mya arenaria*, is shown because it was significantly more numerous during one peak recruitment at the most offshore station. It was, as

Species	Feeding Type	Habitat Type	Repro Type	Barrier Type	References
Bivalves					
Gemma gemma	filter	burrower	brooder	$CaCO_3$	Thompson, J.K. (1982), personal knowledge
Macoma petalum	mixed1	burrower	spawner	$CaCO_3$	Stanley, S.M. (1970); Dankers, N.H. et al. (1981); Thompson, J.K. & F.H. Nichols (1988)
Musculista senhousia	filter	surface	spawner	$CaCO_3$	Morton, B. (1974); Wilan, R.C. (1987); Crooks, JA (1996)
Mya arenaria	filter	burrower	spawner	$CaCO_3$	Green, J. (1968); Stanley, S.M. (1970); Dankers, N.H. et al. (1981)
Potamocorbula amurensis	filter	burrower	spawner	$CaCO_3$	personal knowledge
Cnidaria					
Anthozoa sp.	filter	surface	spawner	tissue	Brusca, R.C. & G.J. Brusca (1990)
Crustacea					
Ampelisca abdita	filter	tubicolous	brooder	chitin	Mills, E.L. (1967)
Cirripedia spp.	filter	surface	mixed	chitin	Brusca, R.C. & G.J. Brusca (1990)
Corophium spp.	mixed1	burrower	brooder	chitin	Miller, D. C. (1984), Dixon, I.M.T. & P.G. Moore (1997), McCurdy et al. (2000)
Grandiderella japonica	mixed1	burrower	brooder	chitin	Chapman, J.W. & J.A. Dorman (1975), Niesen, T. (2002), Chapman, J.W. (2002)
Melita sp.	deposit1	burrower	brooder	chitin	Borowsky, B. et al. (1997)
Sphaeroma quoyana	filter	burrower	brooder	chitin	Green, J. (1968), Rotramel, G. (1972), Ricketts, E.F. et al. (1985)
Synidotea laticauda	carnivore	surface	brooder	chitin	Menzies R.J. & M.A. Miller (1972)
Gastropods					
Odostomia spp.	carnivore	surface	oviparous	$CaCO_3$	Fretter, V & A. Graham (1949); Kohn, A.J. (1983); White, M.E. et al. (1985)
Ilyanassa obsoleta	mixed2	surface	oviparous	$CaCO_3$	Scaefer (1969); Sastry, A.N. (1971), Ricketts, E.F. et al. (1985)
Polychaetes					
Capitella capitata	deposit2	burrower	oviparous	tissue	Rasmussen, E. (1956); Rasmussen, E. (1973); Fauchald, K. & P.A. Jumars (1979)
Eteone spp.	carnivore	surface	spawner	tissue	Rasmussen, E. (1973); Fauchald, K. & P.A. Jumars (1979); Rouse G. W. & F. Pleijel (2001)
Euchone sp.	filter	tubicolous	brooder	tissue	Fauchald, K. & P.A. Jumars (1979), Rouse G. W. & F. Pleijel (2001)
Glycera sp.	carnivore	burrower	spawner	tissue	Ockelmann, K.W. & O. Vahl (1970); Fauchald, K. & P.A. Jumars (1979)
Heteromastus filiformis	deposit2	burrower	oviparous	tissue	Rasmussen, E. (1956); Fauchald, K. & P.A. Jumars (1979), Shaffer, P.L. (1983)
Maldanidae	deposit1	tubicolous	mixed	tissue	Fauchald, K. & P.A. Jumars (1979), Rouse G. W. & F. Pleijel (2001)
Marphysa sanguinea	mixed2	burrower	spawner	tissue	Fauchald, K. & P.A. Jumars (1979), Cassai, C. & D. Prevedelli (1998)
Neanthes succinea	mixed2	burrower	spawner	tissue	Pettibone, M.H. (1963); Rasmussen, E. (1973); Fauchald, K. & P.A. Jumars (1979), Fong (1985)
Oligochaetes spp.	deposit2	burrower	mixed	tissue	Barnes, R.D, (1980)
Polydora cornuta	mixed1	tubicolous	brooder	tissue	Rasmussen, E. (1973); Zajac, R.N. (1991), Blake, J. A. & P. L. Arnofsky (1999)
Pseudopolydora kempi	mixed1	tubicolous	mixed	tissue	Taghon, G.L. & R.R. Greene (1992), Wilson, W.H., Jr. (1994), Blake, J. A. & P. L. Arnofsky (1999)
Sphaerosyllis sp.	carnivore	surface	brooder	tissue	Fauchald, K. & P.A. Jumars (1979); Kuper, M. & W. Westheide (1998)
Streblospio benedicti	deposit1	tubicolous	brooder	tissue	Dean, D. (1965); Fauchald, K. & P.A. Jumars (1979); Levin, L.A. (1984), Blake, J.A. & P.L. Arnofsky (1999)
Tharyx sp.	deposit1	tubicolous	mixed	tissue	Farke, H. (1979), Fauchald, K. & P.A. Jumars (1979); Rouse G. W. & F. Pleijel (2001)

Feeding Type:
deposit1=surface deposit feeder
deposit2=sub-surface deposit feeder
mixed1=surface deposit feeder and filter feeder
mixed2=surface deposit feeder and scavenger

Table 1. Species list and functional groups for Palo Alto stations (from Shouse 2002).

shown below, a common inhabitant of the benthic community at the nearshore station throughout the study. The polychaete *Heteromastus filiformis* (discussed below) is the only species to show a consistent pattern of increasing in abundance at all three stations.

The only biomass estimates for all three stations shows benthic community at the near shore station (45) and furthest offshore station (47) to have similar average annual biomass (13 g ash free dry weight (AFDW)/m^2/yr at St. 45 and 12 g AFDW/m^2/yr at St. 47) and the biomass at the mid-elevation station (46) to be highest (25 g AFDW/m^2/yr) (Nichols 1977). Secondary production showed a similar trend with the nearshore station (45) and the offshore station (47) showing similar values (60 and 54 g AFDW/m^2/yr) and the mid-elevation station being significantly more productive (110 g AFDW/m^2/yr) (Nicholes 1977).

Although the benthic community at these three sites varies in production and biomass, the benthic community at the near shore station represents the intermediate values of the three sites. Similarly, although the absolute magnitude of the species present varies between stations, the seasonal pattern of these species are similar. Therefore for the purposes of this report, the remainder of this discussion will focus on the data at the nearshore station where we have the most complete data.

A Summary of Benthic Community Structure 1974-2003

Functional Ecology of the Mudflat Community

As shown in Table 1 most of the species in this community are surface deposit feeders, filter-feeders, or a combination of surface deposit feeder and filter feeder. Over half of the species are burrowing species with the rest evenly split between surface dwellers and tube dwelling species. The majority of the species brood their young or can either spawn their gametes or brood their young ("mixed" designation on Table 1). Four species are oviparous (egg layers).

The dominant functional form, when the abundance of each species is considered, is an organism that burrows in the sediment or lives in a tube at the surface, broods their young, and filter feeds or is capable of switching between filter-feeding and deposit feeding (Figures 7, 8 and 9). A combination of these functional groupings describes the three species (*G. gemma, A. abdita, and S. benedicti*) that dominated the community until the 1980's and continues to describe the dominant species since 1998 (*G. gemma*) despite the decline in the other two species. Although the primary habitat of the most abundant species has shifted from a combination of tube dwellers and burrowers to a community now dominated by burrowers, (Figure 8) neither feeding mode (dominated by filter feeders, Figure 7) or reproductive mode (dominated by brooders, Figure 9) has shown a similar shift. It should be noted that both oviparous and spawning species may be showing a slight increase in recent years. As reported by Shouse (2002), the number of individuals in the benthic community has changed in recent years to become more evenly distributed among species, with at most, only one strongly dominant species (*G. gemma*).

Descriptive Ecology of the Mudflat Community

The continuation of the data at station 45 shows that the number of species has become less variable in recent years but that the volatility of the total abundance of organisms remains high (Figure 10).

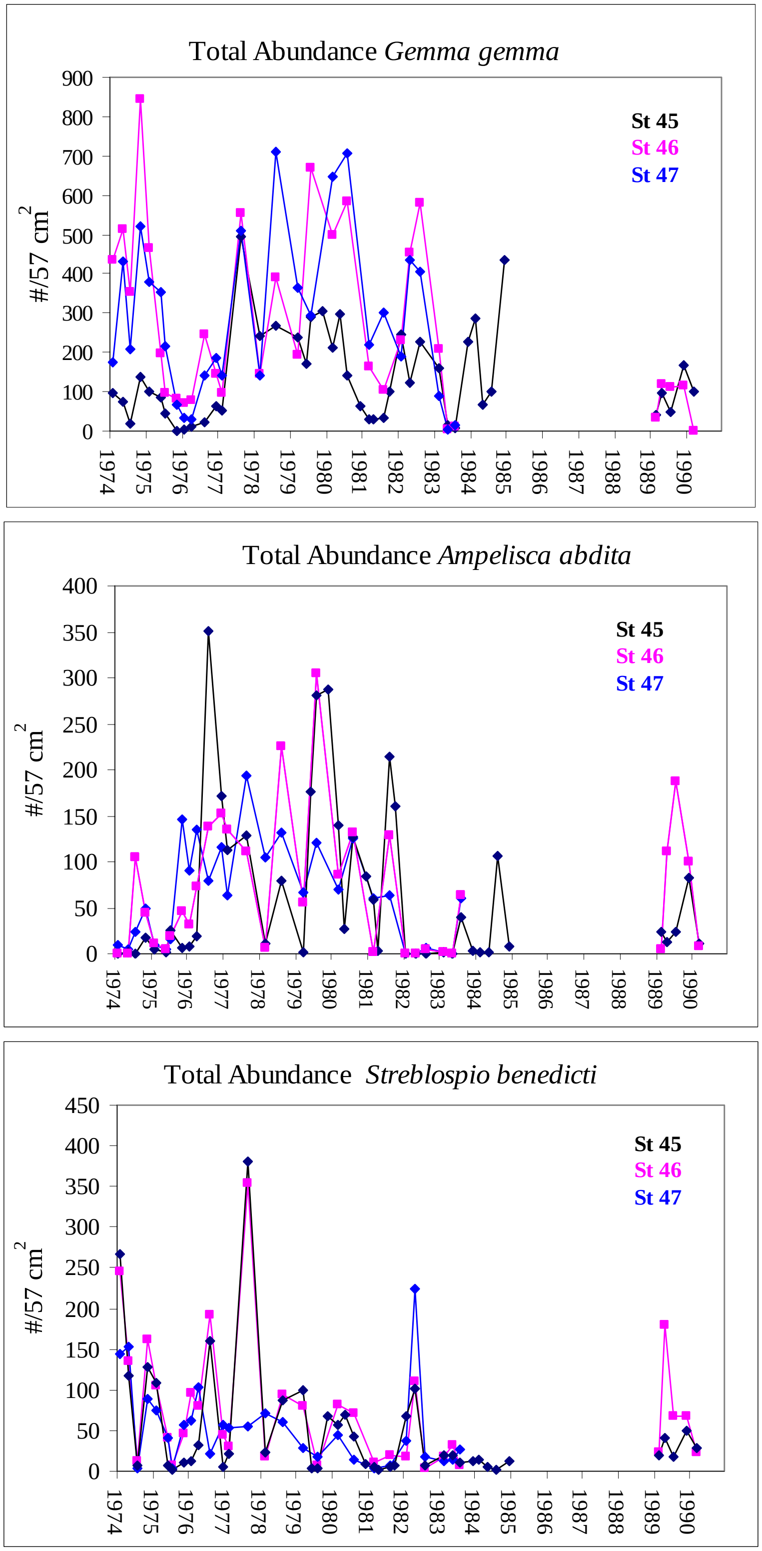


Figure 5. Average abundance of the three most abundant species in the mudflat. Values shown are from quarterly samples to standardize the data between years.

