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Crissy Field Restoration Project
Summary of Monitoring Data
2000-2004

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Kristen Ward
Myla Ablog
Golden Gate National Recreation Area
Fort Mason, Building 201
San Francisco, CA 94123

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EXECUTIVE SUMMARY

- The Crissy Field marsh underwent dramatic morphologic change in the first 18 months following tidal restoration. This included the development of flood and ebb shoals as well as dramatic changes in the orientation and elevation of the inlet channel. The inlet channel elevation rose from approximately -1.5 feet NGVD immediately following restoration to about +1.5 feet NGVD by May of 2001.

- The reduced effective tidal prism that resulted from morphologic adjustments has led to intermittent closures and reopenings of the tidal marsh inlet. The inlet channel closed 19 times between May 2001 and November 2004. Although most closures are brief (1-2 weeks) and resolve themselves naturally, a few have required mechanical intervention.

- Water quality in the marsh exhibits both spatial and temporal variability. The southeast corner of the marsh is sometimes characterized by low dissolved oxygen and vertical stratification, which is more pronounced during inlet closures. Water quality also shows seasonal, diurnal, and tidal variations. Dissolved oxygen levels in the marsh fluctuate greatly and levels below 5 mg/L are not uncommon, even when the inlet is open.

- Sedimentation in the interior, intertidal areas of the marsh has occurred at a rate of less than 1 cm/year at most and has been highly variable. Two of the three low marsh stations and one mid marsh station have experienced net erosion. Erosion at the two low marsh stations may have been exacerbated during inlet closures when water levels stayed near the elevation of the sedimentation markers for much of the closure.

- Soil porewater salinities from samples collected at six monitoring stations in August 2003 and August 2004 ranged from 1 to 99 ppt and showed no clear patterns with relation to elevation. Low salinities were often associated with brackish vegetation and occurred in areas near seeps or near landscaped areas that receive irrigation runoff. When measured before and after the spring 2004 marsh inlet closure, mean soil porewater salinities increased significantly at high elevations but showed a decreasing trend at low and middle elevations. Other soil parameters have yet to be analyzed (texture, TKN, organic matter).

- Nineteen species of fish from twelve families were collected in Crissy marsh between June 2000 and July 2004. Numerically dominant species include *Clevelandia ios* (arrow goby), *Gasterosteus aculeatus* (threespine stickleback), *Leptocottus armatus* (staghorn sculpin), *Ilypnus gilberti* (cheekspot goby) and *Atherinops affinis* (topsmelt). Two non-native fish species have been collected: *Acanthogobius flavimanus* (yellowfin goby), and *Luciana parva* (Rainwater killifish). Taxa richness and abundance are highest in summer and lowest in winter.

- Thirteen macrocrustacean taxa have been collected in beach seine surveys at Crissy marsh since 2000. The most abundant species are *Hemigrapsus oregonensis* (yellow shorecrab) and *Crangon nigricauda* (Blacktail bay shrimp). Two non-native taxa have been collected: *Palaeamon macrodactylus* and *Carcinus maenas* (European green crab). Like fish, macrocrustacean density and richness are highest in the summer months.

- Benthic invertebrate samples collected at Crissy Field from 2000-2004 are still in the process of being sorted and identified. Ninety-five taxa have been identified in samples processed to date. Numerically dominant taxa include amphipods (predominantly *Grandidierella japonica* and *Corophium* sp.), oligochaetes from the Tubificidae family, nematodes, and several species of polychaetes (*Capitella capitata*, *Tharyx parvus*, *Polydora spp*, *Pseudopolydora spp*.).

- One hundred fifty-four species of bird from 36 families have been detected in the Crissy Field Restoration Area since surveys began in 1999. During all seasons for all years, bird densities were highest in the wetland, followed by the dune swale and rear dune area. Species richness was also highest in the wetland. Nine state- or federally-listed species have been detected at Crissy Field including two common visitors: brown pelican *(Pelecanus occidentalis californicus*) and the snowy egret *(Egretta thula*). The federally threatened western snowy plover (*Charadrius alexandrinus*) has been observed roosting on the beach in the Wildlife Protection Area.

- An adaptive management plan for addressing tidal closures was adopted in January 2002. The regular monitoring program is adapted during inlet closures to track marsh conditions. Season, weather, marsh water levels, tide conditions, and monitoring results are all considered in order to evaluate the likelihood of a natural reopening, and determine whether a mechanical excavation is necessary.

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INTRODUCTION

BACKGROUND AND HISTORY

Crissy Field is located on the northern end of the San Francisco Peninsula in the Presidio of San Francisco. Pre-historically, Crissy Field (and the Marina Green) was part of an extensive 127-acre backdune marsh that drained Tennessee Hollow watershed to San Francisco Bay. Over many decades, and culminating with preparations for the 1915 Panama-Pacific International Exposition, the marsh was filled and the resulting land was used by the U.S. military. In 1994, the Presidio was transferred to the National Park Service as part of the Golden Gate National Recreation Area.

The 1994 Presidio General Management Plan (GMPA) envisioned the re-establishment of wetlands at Crissy Field based on a future feasibility study that would focus on the feasibility, type and extent of wetlands. The Final GMPA Environmental Impact Statement (EIS) considered restoration of a 20-80 acre tidal wetland at Crissy Field.

From 1997-2000, 40 acres of natural habitat were restored including an 18-acre* tidal marsh and 22 acres of dune and dune swale habitat. More than 230,000 cubic yards of fill were removed and a 40-foot-wide channel to the bay was opened in November 1999. Almost 100,000 native plants representing 110 species were planted or seeded in the restoration site including seven special status species.

The Crissy Field Restoration Project was made possible through a diversity of funding partnerships and extensive community involvement. The Project is cooperatively managed by the National Park Service, Golden Gate National Recreation Area (GGNRA) and the Golden Gate National Parks Conservancy (Parks Conservancy).

An evaluation of the Crissy Field Restoration and its success in meeting restoration plan objectives was completed in 2001 (Stringer 2001). In contrast, this report presents results from monitoring.

MONITORING PLAN AND OBJECTIVES

A draft monitoring plan for following the development of the restored areas at Crissy Field was initially developed by Meredith Savage of the Golden Gate National Parks Conservancy (Savage 2000). This plan called for monitoring of hydrology and geomorphology, water quality, soils, sedimentation, vegetation, fish, invertebrates and birds. The plan was completed in May 2000 and included detailed protocols for sampling each parameter. Protocols were developed following thorough literature review, and went through several revisions which were guided by input from local experts as well as NPS natural resources staff.

Parameters were selected for one or more of the following reasons: 1) to measure the evolution of key biological and physical characteristics as the site develops and allow for comparision to other estuarine restorations in the park or in the central San Francisco Bay 2) to address restoration and management objectives and provide information necessary to guide

*area below 6 feet NGVD

adaptive management, 3) to provide educational, interpretive, and/or research opportunities, and 4) to address concerns brought up in the Crissy Field planning process.

The draft monitoring plan was implemented from July 2000 through July 2003. However, due to staff constraints, all parameters included in the plan were not necessarily sampled and/or the frequency called for was not met. Nonetheless, this period of implementation provided field-testing of methods and a more thorough understanding of the system. Based on this enhanced understanding, the original plan was modified, protocols were improved, and some new parameters were added to an updated monitoring plan (GGNRA 2003). The monitoring plan was subsequently peer-reviewed and underwent further refinement based on the recommendations received during this process.

Although the updated monitoring plan has only been implemented for one calendar year, this document presents the results of monitoring conducted since 2000. The purpose of this report is solely to present the data. Interpretation of results and further analysis will be reported in future documents. A final report summarizing all of the data collected at Crissy Field will be available in fall 2007.

OTHER RESEARCH AT CRISSY FIELD

Beyond the regular monitoring program, additional research has been initiated at Crissy Marsh to guide management. Research has been done in-house as well as through USGS and university researchers. Some of the research has been aimed at helping address the management challenges resulting from inlet closures, while other research addresses impacts of potential land use in areas adjacent to Crissy Field. These studies are summarized on p.33.