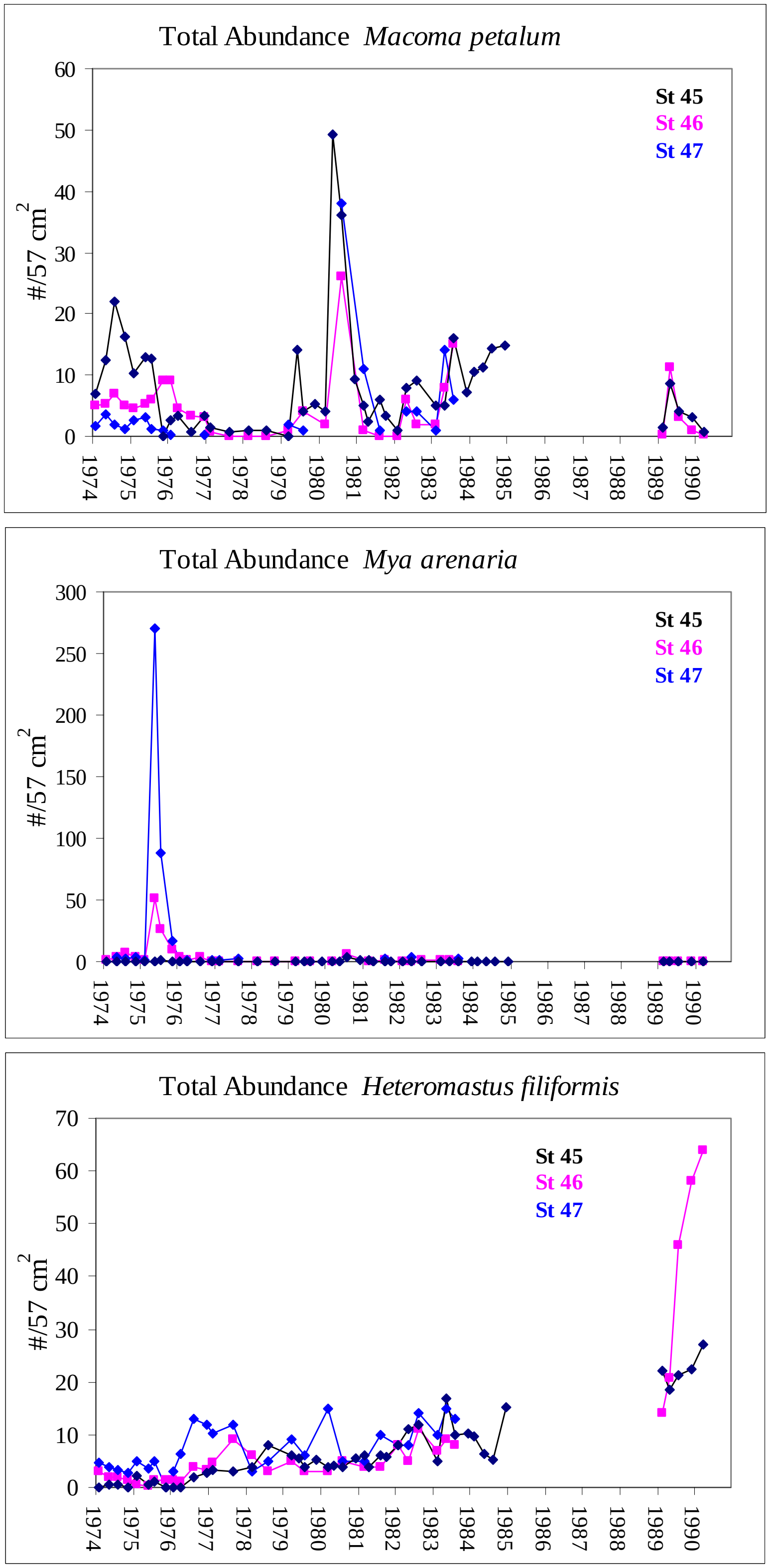


Figure 6. Average abundance of two important prey items for birds (*M. petulam and M. arenaria*) and one species that shows a long term trend (*H. filiformis*). Values shown are from quarterly samples to standardize the data between years.

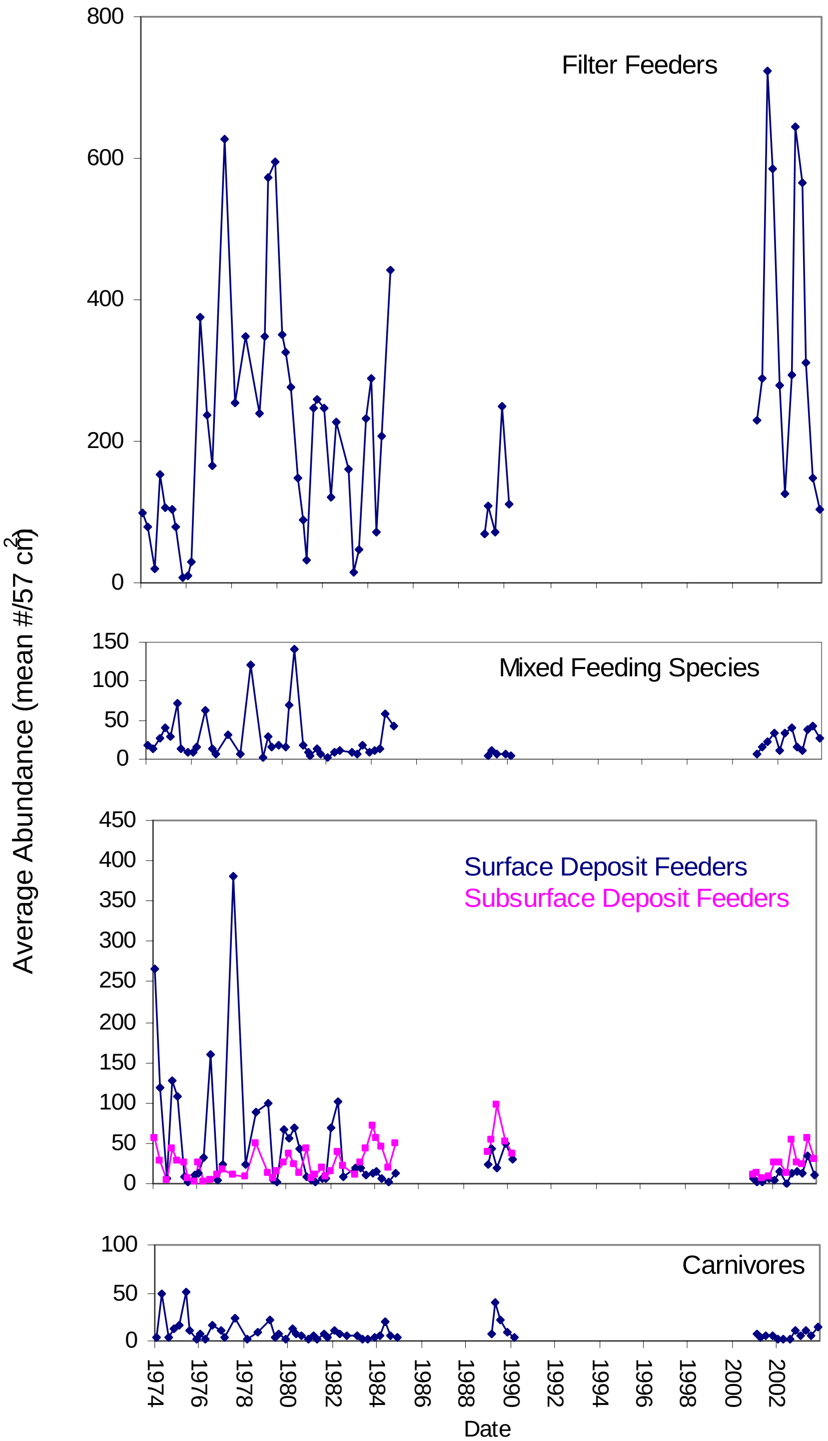


Figure 7. Number of individuals in each feeding group. Mixed feeding species include those that can surface or subsurface deposit feed and filter feed.

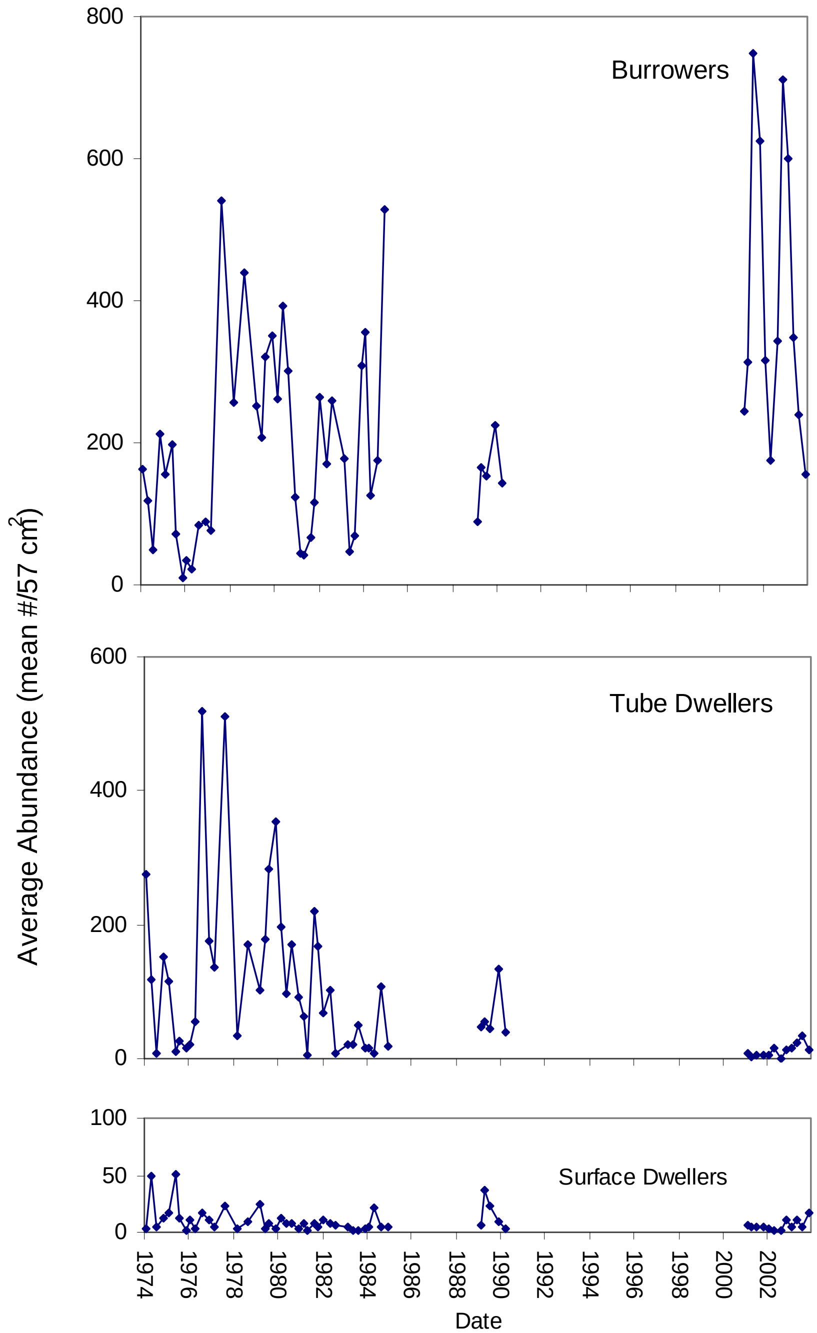


Figure 8. Number of individuals in each habitat group.

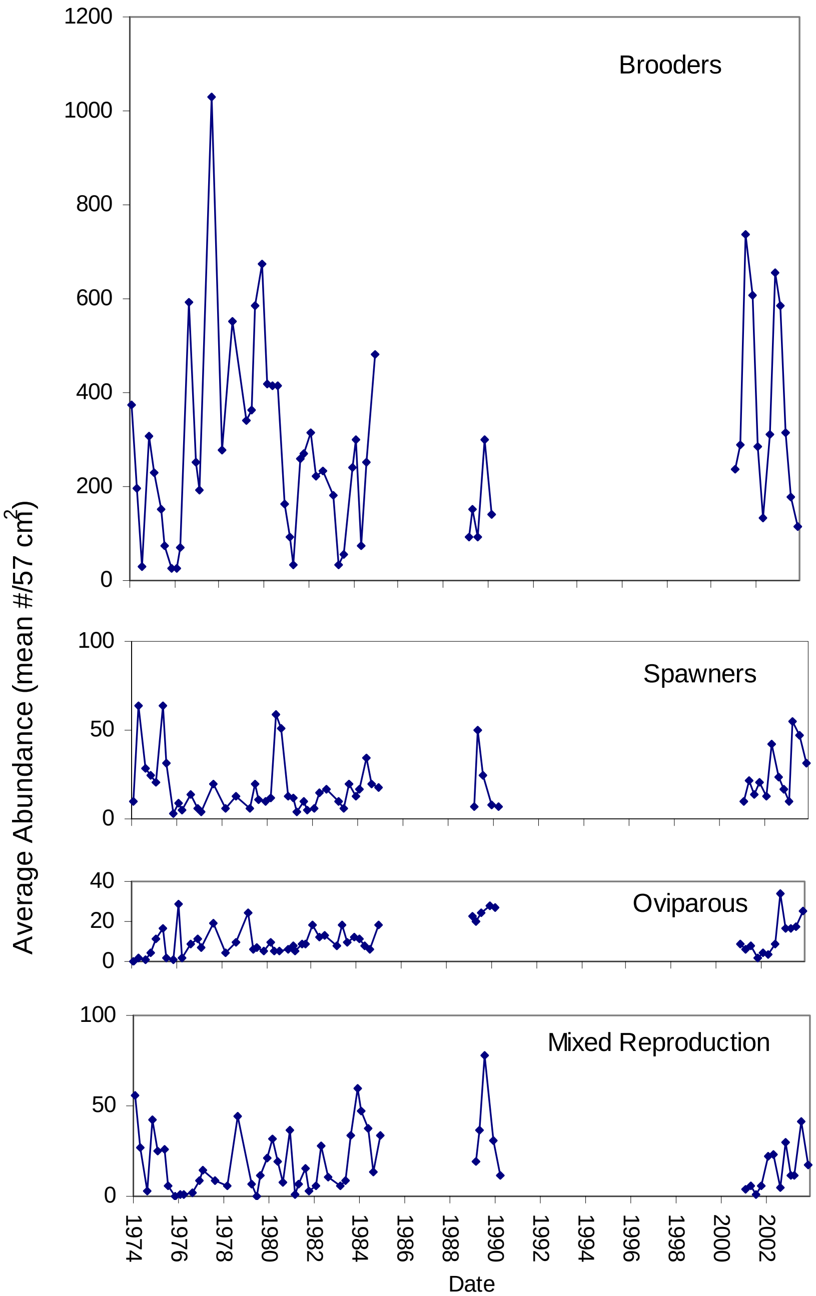


Figure 9. Number of individuals in each reproductive group. Mixed reproduction species include those species that can spawn and brood their young.

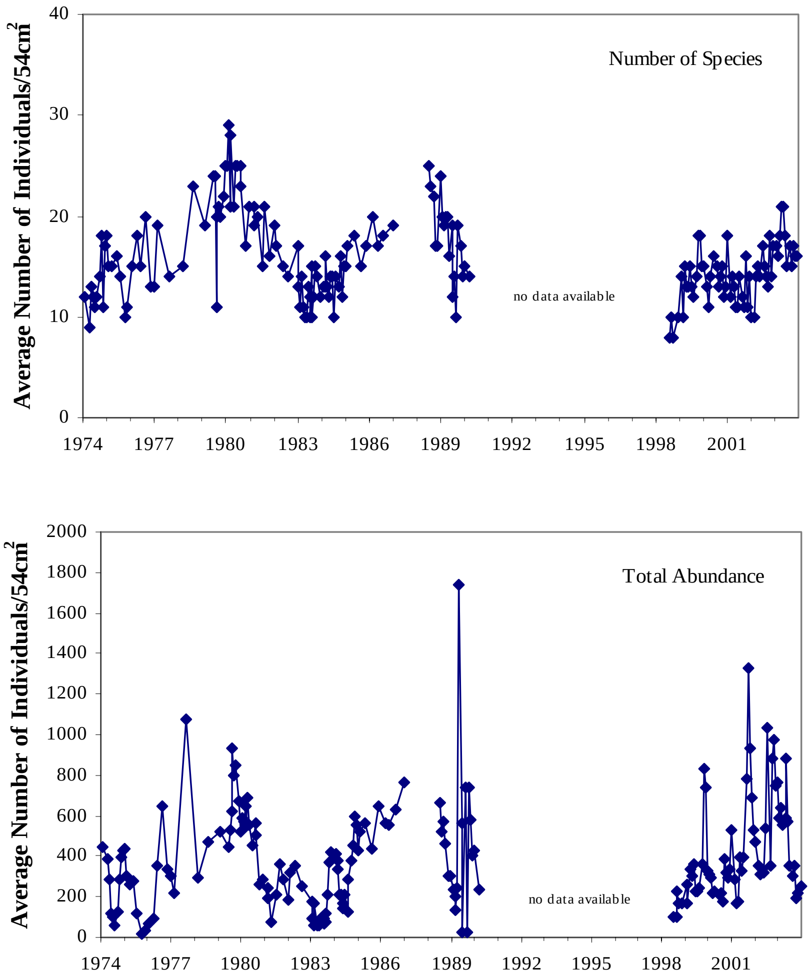


Figure 10. Number of species and total abundance of organisms at station 45, the nearshore station.

We include, in the following sections, descriptions of the dominant species including their habitat, reproductive mode and larval dispersal, recruitment period, their prey and predators, and their distribution in the bay. The potential for their spread into newly available habitat will be discussed where relevant.

Gemma gemma: This small (maximum length 5mm) venerid bivalve was introduced into San Francisco Bay in the 1890's, probably with the Atlantic oyster. It has been a consistently dominant species on the Palo Alto mudflat and is reported to occur throughout South Bay and San Pablo Bay (Hopkins 1986). It shows little habitat preference and occurs in the high intertidal and in the deep channel habitats in the bay; *G. gemma* has been found by the author in all sediment types except shell hash and gravel in the bay. Fully formed juvenile bivalves are released from the female as "crawl away" juveniles in spring and fall with the dominant recruitment period occurring in fall in recent years (Figure 11). Thompson (1982) reported the primary reproduction and