METHODS

A brief description of the methods used to collect monitoring data for each parameter is presented here. More detailed information, including monitoring protocols and QA/QC measures can be found in the “Crissy Field Restoration Area Monitoring Program Quality Assurance Project Plan” (GGNRA 2003).

HYDROLOGY AND GEOMORPHOLOGY

Detailed topographic and bathymetric surveys have been conducted at the site since 2000. Surveys were conducted twice a year (spring and fall) through 2002 and have been repeated annually in the fall since 2003. Monitoring includes beach profile surveys, channel thalweg and cross section surveys, detailed topographic surveys of the flood and ebb shoals, and bathymetric surveys to a distance of approximately 500 feet offshore. From this information, Digital Terrain Models (DTMs) are developed to estimate changes in sand volume on the flood shoal, the ebb shoal and on East Beach. Topographic monitoring is concentrated in the area around the tidal inlet where the most dynamic changes have occurred. Most of this work has been conducted by the consulting firm, Philip Williams and Associates, Ltd. Detailed results and interpretation are presented in several reports (Phillip Williams and Associates 2000, 2001a, 2001b) and technical memos (dated 2001-2003)

Water Surface Elevation

Continuous water level monitoring is recorded through the use of a Druck submersible pressure transducer (# PS9800, Aquistar 1998) which sits inside a 3-inch, perforated aluminum stilling well. The gage is installed on a concrete piling under the footbridge. The pressure transducer sits inside the stilling well (at a level below the water surface and above the mud) and is connected by cable to a datalogger. The datalogger is programmed to record water level every 10 minutes. Data from the tide gauge is downloaded on a monthly basis and is corrected to feet NGVD by reference to a nearby staff gauge. Detailed QA/QC procedures are followed to ensure the accuracy of the data and equipment.

WATER QUALITY

Water quality monitoring includes spot sampling at nine stations around the tidal marsh on a monthly basis and continuous sampling at one location using an in-situ multiprobe datalogger (Figure 1). Sampling sites include the area adjacent to each of four storm drain outfalls, which empty into the marsh, an equal number at representative locations around the marsh and one station at the tidal inlet). Monthly spot sampling of dissolved oxygen, temperature, and salinity is measured with a hand-held YSI® 85 water quality meter. In addition, water quality (temperature (°C), dissolved oxygen (mg/L, % saturation), pH, salinity (ppt), and conductivity (mS)) is recorded every 30 minutes around the clock with a Hydrolab Minisonde datalogger installed underneath the pedestrian footbridge. Data are downloaded from the datalogger every two weeks. At that time, the equipment is calibrated, cleaned and returned to the water. Data is processed according to detailed QA/QC procedures.

SEDIMENTATION

Dr. John Callaway at the University of San Francisco has been measuring sedimentation rates in the marsh since fall of 2000. Surface elevation changes in the interior portion of the tidal marsh have been measured using sedimentation-erosion tables (SETs) and feldspar marker horizons. Three monitoring stations were deployed in June 2000 and are located in the interior portion of the marsh basin in areas not covered by topographic surveys (Figure 1; see “Hydrology and Geomorphology” above). This monitoring provides finer-scale information on sediment dynamics in the tidal marsh basin. Monitoring was conducted on a semiannual basis for the first two years following marsh excavation (through 2002), but was reduced to annual surveys thereafter.

SOILS

Soils are collected once annually, in August of each year, at six locations in the tidal marsh with equal representation among low, middle and high elevation bands (Figure 1). Soils are collected to a depth of 10 cm using a soil core. A composite sample of three replicate cores is taken at each of three elevation bands (low, middle, high) at each of the six monitoring stations (n = 18). Soils have been collected from these six monitoring stations in August 2002, 2003, and 2004. In 2004, a second set of soil samples was taken at locations corresponding to randomly selected vegetation monitoring plots. This was done in order to better assess the influence of soil parameters on vegetation; in future years, we may switch to this method entirely. Soils collected in 2002 will be analyzed for salinity, TKN, organic matter, and soil texture. Because soil texture changes very slowly following restoration, texture will not be analyzed for soils collected after 2002. For most parameters, soils will be sent to a laboratory for analysis. However, soil salinity testing is done in-house using the soil paste method after drying the soils at ~65 °C for 24 hours. Soil salinity testing has been conducted on soils collected in 2002 and 2003, but is not yet complete for 2004. Only data from 2003 are presented in this report.

VEGETATION

Vegetation monitoring in all restored areas is conducted annually to assess trends in species cover, diversity, and relative abundance as the site matures. Species composition and percent cover are recorded in quadrats within each habitat type. Dune and dune swale monitoring is conducted in the spring in order to capture the many annuals present in these systems. Salt marsh vegetation is monitored both in the spring (reduced effort) and near the end of the growing season (mid- to early-September) when these species reach peak biomass.

Vegetation monitoring methods changed in both the dunes and the marsh since monitoring began. In response to peer review comments as well as recommendations from a statistician, vegetation monitoring methods were changed in the dunes in 2003 and in the tidal marsh in 2002 and again in 2004. Monitoring is now done within quadrats which are randomly located within varying strata in both the dunes and the marsh. Previously, monitoring occurred along established transects. In 2002, both monitoring methods were used in the dunes. From 2003 on, only the randomly located quadrats approach has been used. In the tidal marsh, monitoring within randomly located quadrats was adopted in 2003. However, unlike the dunes, where monitoring along permanent transects was very time intensive, monitoring along permanent transects in the marsh is relatively quick. For that reason, transect monitoring in the marsh has continued. Monitoring methods are described in more detail in the Crissy Field Quality Assurance Project Plan (QAPP; GGNRA 2003) and in the original monitoring plan (Savage 2000).

Additionally, the tidal marsh is monitored regularly for the presence of non-native *Spartina spp.* Visual inspections of the marsh are conducted from late spring to early fall to check for the establishment of seedlings. Transect sampling of the outplanted *Spartina foliosa* plugs is conducted periodically in coordination with the San Francisco Estuary Invasive Spartina Project. Genetic testing is performed on a subset of *Spartina* leaves collected along transects around the perimeter of the marsh as well as any seedlings found in the marsh. If non-native *Spartina spp.* are found in the restored areas, appropriate actions will be taken to eradicate it to the extent possible.

FISH AND MACROCRUSTACEANS

Fish and epibenthic macrocrustaceans are sampled quarterly (January, April, July, October) at five locations around the tidal marsh (Figure 1): four intertidal sites along the wetland shoreline (stations F1, F2, F3, F5), one subtidal site (station F4) and one site in the inlet channel (station F6). Each of the intertidal stations encompasses a shoreline length of 100 m. Three seining locations are randomly selected along this distance (without replacement) . The four intertidal stations were chosen to represent a variety of hydrologic conditions; each differs either in slope of bed or substrate composition. Station F3 is located on the steep-sided north shore with primarily sand substrates. Station F2 is located on the gently sloping western shore with bottom substrates comprised primarily of sands overlain with anoxic, organic muck. Station F1 is located on the southeastern shore with intermediate bottom slopes of mud and sand. Subtidal habitat is sampled at one station (station F4) for qualitative information on taxa composition and abundance. Fish and macrocrustaceans are collected using beach seines and are identified, measured, counted and released. Fish are measured as total length, shrimp are measured from rostrum to telson, and crabs are measured as carapace width. Intertidal sites are sampled using a small beach seine (1/8th inch) to capture smaller slow-moving fish, and the subtidal station is sampled using a 1/4-inch bag seine to capture larger, more mobile fish. Station F5 was originally a subtidal station sampled with the large seine, but was changed to an intertidal station sampled with the smaller seine in 2002. Adult topsmelt at this site were often too abundant to count and measure without some incidental mortality. Habitat information (water quality and vegetative cover) is collected using a handheld YSI 85 water quality meter.

BENTHIC INVERTEBRATES

Benthic invertebrates are collected once annually each summer at four locations in the tidal marsh (Figure 1). Three of the four benthic invertebrate sampling sites are also fish sampling locations. At each station, sampling occurs within each of three elevation bands intended to target distinct habitats zones: the marsh plain (sampled at approximately 3-3.5 feet NGVD), the low marsh (~2-2.5 feet NGVD), and the nearshore subtidal area (~0-0.5 ft. NGVD). Shallow cores are collected with a 10-cm diameter clam gun to a depth of 5 cm. In nearshore subtidal areas, deep cores (20-cm depth) are collected in addition to the shallow cores. Shallow cores are rinsed in the field through a 0.5-mm sieve; deep cores are rinsed and sieved through a 3.5-mm sieve. All samples are stored in 70% ethanol. Beginning in 2004, we began storing samples in 10% formalin for 24 hours, prior to rinsing and storing in 70% ethanol. This step was added to improve the preservation of specimens and facilitate idenitification. After collection, samples are sorted into broad family groups and sent to a taxonomic specialist (Susan McCormick) for identification to the lowest taxonomic level possible.

BIRDS

Bird use of the restored habitats at Crissy Field has been surveyed using a modified area search method (Ralph et al. 1993) since May 2000. In 1999, prior to adoption of standard area search protocols, bird surveys were performed by a local birder (Josiah Clark). Although this data is not used for assessing trends, birds observed during these surveys are included on the master list of birds detected at Crissy Field (Table 12).

Area search surveys are conducted in five areas (Figure 2) which roughly correspond to five different habitat types: wetland, beach and nearshore, foredunes, dune swale and rear dunes, and Fort Point. The wetland search area is approximately 7.3 hectares (18 acres) and includes the open water and intertidal areas of the tidal marsh, and the vegetated transitional upland perimeter within the fence. The beach and nearshore search area covers approximately 40.5 hectares (100 acres), encompassing the beach and nearshore to 90 meters offshore. It extends from Torpedo Wharf to the eastern boundary of Crissy Field. The foredune search covers approximately 7.3 hectares (18 acres) and includes all of the fenced foredunes, the paths between them, and the Promenade. The dune swale and rear dune search areas are combined and include the fenced freshwater dune swale and the associated upland and the fenced upland scrub east of the tidal marsh. At 1.2 hectares (3 acres) this is the smallest of the search areas covered. The Fort Point surveys include the open Bay water from the base of the south tower of the Golden Gate Bridge to Torpedo Wharf extending to within 90m (300ft) of the shoreline. Results from the Fort Point surveys are not presented in this report.

Surveys are performed according to season (winter, spring, summer, and fall) with more surveys performed during peak breeding and migration periods. Information collected includes species, population size, activity (feeding, resting, aerial, breeding) and habitat. When scheduled, wetland and beach and nearshore areas are surveyed twice per day to capture differences in use between high and low tides. For all other areas, surveys are conducted within five hours of sunrise.

Point counts (Variable Circular Plot method) have been conducted at six locations along the length of the restored dunes (Figure 2) in the springs of 2001, 2002, 2003 and 2004. In each year, three sets of point counts were conducted between late April and early May with each point count separated by 10–15 days. These results have been presented in earlier reports Gardali 2002, Gardali 2003).

ADAPTIVE MANAGEMENT

Inlet Closures

NPS has adopted an adaptive management strategy to address inlet closures. During periodic closures of the marsh inlet, monitoring of water quality, soil conditions and plant stress is intensified. Because most inlet closures are brief and resolve themselves naturally, increased monitoring is generally only conducted when closures exceed two weeks. After two weeks of closure, water quality monitoring is increased from monthly to 1-3 times weekly depending on tide and weather conditions. If a closure exceeds 30 days during the active growing season (spring-fall) plant stems cross-sections from submerged plants are examined under a microscope for signs of waterlogging stress. In late 2003 and 2004, soil chemistry (redox potential) was also monitored in an attempt to determine its usefulness as an easily-measured field indicator of stress to plants. Monitoring results are used to help guide decision-making and determine when and if mechanical excavation is appropriate. Season, water levels, tide conditions, and weather are also considered when making these decisions.

RESULTS

HYDROLOGY AND GEOMORPHOLOGY

The hydrology firm of Philip Williams and Associates, Ltd. (PWA) has conducted hydrologic and morphological monitoring in the Crissy Field tidal marsh and adjacent coastal area since November 1999. This monitoring has included water level measurements, beach profile surveys, thalweg orientation and cross section surveys, marsh elevation transects, detailed topographic surveys of the ebb and flood shoals, bathymetric surveys, and digital terrain modeling. Detailed results from this monitoring have been reported in several documents (see methods section). A brief summary of major geomorphologic changes is presented here.

Since a tidal connection to the bay was first established in November 1999, the Crissy Field marsh has undergone dramatic morphological change. The greatest change occurred in the first 18 months following restoration in the area around the tidal inlet. Following construction, the restored marsh acted as a sediment sink, diverting sand that would have otherwise deposited on East Beach into the marsh, the inlet, and the area surrounding the inlet. A flood shoal (on the tidal marsh side of the inlet) and an ebb shoal (on the Bay side of the inlet) formed, accumulating 7,000 and 25,000 cubic yards (cy) of material, respectively by May 2001. Subsequent surveys have documented the continued enlargement of these features. While the growth of the flood shoal has slowed considerably, the ebb shoal continues to grow substantially each year expanding its footprint northward into the Bay. Surveys conducted in fall 2004 showed a net gain of over 11,000 cy of material on the flood shoal, and nearly 70,000 cy on the ebb shoal. As the flood shoal has expanded around its perimeter, the inlet channel has responded by lengthening and developing a more defined meander as it hugs the perimeter of the flood shoal.

Concurrent to the formation of the flood and ebb shoals, significant erosion of East Beach occurred. Over 10,000 cubic yards of sand were lost between November 1999 and February 2001. In order to offset the losses and speed recovery, the beach was nourished on two occasions: in August 2000, and again in January 2001. However, by October 2001, the beach recovered most of its pre-construction volume. When surveyed in fall of 2004, East Beach had achieved a net gain of nearly 17,000 cubic yards of sand.

Six elevation transects that cross the marsh were surveyed in fall 2004 for the first time since April 2001. Aside from one transect that crosses the flood shoal, elevation increases in the interior portions of the marsh have been 0.5 feet at most in subtidal areas, and minimal in intertidal areas.

Inlet Channel Dynamics

The formation of the flood and ebb shoals was accompanied by dynamic changes in the inlet channel and an increased risk of inlet closure. After the tidal connection to the bay was first established and the shoals began to form, the inlet channel began migrating east along the beach in response to the predominant eastward longshore sand transport and the reduced effective tidal prism of the lagoon. Sand deposition led to increases in the inlet channel elevation. Shortly after the marsh was first opened to tidal action (Nov. 1999), the inlet channel elevation was -1.5 feet NGVD. By May of 2001 it had risen to approximately 1.5 feet NGVD and the inlet channel closed for the first time.

The inlet channel closed 19 times between May 2001 and November 2004 (Table 2). Most closures occur during a neap tide period when the inlet is in a “low–efficiency” position and re-open naturally during a subsequent spring tide series. In these situations, the inlet usually re-opens at the location of the former mouth (east end of beach). However, if sufficient sand has accumulated on the ebb shoal and in the tidal inlet, the likelihood of a natural re-opening decreases and the inlet may remain closed through several tidal cycles. Generally, the inlet channel will close and re-open naturally one or two times in the weeks or months leading up to a long-term closure.

The position of the inlet channel migrates within an area bounded by the west abutment of the promenade bridge to a position approximately 250 meters east. Within this area, migration is fairly predictable. Flow is most efficient when the inlet is in its westernmost position where it is the shortest and is aligned directly south to north. From this position, longshore sand transport causes the inlet to gradually migrate eastward over a period of approximately 3-6 months. As it migrates eastward, the inlet channel elongates parallel to shore and sediment deposition causes a gradual decrease in effective tidal prism and an increased likelihood of inlet closure.