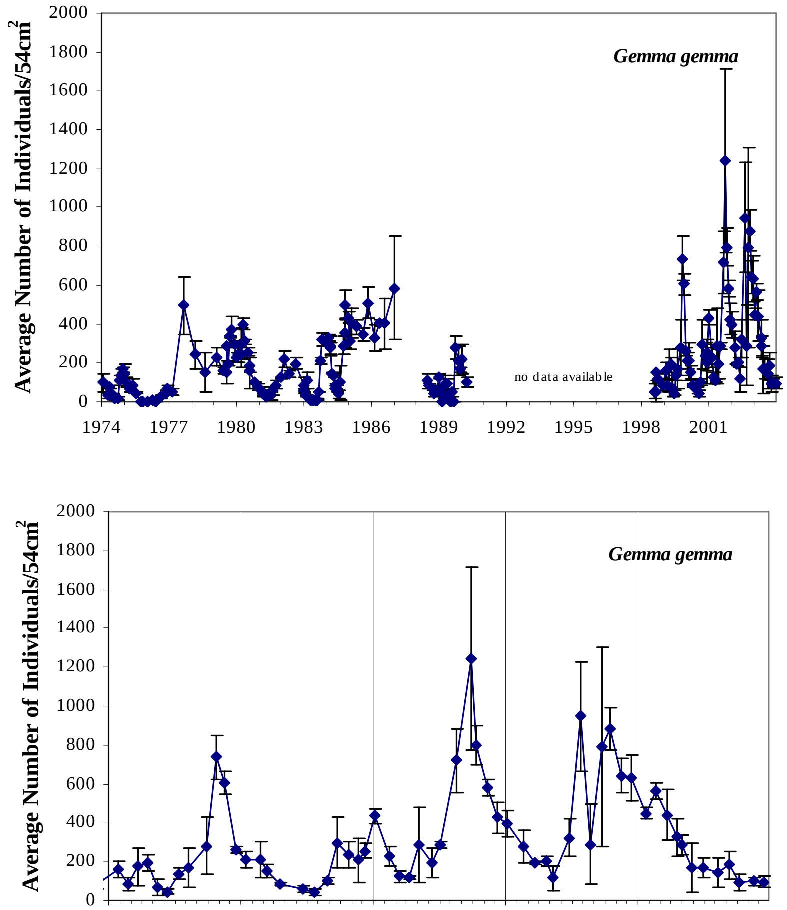
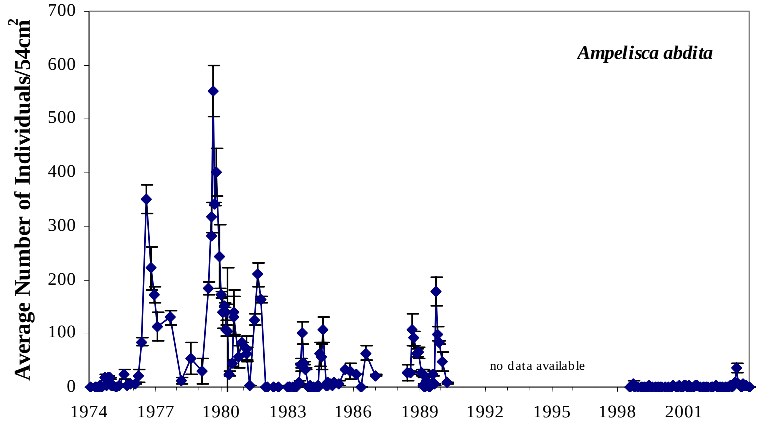


Figure 11. Temporal variability of *G. gemma* at St. 45 1974-2003. Abscissa of second graph (1999-2003) is expanded to show details of seasonal mortality and recruitment.

recruitment period to be in spring in 1974 so the relative dominance of the recruitment periods may vary between years. *G. gemma* is a filter feeder that lives near the surface of the sediment and thus is likely to filter out pelagic and bed load particles. These small bivalves are known to be preyed upon by shore birds (Recher 1966) and ducks (Painter 1966), are most likely eaten by *Carcinus maenas* which prey upon the similarly sized bivalve, *Transennella,* in Bodega Bay (Grosholz and Ruiz 1995), and are possibly consumed by *Philine auriformis* (Gosliner 1995). Because of their near surface growth position, *G. gemma* are reported as being resuspended and transported as juveniles and adults resulting in substantial changes in population structure and density (Thompson 1982). Thus this species is capable of spreading out of existing areas despite their reproductive mode, but they are unlikely to spread as quickly as species with pelagic larvae because *G. gemma* are most likely to be transported as bedload.

Ampelisca abdita: First seen in the bay in the 1950's this tube dwelling amphipod can become extremely dense such that beds have the appearance of shag carpet. *A. abdita* was a very dominant species in our Palo Alto mudflat until the 1990's when it



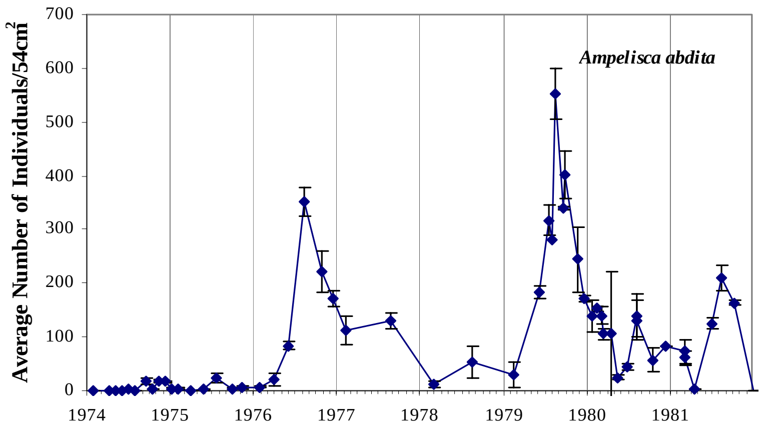


Figure 12. Temporal variability of *A. abitda* at St. 45 1974-2003. Abscissa of second graph (1974-1981) is expanded to show details of seasonal mortality and recruitment.

became a common but not abundant organism on the mudflat (Figure 12). *A. abdita* has been reported throughout the South Bay, San Pablo Bay, and into Suisun Bay in dry years (Hopkins 1986) and has been reported in habitats and depths similar to those reported for *G. gemma*. *A. abdita* is a filter-feeder that feeds from within its tube (Mills 1967) and like *G. gemma* is likely to filter particles that are both pelagic and tumbling along the bottom. We have noted that females have fully developed young in their brood in spring and in fall and that juveniles are common in late fall and early summer in Palo Alto. As reported by Hardin and Kinney (1983), *A. abdita* populations are extremely variable in time, and time series data show that these amphipods are likely to become pelagic and move as a group. Mills (1967) reports that the largest numbers of individuals leave their tubes and swim during full moons and spring tides on the Atlantic coast and that fertilization occurs during these swarms. However, Mills also reports that there are always individuals in the water column during every night. Males disappear after the breeding period and females die after the juveniles leave the brood chamber. Given this semi-pelagic lifestyle it is not surprising that *A. abdita* have been reported in stomach contents of fish without any indication of tube debris; i.e. it is most likely that these individuals were consumed while in the water column (Thomas 1976). Due to the swimming behavior of *A. abdita*, if there are extant populations of this amphipod near a newly opened habitat they are capable invading the habitat as adults or as juveniles.

Streblospio benedicti. This spionid polychaete is similar to *A. abdita* in that it is a tube dwelling organism that used to be a dominant member of the benthic community but is much less common today (Figure 13). *S. benedicti* is a true opportunistic species that (1) can filter feed and deposit feed by either extending its tentacles into the flow or out

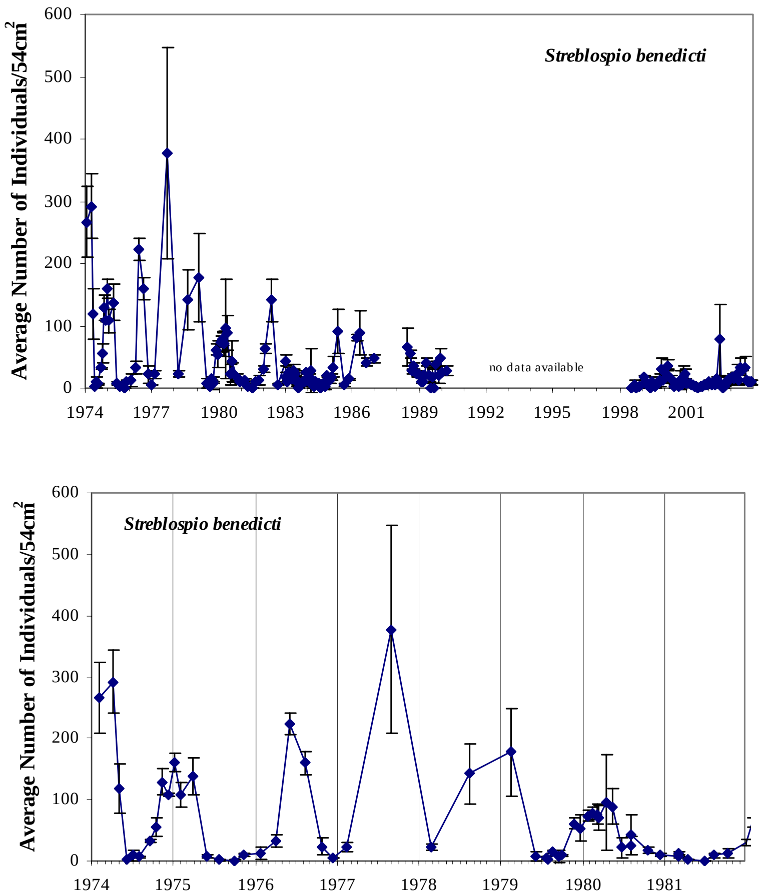


Figure 13. Temporal variability of *S. benedicti* at St. 45 1974-2003. Abscissa of second graph (1974-1981) is expanded to show details of seasonal mortality and recruitment.

onto the mudflat surface, (2) has a sexual reproductive mode with planktonic larvae and an alternative brooding mode whereby crawl away juveniles are released (Dean 1965, Fauchald and Jumars 1979), and (3) like the previous two species, is distributed throughout the bay in all depths and most sediment types. *S. benedicti* is also an exotic species that was first seen in the bay in 1932 and Cohen and Carlton (1995) have proposed that it came into the bay with ballast or the importation of Atlantic Oysters. *S. benedicti's* reproductive periods appear to be similar to that of *G. gemma* and *A. abdita* with gravid and brooding females appearing in spring and fall. We can expect *S. benedicti* to invade any new environment quickly if the water quality is acceptable and if there are extant populations in the area. Although the species has declined in abundance in our studies, it is still consistently present in our samples.