Large storm events can disrupt the otherwise predictable patterns of the tidal inlet and in some cases may effectively "re-set" the system to an earlier point in the closure cycle. Of the 19 closures that occurred between May 2001 and November 2004 (Table 2), two re-opened during storm events (closures #16 and #19 in Table 2). In both cases, waves breached the ebb bar on an incoming tide in a position directly north of the promenade bridge. As the water drained through the new channel on the subsequent ebb tide, the channel widened and deepened. The resulting scour "re-set" the system to an earlier point in the closure cycle by reducing the thalweg elevation and returning the inlet channel to a high-efficiency north-south alignment.

Water Surface Elevation

Marsh water levels are muted relative to San Francisco Bay tides. Although high tides within the marsh match those in the Bay, low water elevations are limited to the elevation of the inlet channel where it crosses the flood shoal. Hence, low water levels in the marsh range from 4-6 feet higher than those in the Bay, depending on tide and inlet conditions.

The orientation and elevation of the inlet channel thalweg affects the tidal cycles in the marsh. As discussed in PWA's recent technical study (PWA 2004), the inlet channel migrates within a window ranging from its most efficient alignment (draining directly from south to north), to its least efficient alignment (elongated eastward parallel to the shoreline). Although high tides in the marsh occur at the same time as those in the Bay, there is often a lag time between Bay and marsh low tides. The lag can reach up to two hours when the inlet channel is in its least-efficient alignment.

Marsh water levels recorded with the pressure gage have provided a record of most of the inlet closures to date and have helped elucidate conditions before and after closures. As the marsh inlet migrates east along the beach, continued sand deposition in the inlet leads to gradual increases in the low water elevation in the marsh. Most long-term closures (e.g., winter 2002, winter 2003, spring 2004) have occurred after the low water elevation in the marsh has reached levels of approximately 2-2.5 feet NGVD. Following a breach there is generally a period of scour, when the inlet channel deepens and the low water levels decrease. Marsh water levels decreased to <0.5 feet NGVD following the mechanical breaches in winter 2002 and 2003 and to ~1 foot NGVD following the breach in spring 2004.

WATER QUALITY

Continuous Logger

A continuous logger (Hydrolab® Minisonde) installed underneath the footbridge has been continuously recording water temperature, dissolved oxygen (DO), and salinity every 30 minutes since May 2001, with some data gaps during periods of instrument malfunction. Daily maximum, means and minimums were calculated throughout each deployment period (Figures 3–11) and for each month (Tables 3-5). Because of inconsistencies in data collection and equipment malfunctions in 2001, only data from 2002 on are presented here. Water quality parameters changed with season, time of day, tidal stage, weather and inlet status (open, closed, partially closed).

Water Temperatures

Marsh water temperatures tracked the seasons more closely than either dissolved oxygen or salinity. Mean water temperatures were lowest in the winter (~13°C from November through March) and gradually increased from spring through summer in all years (Figures 3-5). Water temperatures were highest in the summer months (~17-18°C from June through September) and began decreasing again in October. Within each month, however, temperatures fluctuated substantially (see min/max values in Tables 3-5). Water temperatures were most variable during the spring and summer months, reaching maximums in the mid- to late-afternoon and declining at night. Occasional high water temperatures approaching 25°C were associated with warm, clear days with no fog.

Salinity

Marsh water salinities were similar to those in the central San Francisco Bay (31-33 ppt) during the summer months, but declined in the winter with inputs of rainfall and stormwater runoff (Figures 6-8, Tables 3-5). Water salinities also declined during inlet closures, when freshwater runoff from storm drains continued, without inputs of saline water from the Bay. Groundwater contributions may also contribute to lower water salinities during inlet closures. Cool, foggy weather and continued freshwater inputs seem to protect Crissy marsh from the hypersaline conditions that many coastal systems experience as a result of evaporative water loss during periods of tidal exclusion.

Dissolved oxygen

Given the multiple factors that influence dissolved oxygen concentrations (e.g., tidal stage, time of day, storm condition, season, water temperature), it is not surprising that DO levels measured in Crissy marsh were highly variable (Figures 9-11, Tables 3-5). Although interactions between the multiple factors affecting DO make interpretation of the data complex, seasonal patterns are evident. Dissolved oxygen is most variable during the summer months when days are longest, water temperatures are highest and biological oxygen demand is high. In contrast, variability tends to decrease during the winter months, when less photosynthetic activity occurs and biological oxygen demand is lower.

Diel and tidal patterns affect DO levels year round; however, it is difficult to determine the relative effects of each without more in-depth analysis. For example, in summer 2003, DO levels reached maximum values around midday to early afternoon. During the winter months, DO peaked in the late evening to early morning hours. However, in both seasons, DO peaks tended to occur 1-2 hours prior to maximum water level in the marsh. Without removing the periodicity in the data due to one of the two factors, the relative importance of diel vs. tidal influence is unclear.

Inlet closures provide an opportunity to evaluate the effects of diel patterns, since tidal periodicity is removed from the data. During the inlet closure in spring 2004, dissolved oxygen levels peaked in the mid- to late- afternoon and declined steeply at night (Figure 12). However, weather conditions during this particular closure contributed to large algal blooms. High daytime DO levels were most likely due to algal photosynthetic activity; while low values at night would result from algae continuing to respire without producing oxygen. After tidal flushing was restored, DO levels showed far less variability. The combined effects of tidal flushing and increased mixing, along with algal die-off may have led to decreased variability. A similar pattern was observed during the late winter/early spring closure in 2003 (1/13/03 – 3/19/03). DO levels peaked around mid-day and declined steeply at night (Figure 13).

Dissolved oxygen levels in Crissy marsh frequently fall below 5.0 mg/L - the numerical objective for dissolved oxygen in tidal waters of the San Francisco Bay (California Regional Water Quality Control Board, 1995). It is not clear if the RWQCB criteria was intended to include estuarine areas where DO levels below 5.0 mg/L are not uncommon. The Environmental Protection Agency (EPA) has established similar DO criteria for estuarine animals of the northeast Atlantic coast, but has not yet established criteria for the west coast. The EPA criteria for the east coast are tiered, with protective criteria for growth set at 4.8 mg/L, and protective criteria for juvenile and adult survival set at 2.3 mg/L.

At Crissy Field, DO levels fall below 5 mg/L during both open and closed inlet conditions, but are more common during inlet closures. In 2002, DO was less than 5 mg/L 45% of the time when the inlet was closed and 30% of the time when the inlet was open. The pattern was similar in 2003, although declines below 5 mg/L were less frequent overall. DO fell below 5 mg/L 27% of the time when the inlet was closed and only 11% of the time when the inlet was open. Declines below 2.3 mg/L were infrequent in both 2002 and 2003.

Monthly Spatial Sampling

Information collected during monthly spot sampling at nine stations around the tidal marsh confirmed seasonal patterns evident from the continuous logger, but also provided insight on spatial patterns and vertical stratification.

Although marsh water quality is usually consistent throughout the marsh in the area west of the flood shoal (WQ2-WQ8), stations WQ1 and WQ9, at the east end of the marsh usually reflect different conditions. Station WQ1 is located directly adjacent to the southeastern most storm drain outfall in the marsh in shallow water (30-40 cm depth) and is often characterized by strong anaerobic odors. Wind and eastward surface water currents have contributed to relatively high levels of wrack deposition on the southeast shore. Dissolved oxygen at this station is consistently lower than at most other stations. In contrast, station WQ9, which is located in the marsh inlet where tidal influence is greatest, is generally characterized by the lowest water temperatures, highest salinity and highest DO values.

Because of the relative homogeneity of water quality across most of the site, and in order to simplify graphs, sampling stations were placed in four "groups". Stations WQ3, WQ5, and WQ7, which are all adjacent to a storm drain, were grouped; stations WQ2, WQ4, WQ6 and WQ8, which were not associated with storm drains were grouped; and stations WQ1 and WQ9, were each treated independently. Data from August 2002 through December 2004 are presented in this report (Figures 14-22).