Macoma balthica (*petulam*). Until recently, this tellinid bivalve was believed to be one of the few native bivalves left in the system. Genetic studies by Meehan et al (1989) indicate that all previously identified *M. balthica* are likely to be *M. petulam*, at least for the last 150 years or more. As the largest infaunal invertebrate in this community, *M. petulam* is a major contributor to the biomass and secondary production

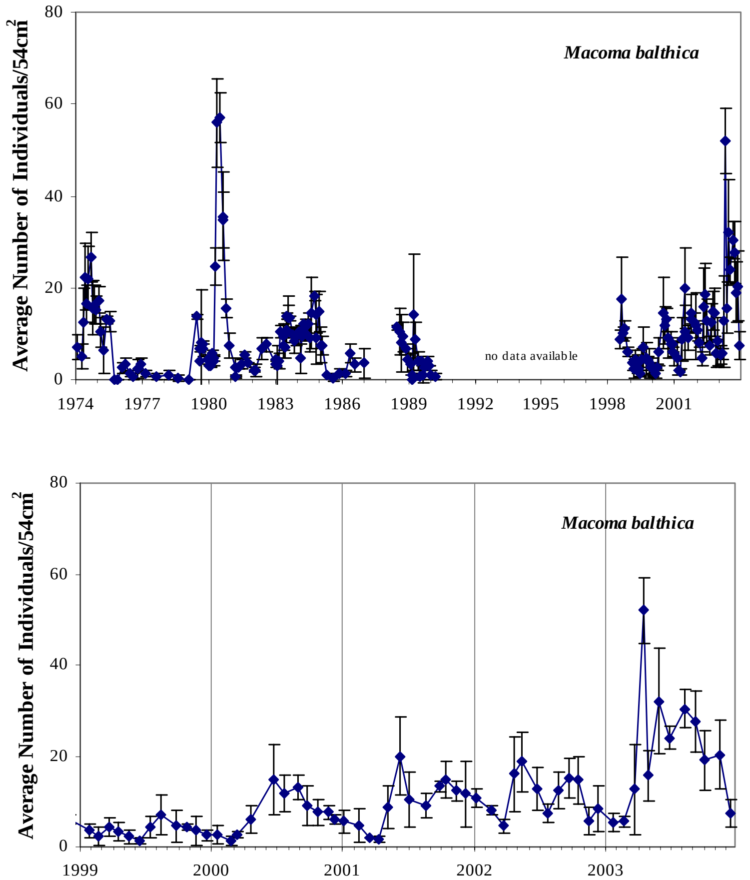
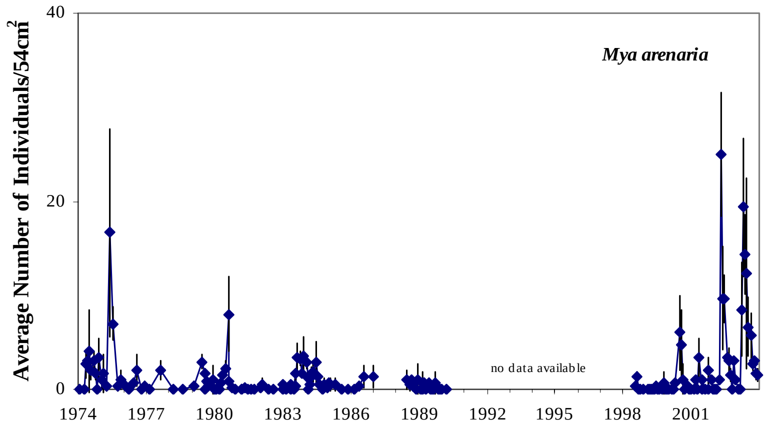


Figure 12. Temporal variability of *M. balthica* at St. 45 1974-2003. Abscissa of second graph (1999-2003) is expanded to show details of seasonal mortality and recruitment.

of the Palo Alto mudflat community (Nichols 1977) and is an important prey item for birds (Painter 1966) and bat rays (personal observation) throughout the bay (Hopkins 1986). This bivalve is both a surface deposit feeder and filter feeder and thus can utilize two major food sources in the system. *M. petulam* has external fertilization, and spawns in late fall and spring of most years (Thompson and Nichols 1988, Hornberger et al 2000). Declines in population density in winter of every year (Figure 14) may be due to a combination of increased predation from migrating bat rays and birds and increased physiological stresses during the winter period. Juvenile *M. petulam* have been reported in the South Bay in early winter and spring. Because this species is found throughout South Bay (Hopkins 1986 and personal observation) and the larvae are pelagic, this species is likely to invade a new habitat within a year if the sediment and water quality are agreeable and circulation patterns allow for transport of larvae.

Mya arenaria: This bivalve is commercially important in other systems and was a valuable fishery in San Francisco Bay in the late1800's and early 1900's (Skinner 1962). Evidence of the potential size of these animals can still be seen in the shell debris adjacent to the Palo Alto site where *M. arenaria* shells in excess of 10 cm in length are not uncommon. We have not seen evidence of animals in this size range since



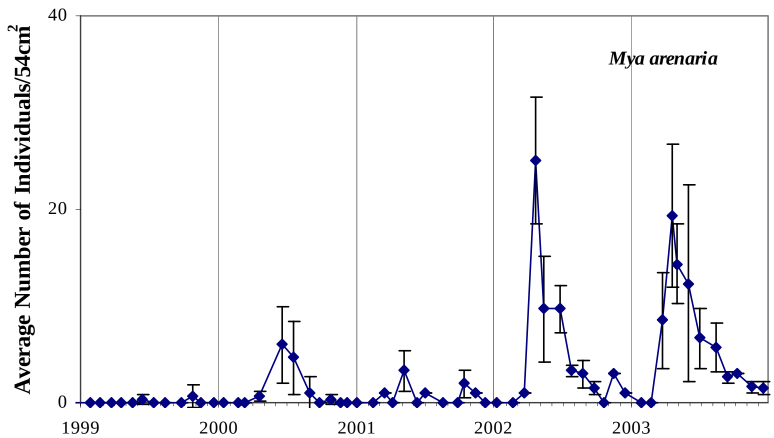
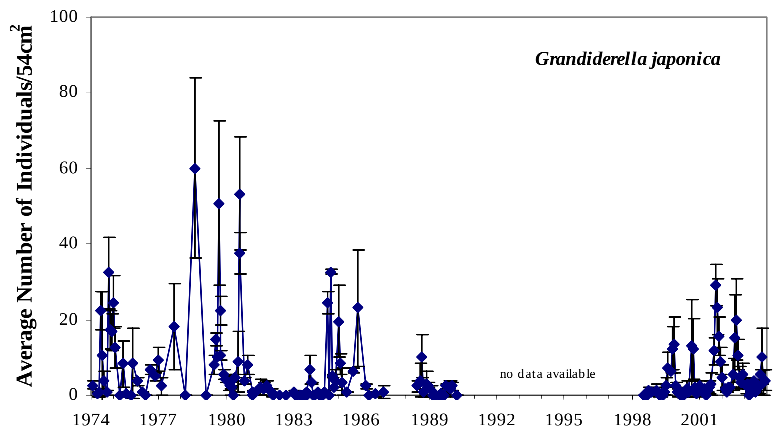


Figure 15. Temporal variability of *M. arenaria* at St. 45 1974-2003. Abscissa of second graph (1999-2003) is expanded to show details of seasonal mortality and recruitment.

we began sampling the benthic community in south bay in the early 1970's. We have seen siphons in the northern bay in recent years that may indicate that the species is re-emerging as an important species in the northern bay. *M. arenaria* is a filter feeder with external fertilization and pelagic larvae. Rosenblum and Niesen (1984) report that *M. arenaria* has a long spawning cycle beginning in spring and continuing through summer in the South Bay. Recruitment in this study and the large spatial study for bivalves (Thompson 1999) show juveniles beginning to appear in mid to late spring with only limited evidence of summer recruitment (Figure 15). This large bivalve was sufficiently preyed upon by bat rays and flounder that clam beds in the early 1900's were fenced (Skinner 1962). Its rapid disappearance from the mudflat and from other locations in South Bay whenever it does recruit (Thompson 1999) indicates that birds, fish, and/or invertebrates are heavily preying upon this species. *M. arenaria* is a euryhaline species that lives in intertidal habitats and in deep water, but it does not tolerate freshwater well so its distribution into the North Bay and into the local streams in South Bay is limited by this intolerance. The larvae of this bivalve are likely to invade new environments if its water quality criteria are met however these requirements are likely to be more stringent than for the species listed above.

Grandiderella japonica: Other than *A. abidita*, the dominant macrofaunal crustaceans in South Bay are the burrowing amphipods *G. japonica* and several species of *Corophium*. Due to the many taxonomic difficulties with the *Corophium* group, we show *G. japonica* here because their functional ecologies are identical. Both genera are brooders that burrow in the sediment and can establish temporary burrows in which they can alternately filter feed or deposit feed. *Grandiderella* is an exotic species as are most



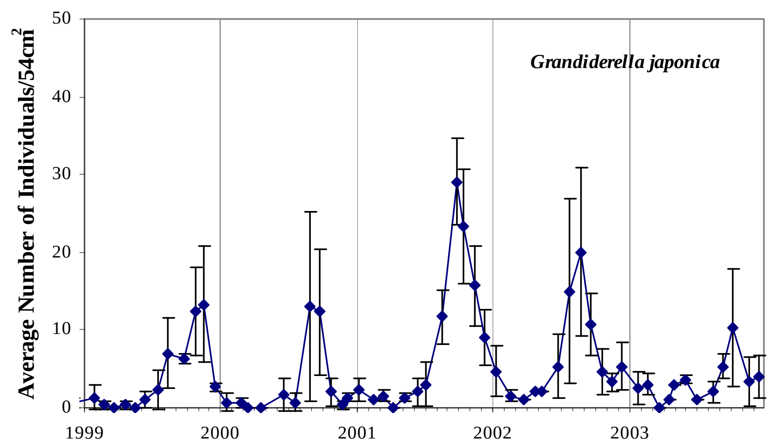


Figure 16. Temporal variability of *G. japonica* at St. 45 1974-2003. Abscissa of second graph (1999-2003) is expanded to show details of seasonal mortality and recruitment.

of the species of *Corophium* that we find in the South Bay today. Although we do not know their recruitment periods, populations peak in fall or summer of most years (Figure 16) and it is therefore likely that recruitment occurs in late spring and fall. Both genera are known for their tolerance of poor water quality and thus they are likely to invade a new area quickly if the environment is marginal for other species. As seen with other amphipods in the mudflat environment, it is expected that they are prey for the many shorebirds in the area.

Other species: There are several common species in this benthic community but none of the other species show high abundance or seasonal patterns such as those discussed above. The abundance plot of the polychaete *Eteone* spp (Figure 17) is representative of this group. The oligachaetes are a difficult taxonomic group that have not been identified to genus level and are therefore not described in detail here. It is obvious from the plot that this group is an important component of the benthic community and given what we know about the group (Barnes 1980), we expect that they will quickly invade new habitat. One species, the polychaete *Heteromastus filiformis*, has shown a trend towards increasing abundance during the study. *H. filiformis* is a subsurface deposit feeder that lays its eggs in the sediment where they hatch into planktonic larvae. As noted by Shouse (2002) the increase in abundance of this species over the period of this study may be due to reduced loading of trace elements from the nearby water quality control plant. The resultant decline in sediment concentrations of these trace elements may have resulted in increased population abundance by benefiting the health of juvenile and adult *H. filiformis* who must consume large volumes of sediment to feed.