Water quality parameters varied depending on the status of the inlet (open, closed, partially closed) and with ambient conditions. Because monthly surveys are always performed in the morning on an outgoing tide, tidal and diurnal variability effects were reduced. Sampling confirmed patterns of declining salinity during inlet closures and quick returns to levels similar to those in San Francisco Bay following mechanical excavation (see Figure 15 and Figure 16). It also confirmed marsh-wide declines in DO during the inlet closure in April and May of 2004. These declines were punctuated by brief increases in DO when high spring tides overtopped the ebb bar (Figure 22 and Figure 23).

The marsh is well-mixed with little to no vertical stratification of the water column. A July 2004 survey conducted along transects across the marsh in areas not captured by monthly sampling confirmed this pattern (GGNRA, unpublished data). Even in deeper portions of the marsh, vertical stratification is not evident. Frequent winds and a long fetch likely help to maintain well-mixed conditions. However, during some inlet closures, vertical stratification is evident.

SEDIMENTATION

Dr. John Callaway of the University of San Francisco (USF), has been measuring wetland sediment dynamics in Crissy marsh using Sedimentation Erosion Tables (SETs)and feldspar marker horizons. SETs and feldspar marker horizons were established in August 2000. Transects were established at three locations (Figure 1) with SETs placed in low, mid-, and high-marsh areas along each transect for a total of nine SET locations. Measurements have been obtained in August 2000, March 2001, September 2001, April 2002, November 2002, December 2003, and November 2004. Results are presented in a December 2005 report (Callaway 2005); a very brief summary of that report is presented here.

Sedimentation in the interior, intertidal areas of the marsh has occurred at a rate of less than1 cm/year at most and has been highly variable. Two of the three low marsh sites (Transects 1 and 2) and one of the three marsh plain sites (Transect 1) have experienced net erosion. Low marsh stations may be susceptible to erosion caused by wind waves during inlet closures when marsh water levels remain at approximately the same elevation for prolonged periods of time.

In late 2004, Dr. Callaway established three additional sediment monitoring transects to evaluate the potential contribution of fine sediments from several storm drains that empty into the marsh. A combination of burlap markers and rebar stakes was used to establish . monitoring transects at varying distances from three of the four storm drains that empty into the marsh. Changes in surface elevation will be estimated by measuring the increase in surface elevation above the burlap markers and the change in distance to the sediment surface adjacent to the rebar stakes. Initial measurements were taken in December 2005 and results will be presented in subsequent reports.

SOILS

Soil Salinities

Marsh soil salinities measured on soils collected in August 2003 were spatially variable, but no consistent marsh-wide patterns were apparent with respect to surface elevation (Figure 24). Salinities ranged from a low of 1 ppt in the high elevation band at Station S3 to a high of 80 ppt in the middle elevation band at Station S2. With a few exceptions, salinities at most sampling stations were fairly typical of tidally influenced soils in areas of limited freshwater influence. Mean salinities (± S.E.), averaged over the entire marsh were 29 ± 6 ppt at high elevations, 41 ± 5 ppt at mid elevations and 39 ± 4 ppt at low elevations. Water salinity in San Francisco Bay just outside Crissy Field is typically 31-33 ppt.

Salinities measured at station S1 in 2003 exhibit a common pattern seen in salt marsh soils: lower salinities at low elevations, and progressively increasing salinities at higher elevations where there is less tidal influence and evaporative water loss leads to increased salt concentrations. This trend reversed itself in 2004, exhibiting the opposite pattern: lower salinties at high elevations and progressively higher values at lower elevations, suggesting a freshwater influence at higher elevations. This trend was also seen at stations S3 and S5 in both years. Groundwater seeps and/or irrigation runoff are the likely causes of the lower soil salinities found at higher elevations at these stations.

Station S3 is located near a groundwater seep . Within approximately 30 meters of the sampling location, there is a large patch of brackish vegetation (primarily *Juncus lesueurii* and *Schoenoplectus pungens* (formerly *Scripus pungens*)). Despite the low soil salinities at S3-high, vegetation in the areas immediately around the sampling location is sparse (~5-10% cover). The limited vegetation that does occur in the area is predominantly split leaf plantain (*Plantago coronopus*) with scattered individuals of seaside daisy (*Erigeron glaucus*). Poor vegetative cover is likely a result of poor soils. The area is characterized by coarse pebbly sand on the surface, and a hard, compacted layer exists 5-10 cm below the surface.

Salinity data from samples collected in August 2004 showed patterns fairly similar to those found in 2003. Overall soil salinities ranged from 12 to 99 ppt in 2004. Mean soil salinities (± S.E.) at high marsh elevations were 29 ± 6 ppt in 2003 and 28 ± 7 ppt in 2004. Marsh plain soil salinities were 41 ± 5 ppt in 2003 and 52 ± 10 ppt in 2004. Low marsh soil salinities were 39 ± 4 ppt in 2003 and 60 ± 3 ppt in 2004.

In 2004, additional soil samples were collected at 90 locations corresponding to vegetation monitoring quadrats. Samples were collected at these locations both during and after a 53-day inlet closure in early summer 2004. Marsh soil salinities were different when measured during and after the inlet closure, but the direction of change varied between elevation zones. When measured one month following mechanical excavation of the inlet, mean soil salinities increased significantly at high elevations (from 7 to 19 ppt, paired t-test, $\alpha_{24, 1} < 0.01$), but showed a non-significant decreasing trend at low and middle elevations (from 38 to 31 ppt and from 54 to 46 at middle and low elevations respectively).

VEGETATION

Vegetation monitoring has been conducted in both the dunes and the marsh in all years since 2000. However, several factors affect our ability to draw rigorous conclusions from the data. First, ongoing manipulation of the site has continued through stewardship activities between 2000 and the present. This has included varying levels of weeding and additional outplanting. Second, monitoring methods have changed since moinitoring began (see p. 10). Efforts are currently underway to analyze vegetation monitoring data and "marry" the different methods for interpretation. This report includes preliminary data from monitoring as well as general observations.

Tidal Marsh

Twenty-three plant species were reintroduced into the restored marsh at Crissy Field, with most outplanting occurring in 1999 and 2000 (see Heimbinder 2000 for more details) and initial survivorship rates were high (overall average of 67%, Heimbinder 2000).

Trends along permanent transects

Data from the new "random" quadrats methodology conducted since 2003 has not yet been anlayzed and will be presented in subsequent reports. Data reported here are from 18 sets of three parallel transects which target high, middle and low elevation bands within the intertidal zone. Upland transitional areas around the perimeter of the marsh are not monitored. See GGNRA 2003 for more details on methods.

On average, total plant cover (100 - %cover of bare ground) has showed an increasing trend along all transects from 2002-2004 (Tables 6-8). Listed in order of decreasing frequency of occurrence along transects in 2004 (Table 6), low elevations are dominated by *Sarcocornia pacifica* (formerly *Salicornia virginica*, 78% of transects), *Spartina foliosa* (67%), *Distichlis spicata* (39%), and *Jaumea carnosa* (33%). In general, average percent cover and percent frequency of occurrence increased for most species between 2002 and 2004. Native species richness along low marsh transects did not change appreciably between years, ranging from 0 to 8 species in 2002 and 2004, and from 0 to 6 species in 2003. The mean number of species encountered along low marsh transects ranged from 2.0 species in 2002 to 2.9 species in 2004 (Table 6).

Middle elevation transects are dominated by *S. pacifica*, *Frankenia salina*, *J. carnosa*, and *D. spicata*. Average percent cover for each of these four species ranged from 11% (*S. virginica*, *J. carnosa*) to ~20% (*F. salina*, *D. spicata*). All four of these species have a tendency to form a dense cover where they successfully establish. Other species that are common at mid elevations, but occur at lower densities include *Spergularia marina*, *Limonium californicum*, *Spergularia macrotheca*, and *Plantago maritima.* Species richness along transects ranged from 1 to 9 species. Mean species richness along transects was close to four in all three years. Non-native species cover along middle elevation transects was low in 2004, and composed primarily of split-leaf Plantain (*Plantago coronopus*).