Large Scale Patterns of Bivalves – What These Patterns Tell Us About Predators on Benthic Community and Recruitment Processes

While doing a study of the spatial distribution of bivalves in South Bay as part of a larger study on the grazing effects of bivalves on the phytoplankton dynamics of the southern bay, it became clear that bivalve distributions were not consistent in either time or space. Monthly samples at 6 to 13 stations showed bivalves were mostly absent in the shallow water each winter/spring. Although the deep water populations frequently showed a decline in winter, the bivalves did not disappear from these locations (Figure 18). In addition, the highest elevation mudflats on the eastern shore seemed most likely to have limited recruitment during some years; i.e. shallow stations that were closer to the channel had successful bivalve populations in 1992-1993 but those like the northeast station shown here, which were further removed from the channel, did not have bivalve recruits during these years. This general pattern was confirmed in the spatially intensive sampling in 1993-1995 (Figure 19); although the shallow water bivalves disappeared the bivalves in the deep, channel areas persisted throughout the year. In addition, although an annual spring recruitment of bivalves occurred in four years of the five year study throughout the bay, recruitment was not spatially uniform.

Thompson (1999) hypothesized that migratory birds and bat rays which migrate into the system every late fall eliminated the bivalves in the shallow water every winter and that the deep water bivalves were thus responsible for supplying recruits to the system each year. These new recruits were observed to grow quickly and the biomass of bivalves in the shallow water became quite large by fall (Figure 19). Because the shallow water bivalves were dependent on the adults in the deeper water to supply recruits, the failure of all bivalves to recruit during one year (1994, Figure 18) might have resulted in a depauperate benthic community in the following year because most of the bivalves in South Bay live about 2 years. However, the following year, 1995, was an extremely wet year and the bivalves appeared to have recruited from larvae delivered with the freshwater from the northern reaches of the bay. From these studies we have concluded that bivalve recruitment in the shallow water in south bay is dependent

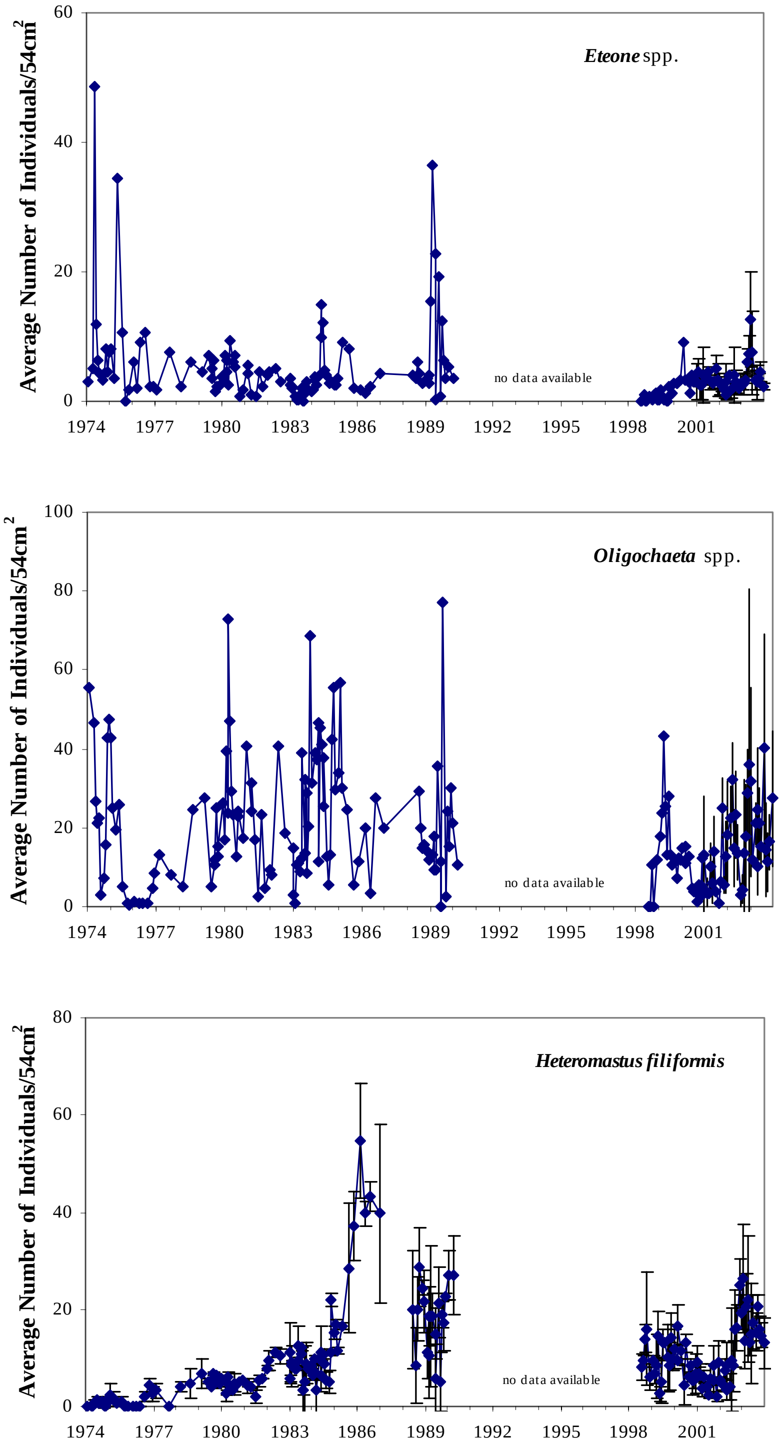


Figure 17. Temporal variability of *Eteone* spp, Oligochetes, and *H. filiformis* at St. 45 1974-2003.

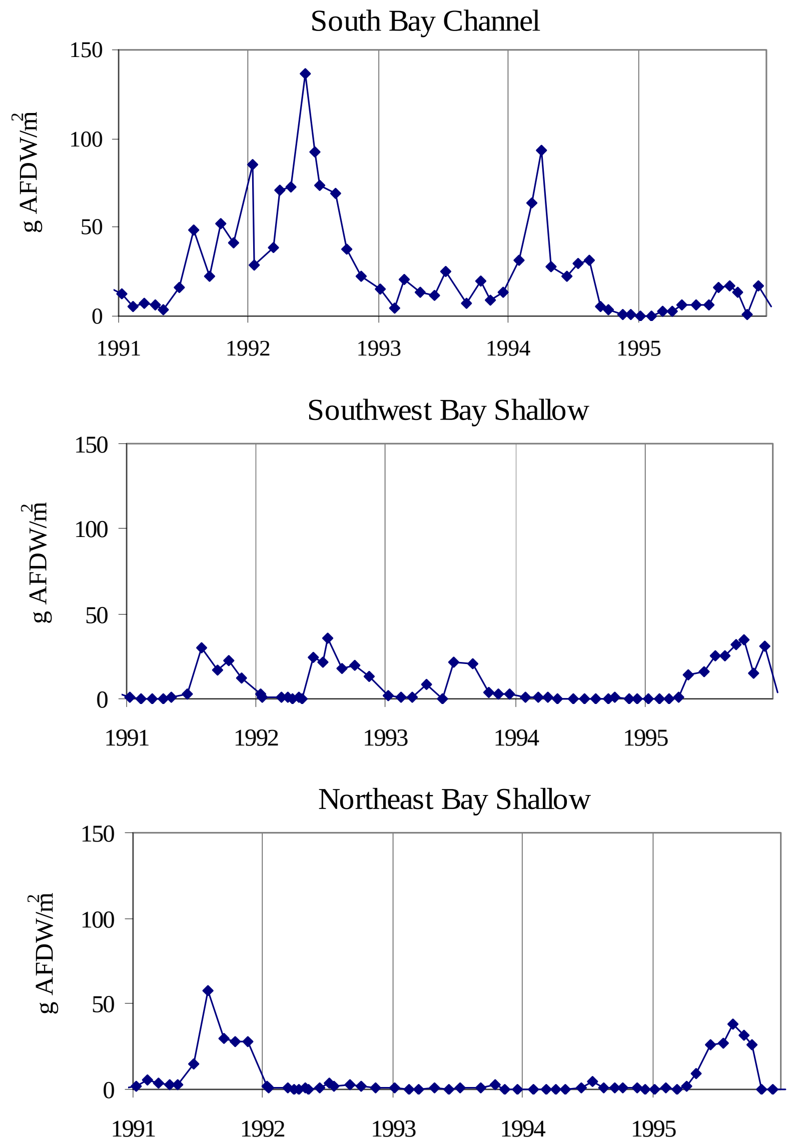
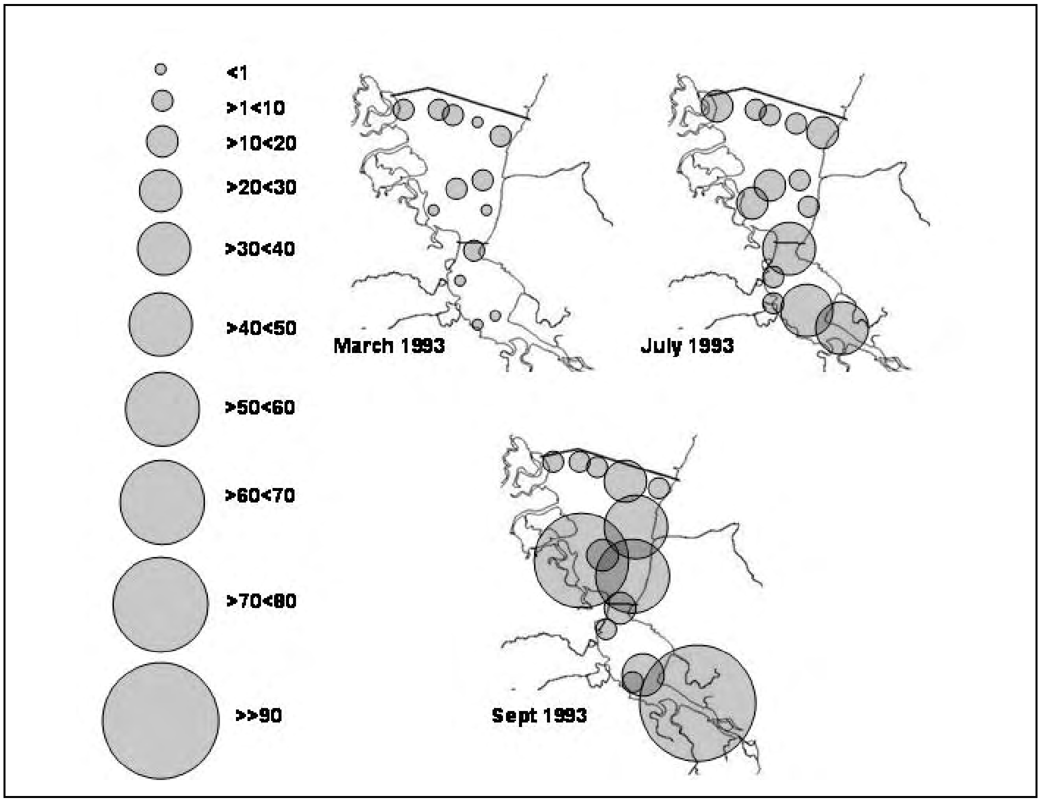


Figure 18. Biomass at a channel station (St. 49 on Figure 2) and at two shallow stations in South Bay. The northeast station (St. 44 on Figure 2) is about five times the distance from the channel as the southwest station (St. 25 on Figure 2).

on (1) the number of adults bivalves available in the deep water, (2) the circulation patterns that are available for transport of larvae onto the mudflats from the deep areas, and (3) transport of larvae from the northern bay if there are few adult bivalves available in the southern bay. Based on this study, it is possible that bivalves will be slow to recruit into newly development habitat which is far removed from the channel populations of adult bivalves.