Distichlis spicata dominates along high elevation transects, occurring on 17 of 18 transects at an average percent cover of 18%. Other species that occur along at least half of the transects include *S. pacifica, S. macrotheca, S. marina, J. carnosa, F. salina*, and *P. maritima*.

Limonium californicum occurs on 8 of 18 transects. Species richness along high marsh transects ranged from 0 to 9 species along all transects with a mean between 4.2 and 5.2 species found along transects between 2002 and 2004.

General Observations:

The success of vegetative establishment and growth varies across the marsh. Some of the 'best' vegetated intertidal habitat occurs at the west end of the marsh where the slope is the widest and flattest. This area supports a diverse, dense assemblage of marsh plants. Efforts to re-establish the rare salt marsh annual, *Cordylanthus maritimus* ssp. *palustris* in this area were highly successful in 2004. In contrast, steep slopes on the north side of the marsh left less space for intertidal habitat. Efforts to re-vegetate this area were slowed by sandy, highly erosive soils. Initial efforts at re-vegetation met with poor success and overall vegetation development has been slower. Soils on the north slope are extremely sandy especially at the east end, closer to the tidal inlet. However, erosion of sand from the higher portions of the slope appears to have flattened the contour in some areas and may lead to expansion of intertidal vegetation. The densest patch of vegetation on the north slope is near the center of the marsh, where the shoreline extends further south, providing a wider intertidal band than areas further east and west.

Intertidal habitat on the south slope of the marsh is limited; however, there is more space available here than on the north slope. The lower intertidal here is characterized by fine sediments, especially in the southeast corner of the marsh. Based on 1851 topography, the southeast corner is the only area that overlaps with the probable footprint of historic marsh habitat. Other portions of the restored marsh are in areas that were more likely beach and dunes. If more space had been available, this area is likely to have provided high-quality intertidal marsh habitat.

Spartina

Spartina foliosa planting success varied across the marsh. Although it did relatively well along the south perimeter of the marsh, most of the original plantings on the west and north shores failed. In an effort to get *S. foliosa* established in these areas, and inhibit recruitment by non-native *Spartina sp*., additional planting was done in January 2004. Approximately 450 *S. foliosa* plugs were transplanted into the lower intertidal areas along the west and north shores of the marsh. The plugs were collected at Goodman's Lumber marsh in Marin, the site of the original collection in 1999-2000. Approximately 95% of the plugs were still alive as of December 2004 and many showed signs of new growth.

Because of the threat of colonization by non-native and hybrid *Spartina* species, a decision was made early in the project to conduct regular surveys of Crissy marsh to detect *Spartina* colonization, particularly seedlings. There was a concern raised that if invasive *Spartina* were to become established at Crissy Field, it might provide a platform for invasion into parts of the north bay that are only minimally impacted. Therefore, any *Spartina* seedlings found at Crissy Field are collected and sent to UC Davis for genetic testing. In addition, yearly DNA sampling is conducted on a subset of the *Spartina* plants in the marsh to ensure that no non-native or hybrid becomes established within the native canopy. All sampling and testing is done in consultation with the San Francisco Estuary Invasive *Spartina* Project.

Six non-native *Spartina* seedlings or young clones have been detected in the marsh thus far: one in 2002, and five in 2003. The six non-native seedlings were found at several locations around the marsh. The first was found in September 2002 at the southeast end of the marsh near the footbridge in an area with very little vegetation. In May 2003, several *Spartina* shoots growing in an ~0.5m^2 area (probably a 1-year old clone) were discovered and confirmed as hybrid. Likewise, three hybrid seedlings were found growing on the flood shoal in July 2003. One additional hybrid was discovered during the September 2003 annual transect sampling. All of them were removed and no invasive *Spartina* was detected at Crissy Field in 2004.

Seedling Recruitment

Many species have been observed as seedlings in the marsh, with some more abundant than others. Seedlings that have been observed in high numbers in the marsh include *Limonium californicum, Salicornia europaea, Salicornia virginica, Spergularia macrotheca* and *Spergularia marina*. Neither species of *Salicornia* were included in the original planting palette; *S. virginica* was intentionally left out because of its ability to rapidly colonize new sites. Because of their high frequency of occurrence and high recruitment rates, neither *Spergularia* or *Salicornia* species may require additional planting in future restoration efforts at Crissy Field.

Dunes

Most of the planting in the dunes was completed in the winters of 1999 and 2000 and vegetation monitoring was first conducted in the late spring of 2000. Most dune vegetation monitoring data has not yet been analyzed; only results from the first year of transect monitoring is presented here.

Ellen Hamingson (2002), a former GGNRA employee and contractor, completed an analysis of dune vegetation monitoring data from 2000. The objectives of her analysis were the following: 1) to determine the effectiveness of the monitoring approach and recommend changes to methods, and 2) to discern differences in vegetative characteristics between different substrates and zones.

Dunes were classified into three substrate types based on the source material from which they were created: “remnant”, “sand” and “dredge”. “Remnant” dunes existed prior to restoration and were enhanced by restoration efforts; “sand” dunes were created from sand collected somewhere along the Crissy shoreline, and “dredge” dunes were created from dredge material from one of two sources: the St. Francis Yacht Harbor, or the Presidio shoal. Dunes were further classified into two zones: “foredunes” and “transitional”. Areas showing evidence of moving sand (blowouts, hummocks, generally fine sand) were classified as “foredunes” and all other areas were classified as “transitional”. Response variables measured included: 1) species richness; 2) total percent vegetative cover; 3) percent exotic species cover; and 4) relative abundance.

Six species dominated the dune plant assemblages in 2000: *Abronia latifolia*, *Abronia umbellata*, *Ambrosia chamissonis*, *Artemisia pycnocephala*, *Camissonia cheiranthifolia* and *Leymus mollis*. All but *A. pycnocephala* were reported from Crissy Field in a site survey in

1993 (Vasey, 1996). In addition to these five species, *Eschscholzia californica* var. *maritima* was also reported to have been in the Crissy dunes in 1993. Though the six common species are largely foredune, not transitional, species, 2000 monitoring data confirmed that all but *Leymus* appear to have established successfully in the transitional dunes, whether through outplanting or natural recruitment.

Hamingson found that vegetative percent cover was higher in remnant transitional areas than in any other substrate/zone combination. However, it is not clear whether this was due to pre-existing vegetation on remnant dunes, higher outplanting rates, or characteristics of the soil substrate. Species richness patterns were not clear. Although exotic species relative abundance was highest in dredge foredunes (12%), the ratio of exotic to total species (0.35) was lower here than in any other substrate/zone combination.

Based partially on Hamingson's results, as well as recommendations from a statistician, methods were changed to a "random quadrat" approach rather than monitoring along permanent transects beginning in 2002. Monitoring data collected from 2002 on will be presented in subsequent reports

Seedling Recruitment in the Dunes

Many species have been observed as seedlings in the dunes and shellmound with some more abundant than others. Seedlings that have been observed in high numbers include *Abronia latifolia*, *Abronia umbellata*, *Artemisia pyncnocephala* and *Gilia capitata* ssp. *chamissonis* in the foredunes, and *Crassula connata*, *Eriogonum latifolium, Lupinus chamissonis*, *Lupinus bicolor*, and *Plantago erecta* in the rear dunes and shellmound. High recruitment by these species indicates that they may be able to be planted and/or seeded in lower numbers in similar restoration efforts. However, it should be noted that the two species of *Abronia* and *A. pycnocephala* were both present in the remnant dunes before restoration began (Dames and Moore 1995).

Rare Plants

Attempts have been made to introduce eight special status plant species at Crissy Field: *Chorizanthe cuspidata* var. *cuspidate*, *Collinsia corymbosa*, *Cordylanthus maritimus* ssp. *palustris*, *Erysimum franciscanium*, *Gilia capitata* ssp. *chamissonis*, *Silene verecunda* ssp. *verecunda*, *Suaeda californica*, and *Tanacetum camphoratum*. *Lessingia germanorum* also occurs at the site, but no introduction was attempted. A summary of the reintroduction efforts and monitoring results for each species is presented in Table 9. These populations are monitored as part of ongoing GGNRA rare plant monitoring efforts and more detailed information on their introduction and monitoring results is reported elsewhere (for example see Doherty 2003, Doherty and Brastow 2004).

FISH AND MACROCRUSTACEANS

Fish

The marsh is providing habitat for a variety of fish and macrocrustaceans. Nineteen species of fish representing twelve families have been collected in Crissy marsh since 2000 (Table 10 and Appendix 1). These 19 species include fish that were caught in both small seines and large seines. However, due to inconsistencies in data collection methods using the large seine, graphs and quantitative information presented here only include information for surveys done with the small seine. Raw data from fish collected in large seines is included in the tables in Appendix 1.

Numerically dominant species are *Clevelandia ios* (arrow goby), *Atherinops affinis* (topsmelt), *Gasterosteus aculeatus* (threespine stickleback), *Ilypnus gilberti* (cheekspot goby), and *Leptocottus armatus* (Pacific staghorn sculpin). Two non-native fish species have been collected in Crissy marsh since 2001: *Acanthogobius flavimanus* (yellowfin goby), and *Luciana parva* (Rainwater killifish). Although relatively high numbers of yellowfin gobies were caught in summer 2000, summer 2001, and spring 2002 (50, 404 and 183 fish, respectively), none have been observed since summer 2003 (2 fish). Rainwater killifish were observed once in winter 2001 (2 fish) and again in 2003 (3 fish). Approximately 90% of the the fish taxa collected at Crissy Field to date are native. In comparison, approximately 85% of the fish taxa collected in California Department of Fish and Game (CDFG) midwater trawl surveys conducted in San Francisco Bay between 1980 and 2001 were native species (The Bay Institute, 2003).

Seasonal and spatial patterns

Fish densities were fairly low (<5 fish/m^2) at all sampling stations in 2000 and 2001. In summer 2002, fish densities increased at all sampling stations, reaching a high of 26 fish/m^2 at Station F2. Similarly high densities were observed in summer 2003 and 2004, while winter densities remained low at all stations (Figure 25). From 2002 on, Stations F2 and F5 had the highest numbers of fish. These stations are located in the southwest and northwest corners of the marsh respectively. Both areas are located near storm drains which provide some freshwater inputs. Sediments in these areas are typically muddy and often have high algal cover. Algae (*Enteromorpha* sp. and *Ulva* sp.) may be providing food and cover from predators for some of the fish utilizing these areas.

Fish taxa richness is typically highest in summer (9-10 taxa) and lowest in winter (5-7 taxa), with spring and fall showing less predictable patterns (Figure 26). While only five taxa were observed during the fall 2002 sampling event, ten were observed in fall 2003. Relative percent composition of taxa varied with season, station and year, though no obvious patterns are apparent (Figures 26-29). Year-round, the most abundant fish collected were arrow goby, topsmelt, threespine stickleback, cheekspot goby, and Pacific staghorn sculpin.

The restored marsh is likely providing important spawning and rearing habitat for many fish. Although they did not constitute a large portion of the catch in the April 2004 sampling event, large numbers of topsmelt were observed in the marsh for the duration of the inlet closure (April 11 – June 1, 2004) and were especially abundant in the July 2004 sampling event (Figure 30). Both adult and juvenile topsmelt were found in the marsh, ranging in size from 20 to 140 mm. Topsmelt are likely coming into the marsh in the spring and summer to spawn.

Large Seine

Although the data were not used to estimate density, certain fish were more commonly caught in the ¼-inch mesh bag seine than with the smaller seine. The larger seine samples more subtidal habitat and is better able to capture larger, faster-moving fish that may escape the small seine. Fish that were more commonly caught in the large seine included *Cymatogaster aggregata* (shiner surfperch), *Gibbonsia metzi* (spotted kelpfish), and *Isopsetta isolepsis* (butter sole). *Apodichthys flavidus* (penpoint gunnel) was caught on only one occasion (summer 2002, 1 fish) using the bag seine. Topsmelt over 50 mm were also more common in the large seine.

Epibenthic macrocrustaceans

Thirteen macrocrustacean taxa have been collected in beach seines since 2000 (Table 11, taxa marked with †). By far the most abundant species caught in our seines is *Hemigrapsus oregonensis* (yellow shorecrab) followed by *Crangon nigricauda* (Blacktail bay shrimp). These two species have been detected in almost every sampling event to date. The next three most commonly detected species include *Crangon franciscorum* (California bay shrimp), *Heptacarpus brevirostris* (stout coastal shrimp) and *Heptacarpus paludicola* (California coastal shrimp). *Crangon* shrimp are prey for many estuarine fishes.

Two non-native taxa have been collected: *Palaeamon macrodactylus* and *Carcinus maenas* (European green crab). Forty individuals of the European green crab were caught in summer 2003 and two individuals were caught in summer, 2004. First collected in San Francisco Bay in 1989 or 1990, the green crab is an aggressive introduced predator species. Its prey items include clams, oysters, mussels, and crabs smaller or equal to it in size.

In addition to the larger crab and shrimp taxa, amphipods and mysid shrimp are often abundant in our fish seines. However, these taxa are not identified or counted during surveys. Voucher specimens have been collected for identification and these taxa are included in Table 11.

Like fish, macrocrustacean densities and richness are highest in the summer months. Densities were highest at stations F2 and F5, and lowest at station F3 on the north shore. Substrates are sandier at station F3 and the elevation drops off more quickly than at stations on the south and east shores (Figure 31). Taxa richness has ranged from 2-9, with the most taxa generally found during summer sampling events (5-9) and the lowest in fall and winter (2-3 taxa) (Figure 32).

BENTHIC INVERTEBRATES

At the time of this writing, benthic invertebrate samples collected at Crissy Field are still in the process of being sorted and identified. Therefore, relative abundance, densities and spatial and temporal patterns have not yet been evaluated. To date, at least 95 benthic invertebrate taxa have been identified from samples collected in Crissy marsh since 2000 (Table 11). Numerically dominant taxa include amphipods (predominately *Grandidierella japonica* and *Corophium* sp.), oligochaetes from the Tubificidae family, nematodes, and several species of polychaetes (*Capitella capitata*, *Tharyx parvus*, *Polydora spp*, *Pseudopolydora spp*.). In October 2004, the regular benthic monitoring conducted in Crissy marsh was supplemented by benthic surveys done in conjunction with a USGS-BRD research study undertaken in Crissy marsh (see p. 32 for details). Specimens from samples collected in October 2004 are identified as stations I-4, I-5, I-6, and I-7 in Table 11 (Figure 40).

BIRDS

One hundred forty five species of bird from 36 families were detected in the restored habitats and along the beach and nearshore areas at Crissy Field in surveys conducted between June 2000 through July 2004 (Table 12). Of these, 98 species were observed in the wetland, 76 in the beach and nearshore areas, 64 in the foredunes, and 55 in the dune swale and rear dune area. An additional nine species have been observed either flying over the site, or in landscaped areas adjacent to restored natural areas.

Data is presented by season which are defined as follows: winter (December-February), spring (March-May), summer (June-July), fall(August-November).

In all seasons and all years, the highest bird densities (#birds/hectare) have been detected in the wetland, followed by the dune swale and rear dune (Figure 33). The lowest bird densities were detected in the foredunes and the beach and nearshore areas. Species richness (# of species detected), was highest in the wetland, followed by the beach and nearshore areas, the foredunes, and the dune swale/rear dune areas (Figure 34). However, it should be noted that richness is presented by habitat and the size of the different search areas varies considerably.

Bird species detected at Crissy Field include nine state- or federally-listed species (Table 12). The brown pelican (*Pelecanus occidentalis californicus,* state and federally endangered) and the snowy egret (*Egretta thula,* federal species of concern) are both common visitors to Crissy Field. Additionally, the western snowy plover (*Charadrius alexandrinus*, federally threatened) has been observed roosting on the beach in the Wildlife Protection Area. Other listed species have been observed very infrequently or on just one occasion.