<1
>1<10
>10<20
>20<30
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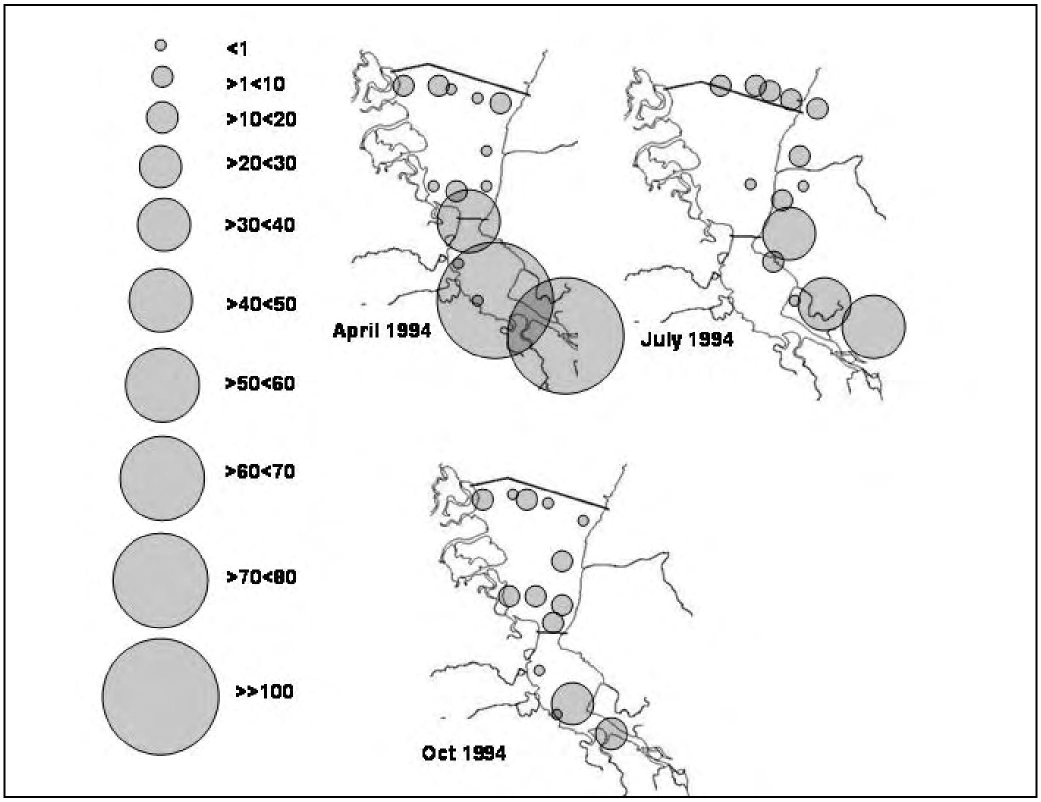
>40<50
>50<60
>60<70
>70<80
>>90
March 1993
July 1993
Sept 1993



<1
>1<10
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April 1994
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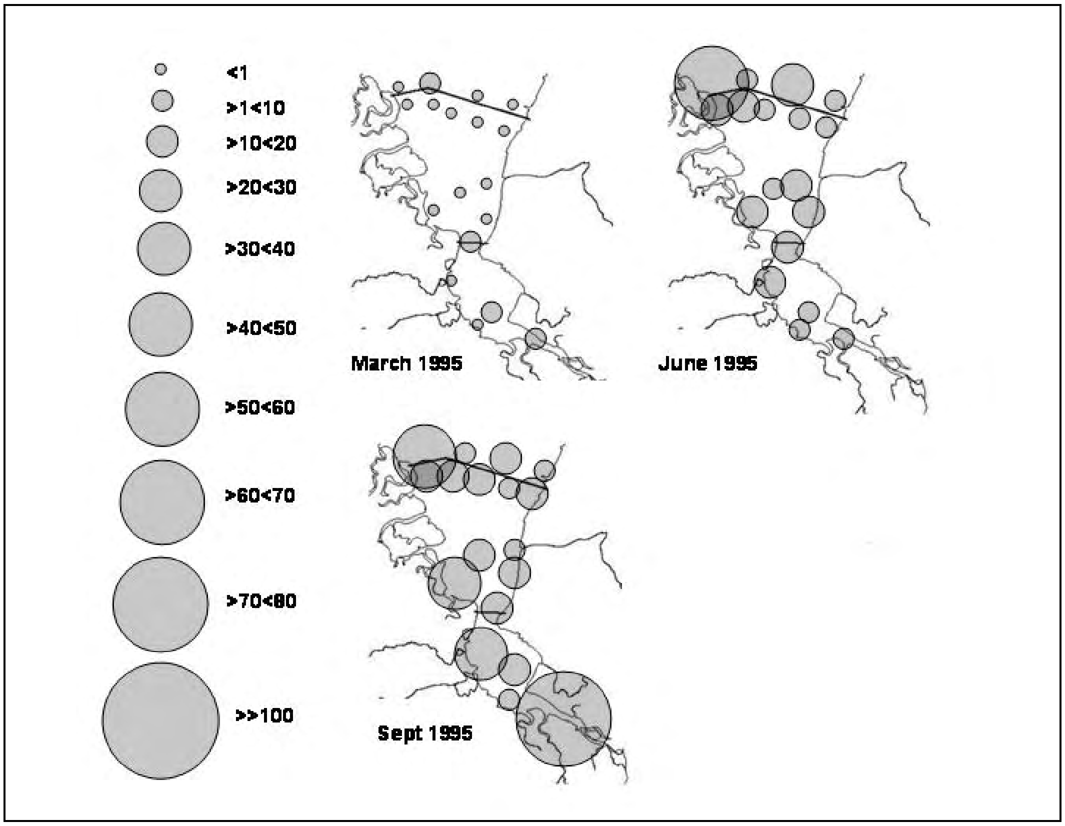

Figure 19. Seasonal bivalve biomass in South Bay in 1993-1995. Each circle represents the average biomass (g AFDW/m^2) in each geographic/bathymetric region.

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Appendix A. Palo Alto mudflat samples available for further analyses. Samples collected but not processed shown as a blank cell. n/s = not sampled.

	Sta. FN45			Sta. FN46			Sta. FN47		
Date	H-1	H-2	H-3	H-1	H-2	H-3	H-1	H-2	H-3
3/22/1979	processed	processed	processed	processed			processed		
8/7/1979	processed	processed	processed	processed			processed		
3/12/1980	processed	processed	processed	processed			processed		
8/12/1980	processed	processed	processed	processed			processed		
3/10/1981	processed	processed	processed	processed			processed		
8/18/1981	processed	processed	processed	processed			processed		
2/3/1982	processed	processed	processed	processed			processed		
5/11/1982	processed	processed	processed	processed	processed		processed	processed	
8/19/1982	processed	processed	processed	processed			processed		
1/11/1983	processed	processed	processed	processed	n/s	n/s	processed	n/s	n/s
2/22/1983	processed	processed	processed	processed			processed	processed	
5/18/1983	processed	processed	processed	processed			processed		
7/13/1983	processed	processed	processed	processed			processed		
8/10/1983	processed	processed	processed	processed			processed		
12/16/1983	processed	processed	processed	processed			processed		
2/21/1984	processed	processed	processed	processed			processed		
5/18/1984	processed	processed	processed	processed			processed		
8/14/1984	processed	processed	processed	processed			processed		
11/5/1984	processed	processed	processed	processed			processed		
2/13/1985	processed	processed	processed	processed			processed		
5/8/1985	processed	processed	processed	processed			processed		
8/19/1985	processed	processed	processed	processed			processed		
11/11/1985	processed	processed	processed	processed			processed		
2/3/1986	processed	processed	processed	processed	processed	processed	processed	processed	processed
3/5/1986	processed	processed	processed						
5/18/1986	processed	processed	processed						
8/7/1986	processed	processed	processed						
12/29/1986	processed	processed	processed						
4/22/1988	n/s	n/s	n/s				n/s	n/s	n/s
5/5/1988	n/s	n/s	n/s				n/s	n/s	n/s
5/18/1988	n/s	n/s	n/s				n/s	n/s	n/s
6/7/1988	n/s	n/s	n/s				n/s	n/s	n/s
6/29/1988	processed	processed	processed						
7/12/1988	n/s	n/s	n/s				n/s	n/s	n/s

	Sta. FN45			Sta. FN46			Sta. FN47		
Date	H-1	H-2	H-3	H-1	H-2	H-3	H-1	H-2	H-3
8/1/1988	processed	processed	processed						
8/16/1988	n/s	n/s	n/s				n/s	n/s	n/s
9/9/1988	processed	processed	processed						
9/27/1988	n/s	n/s	n/s				n/s	n/s	n/s
10/10/1988	processed	processed	processed						
11/7/1988	n/s	n/s	n/s				n/s	n/s	n/s
11/21/1988	processed	processed	processed						

12/5/1988	n/s	n/s	n/s				n/s	n/s	n/s
12/19/1988	processed	processed	processed						
1/3/1989	processed	processed	processed						
1/19/1989	n/s	n/s	n/s				n/s	n/s	n/s
1/30/1989	processed	processed	processed						
2/13/1989	n/s	n/s	n/s				n/s	n/s	n/s
2/27/1989	processed	processed	processed	processed	processed	processed			
3/15/1989	processed	processed	processed						
3/31/1989	n/s	n/s	n/s				n/s	n/s	n/s
4/11/1989	processed	processed	processed						
5/5/1989	processed	processed	processed	processed	processed	processed			
5/26/1989	n/s	n/s	n/s				n/s	n/s	n/s
6/8/1989	processed	processed	processed						
6/20/1989	n/s	n/s	n/s				n/s	n/s	n/s
7/7/1989	processed	processed	processed						
7/19/1989	n/s	n/s	n/s				n/s	n/s	n/s
8/2/1989	processed	processed	processed	processed	processed	processed			
8/17/1989	n/s	n/s	n/s				n/s	n/s	n/s
9/1/1989	processed	processed	processed						
9/29/1989	processed	processed	processed				n/s	n/s	n/s
11/8/1989	processed	processed	processed				n/s	n/s	n/s
12/7/1989	processed	processed	processed	processed	processed	processed	n/s	n/s	n/s
1/5/1990	processed	processed	processed	processed	processed	processed			
3/28/1990	processed	processed	processed	processed	processed	processed			

Appendix B. Benthic samples available for further analyses from South Bay grazing study as shown in Figure 2.

Stations Sampled Each Season

Date	# Stations	Samples/Station	Comments
Mar-93	42	1	large bivalve species removed and measured
Jul-93	46	1	large bivalve species removed and measured
Sep-93	46	1	large bivalve species removed and measured
Apr-94	46	1	large bivalve species removed and measured
Jul-94	46	1	large bivalve species removed and measured
Oct-94	50	1	large bivalve species removed and measured
Mar-95	62	1	large bivalve species removed and measured
Jun-95	62	1	large bivalve species removed and measured
Sep-95	62	1	large bivalve species removed and measured
Mar-97	62	1	no processing
Jun-97	62	1	large bivalve species removed and measured
Mar-98	24	1	no processing
Jun-98	24	1	no processing
Sep-98	24	1	no processing

Stations Sampled Each Month

Date	# Stations	Samples/Station	Comments
13-Dec-90	7	3	large bivalve species removed and measured
10-Jan-91	7	3	large bivalve species removed and measured
12-Feb-91	7	3	large bivalve species removed and measured
13-Mar-91	7	3	large bivalve species removed and measured
15-Apr-91	7	3	large bivalve species removed and measured
6-May-91	7	3	large bivalve species removed and measured
19-Jun-91	7	3	large bivalve species removed and measured
31-Jul-91	7	3	large bivalve species removed and measured
16-Sep-91	7	3	large bivalve species removed and measured
17-Oct-91	7	3	large bivalve species removed and measured
21-Nov-91	7	3	large bivalve species removed and measured
14-Jan-92	6	3	large bivalve species removed and measured
18-Feb-92	6	3	large bivalve species removed and measured
12-Mar-92	6	3	large bivalve species removed and measured
1-Apr-92	6	3	large bivalve species removed and measured
1-May-92	6	3	large bivalve species removed and measured
11-Jun-92	6	3	large bivalve species removed and measured
9-Jul-92	6	3	large bivalve species removed and measured
23-Jul-92	6	3	large bivalve species removed and measured
3-Sep-92	6	3	large bivalve species removed and measured
6-Oct-92	6	3	large bivalve species removed and measured
17-Nov-92	6	3	large bivalve species removed and measured
5-Jan-93	8	3	large bivalve species removed and measured
16-Feb-93	11	3	large bivalve species removed and measured
18-Mar-93	13	3	large bivalve species removed and measured
30-Apr-93	13	3	large bivalve species removed and measured
11-Jun-93	10	3	large bivalve species removed and measured
12-Jul-93	13	3	large bivalve species removed and measured
7-Sep-93	13	3	large bivalve species removed and measured
19-Oct-93	13	3	large bivalve species removed and measured

Stations Sampled Each Month

Date	# Stations	Samples/Station	Comments
16-Nov-93	12	3	large bivalve species removed and measured
20-Dec-93	13	3	large bivalve species removed and measured
2-Feb-94	13	3	large bivalve species removed and measured
9-Mar-94	13	3	large bivalve species removed and measured
7-Apr-94	13	3	large bivalve species removed and measured
4-May-94	13	3	large bivalve species removed and measured
17-Jun-94	13	3	large bivalve species removed and measured
18-Jul-94	13	3	large bivalve species removed and measured
18-Aug-94	13	3	large bivalve species removed and measured
22-Sep-94	13	3	large bivalve species removed and measured
13-Oct-94	13	3	large bivalve species removed and measured
22-Nov-94	13	3	large bivalve species removed and measured
13-Dec-94	13	3	large bivalve species removed and measured
13-Jan-95	13	3	large bivalve species removed and measured
13-Feb-95	13	3	large bivalve species removed and measured
14-Mar-95	13	3	large bivalve species removed and measured
10-Apr-95	13	3	large bivalve species removed and measured
8-May-95	13	3	large bivalve species removed and measured
19-Jun-95	13	3	large bivalve species removed and measured
21-Jul-95	13	3	large bivalve species removed and measured
21-Aug-95	13	3	large bivalve species removed and measured
18-Sep-95	13	3	large bivalve species removed and measured
12-Oct-95	13	3	large bivalve species removed and measured
10-Nov-95	11	3	large bivalve species removed and measured
11-Dec-95	13	3	large bivalve species removed and measured
15-Jan-96	13	3	no processing
06-Feb-96	13	3	no processing
05-Mar-96	13	3	no processing
30-Apr-96	13	3	no processing
10-Jun-96	13	3	no processing
23-Jul-96	13	3	no processing
10-Sep-96	13	3	no processing
08-Oct-96	13	3	no processing
19-Dec-96	13	3	no processing
27-Jan-97	13	3	no processing

Appendix C. Regional Effects Monitoring Program (REM) collections with USGS collection at the site before and after the REM program. Samples were collected at the same intertidal site for all three periods (FN38=REM=PA); location is shown as PA on Figure 2 is of similar tidal elevation as FN47. (CAS: samples at California Academy of Sciences; KLI – samples processed by Kinnetics Laboratory Inc.)

Date	Hauls Collected	Haul #'s Processed	Sample Location	comments
PA REM - Palo Alto				
15-Feb-73	3	3	FN38	CAS
13-Aug-73	3	3	FN38	CAS
09-Aug-75	3		FN38	not processed
24-Oct-75	3		FN38	not processed
13-Jan-76	3		FN38	not processed
01-Mar-76	1		FN38	not processed
29-Apr-76	2		FN38	not processed
05-Aug-76	2		FN38	not processed
30-Jul-77	3		FN38	not processed
22-Sep-86	5	5	REM	processed - KLI
11-Mar-87	5	5	REM	processed - KLI
04-Jun-87	5	5	REM	processed - KLI
21-Jul-87	5	5	REM	processed - KLI
28-Sep-87	5	5	REM	processed - KLI
12-Nov-87	5	5	REM	processed - KLI
14-Jan-88	5	5	REM	processed - KLI
07-Mar-88	5	5	REM	processed - KLI
26-May-88	5	5	REM	processed - KLI
26-Jul-88	5	5	REM	processed - KLI
14-Sep-88	5	5	REM	processed - KLI
02-Nov-88	5	5	REM	processed - KLI
03-Mar-89	5	1	REM	1 haul sorted** USGS
11-May-89	5	1	REM	1 haul sorted** USGS
25-Jul-89	5	1	REM	1 haul sorted** USGS
25-Aug-89	5	1	REM	1 haul sorted** USGS
15-Nov-89	5	1	REM	1 haul sorted** USGS
06-Feb-90	5	1	REM	1 haul sorted** USGS

15-Mar-90	5	2	REM	1 haul sorted** USGS
15-Jun-90	5	1	REM	1 haul sorted** USGS
10-Jul-90	5	2	REM	1 haul sorted** USGS
13-Dec-90	5	1	REM	1 haul sorted** USGS
12-Feb-91	5	1	REM	1 haul sorted** USGS
13-Mar-91	5	1	REM	1 haul sorted** USGS
05-Jan-93	3	*	PAREM	* major bivalves removed
16-Feb-93	3	*	PAREM	* major bivalves removed
18-Mar-93	3	*	PAREM	* major bivalves removed
30-Apr-93	3	*	PAREM	* major bivalves removed
11-Jun-93	3	*	PAREM	* major bivalves removed
12-Jul-93	3	*	PAREM	* major bivalves removed
07-Sep-93	3	*	PAREM	* major bivalves removed
19-Oct-93	3	*	PAREM	* major bivalves removed
16-Nov-93	3	*	PAREM	* major bivalves removed
20-Dec-93	3	*	PAREM	* major bivalves removed
02-Feb-94	3	*	PAREM	* major bivalves removed
09-Mar-94	3	*	PAREM	* major bivalves removed
07-Apr-94	3	*	PAREM	* major bivalves removed
04-May-94	3	*	PAREM	* major bivalves removed
17-Jun-94	3	*	PAREM	* major bivalves removed
18-Jul-94	3	*	PAREM	* major bivalves removed
18-Aug-94	3	*	PAREM	* major bivalves removed
22-Sep-94	3	*	PAREM	* major bivalves removed
13-Oct-94	3	*	PAREM	* major bivalves removed
22-Nov-94	3	*	PAREM	* major bivalves removed
13-Dec-94	3	*	PAREM	* major bivalves removed
13-Jan-95	3	*	PAREM	* major bivalves removed
15-Feb-95	3	*	PAREM	* major bivalves removed
16-Mar-95	3	*	PAREM	* major bivalves removed
11-Apr-95	3	*	PAREM	* major bivalves removed
09-May-95	3	*	PAREM	* major bivalves removed
19-Jun-95	3	*	PAREM	* major bivalves removed
20-Jul-95	3	*	PAREM	* major bivalves removed
22-Aug-95	3	*	PAREM	* major bivalves removed
20-Sep-95	3	*	PAREM	* major bivalves removed
12-Oct-95	3	*	PAREM	* major bivalves removed
13-Dec-95	3	*	PAREM	* major bivalves removed

25-Jan-96	3	PAREM	not processed
06-Feb-96	3	PAREM	not processed
05-Mar-96	3	PAREM	not processed
30-Apr-96	3	PAREM	not processed
10-Jun-96	3	PAREM	not processed
23-Jul-96	3	PAREM	not processed
10-Sep-96	3	PAREM	not processed
08-Oct-96	3	PAREM	not processed
19-Dec-96	3	PAREM	not processed
27-Jan-97	1	PAREM	not processed
19-Mar-97	1	PAREM	not processed
17-Jun-97	1	PAREM	not processed
28-Apr-98	1	PAREM	not processed
22-Jun-98	?	PAREM	not processed
16-Sep-98	1	PAREM	not processed

* major bivalves removed

** taxonomy should be confirmed on polychaeta and arthropoda with W Fields/S. McCormick