Wetland

The relative composition and abundance of birds detected in the wetland varied between seasons and years (Figure 35, Appendix 2: Table A-4). Since surveys began in 2000, mean species richness in the wetland has tended to be highest in the winter (15 species) and lowest in the summer (10 species). Bird abundance trends were similar; birds were most abundant in the winter with an average of 243 birds detected per survey for all years, and least abundant in the summer with an average of 80 birds detected per survey for all years (Figure 35).

With a few exceptions, the most common birds observed in the wetland year round were gulls and terns. The terns included Forster's terns (*Sterna forsteri*), elegant terns (*Sterna elegans*), and Caspian terns (*Sterna caspia*). Numerically dominant gulls included western gulls (*Larus occidentalis*), California gulls (*Larus californicus*), ring-billed gulls (*Larus delawarensis*), and mew gulls (*Larus canus*). In 2000 and 2003, western gulls were the most common bird in spring, summer, and fall with an average ranging from 12 birds per survey in spring 2003 to 76 birds per survey in summer 2001.

Gulls and terns were primarily seen roosting on one of the two loafing islands or the flood shoal. From initial observations, terns appear to prefer the western island, while gulls dominate on the eastern island. The western island is slightly larger than the eastern island. At a tide equal to 1 foot NGVD, an area of 0.085 hectares (0.21 acres) is exposed on the western island. In contrast, the eastern island is about 0.065 hectares (0.16 acres) in size at the same tide level. Although the western island is slightly larger, the eastern island is slightly further from the south shore of the marsh and the bike, pedestrian, and car traffic on Mason Street. Data collection protocols were modified after 2004 to distinguish differences in usage between the two islands. Further results will be presented in future reports.

Other common birds detected included non-native European starlings (*Sturnus vulgaris*), and several species of ducks. During summer 2001, 2002, and 2003, European starlings (*Sturnus vulgaris*) were the second most common bird (following the western gull), with an average of six birds observed per survey. In winter 2001 and 2002 ducks were also among the most abundant birds. In the winter of 2001, an average of 53 greater scaup (*Ayhthya marila*) were counted per survey. Likewise, in winter 2002, greater scaup and bufflehead (*Bucephala albeola*) were among the three most common birds after mew gulls.

The data did not appear to indicate a substantial difference in bird use by most species between high and low tides. However, detecting these differences may be confounded due to the muted tidal regime and temporally variable tidal range in Crissy marsh. To facilitate better comparisons between tides, staff gage readings are now recorded at the beginning of each survey. Although broad differences in use between tides were not detected, a couple of species did show different use patterns. Western and least sandpipers which forage in intertidal areas, were nearly twice as abundant during low tides than during high tides in both 2002 and 2003 (Figure 36).

Beach and Nearshore

In the beach and nearshore area, species richness did not change appreciably between seasons. An average of 8 species were detected in fall and winter surveys and 7 species in summer and fall surveys. However, bird abundance did vary with season. Birds were most abundant in the fall with an average of 95 birds found per survey and least abundant in the summer with only 40 birds found per survey for all years (Figure 37, Appendix 2: Table A-5).

In most years the most common birds detected in surveys year round were large grebe species, gulls, terns, and cormorants. Western grebes (*Aechmophorus occidentalis*) and Clark's grebes (*Aechmophorus clarkii*) were both resident in the winter and spring. Western gulls were seen year round in all years, but were most common in the fall with a combined average of 16 birds seen per survey. Heerman's gulls (*Larus heermanni*) were present in the summer and fall of most years with a combined average of 8 birds seen per survey. Forster's terns and Caspian terns tended to be dominant in spring, summer, and fall. The cormorants observed were primarily double-crested cormorants (*Phalacrocorax auritus*), but Brandt's (*Phalacrocorax penicillatus)* and pelagic (*Phalacrocorax pelagicus*) were seen as well. As in the wetland area, there was a number of greater scaup found in the winter of 2001 with an average of 14 scaup seen per survey.

Wildlife Protection Area

The Wildlife Protection Area at Crissy Field provides resting and foraging habitat for several species of migratory birds including the federally threatened Western Snowy Plover (*Charadrius alexandrinus nivosus*). Following its establishment in 2000, snowy plovers were observed using the beach on several occasions from 2002-2004. Beginning in winter 2005, snowy plovers have been observed regularly during weekly surveys in January through March 2005 and again in August 2005 through the present (December 2005) (GGNRA, unpublished data). Other birds that are commonly observed in the Wildlife Protection Area include surf scoters (*Melanitta perspicillata*), willets (*Cataptrophorus semipalmatus*), several species of gulls, grebes, and cormorants, killdeer *(Charadrius vociferous*), and loons.

Foredunes

In the foredunes, species richness did not change appreciably with season. An average of six bird species were found during surveys conducted in the fall, winter, and spring, while five species were typically seen during summer surveys. However, bird abundance did vary between seasons. Birds were most abundant in the winter with an average of 36 birds per survey and least abundant in the summer with an average of 14 birds per survey for all years (Figure 38, Appendix 2: Table A-6).

The predominant types of birds found in the foredunes were those that glean insects from the ground. Some of the most common species detected included non-native birds such as European starlings and natives associated with urban habitats such as Brewer's blackbird (*Euphagus cyanocephalus*), American crows (*Corvus brachyrhynchos*), common ravens (*Corvus corax*), and rock doves (*Columba livia*). Brewer's blackbirds were one of the most common birds present year round with an average of six birds seen per survey. European starlings were usually one of the most abundant birds found in the spring and summer and were often seen with Brewer's blackbirds. Killdeer (*Charadrius vociferus*) were also common in the spring and summer with a combined average of six birds seen per survey for all years. Killdeer have been seen attempting to breed every year and had one successful nest of fledglings in summer 2001. White-crowned sparrows (*Zonotrichia leucophrys*) were also common and were seen during all seasons except summer with a combined average of 10 birds per survey for all years.

Dune Swale and Rear Dune

In the dune swale and rear dune search area, an average of four bird species per survey were found in fall and winter and three species were found in summer and spring. Bird abundance trends were similar to those in other areas. Birds were most abundant in the winter (mean birds per survey = 31) and least abundant in the summer (8 birds per survey; Figure 39).

The predominant bird species detected in the dune swale and rear dune area were similar to those observed in the foredunes. White-crowned sparrows, killdeer, European starlings, and Brewer's blackbirds were the most common birds detected with few exceptions (Appendix 2: Table A-7). The mean number of white-crowned sparrows in the winter has increased since monitoring began, often making it the most abundant bird detected. An average of 10 birds were seen per survey the first year, while a combined average of 17 birds have been seen per survey over the last three years. This could be related to the increased vegetation cover and therefore food sources over the last four years. Likewise, the increased vegetation cover and availability of fresh water is most likely responsible for attracting some birds such as flycatchers and common yellowthroat (*Geothlypis trichas*).

At least two species have been observed exhibiting breeding behavior in the dune swale and rear dune area. Resident Anna's hummingbirds (*Calypte anna*) were commonly seen exhibiting breeding behavior in spring of most years, though no nests have been detected. Likewise, in summer 2003 and 2004, a pair of red-winged blackbirds (*Agelaius phoeniceus*) was seen exhibiting breeding behavior although it is unsure whether there were successful fledglings.

Fort Point Area

The most common birds seen in the Fort Point area were double-crested cormorants, western gulls, western grebes, and in the winters, greater scaup. At times, there were several hundred cormorants roosting on the southern piling of the Golden Gate Bridge. When large numbers of grebes or scaup were seen in the Fort Point area, they were often seen later in the nearshore area off of Crissy beach or in the wetland.

ADAPTIVE MANAGEMENT

Inlet Closures

During the planning process for the Crissy Field marsh restoration it became apparent that the marsh could not achieve the recommended footprint of 30 acres required to maintain continuous tidal action. Instead, the NPS planned a 20-acre tidal marsh and made a public commitment to mechanically excavate the marsh if necessary, and to assess the possibility of marsh expansion at some time in the future. The closure potential and the commitment to mechanically open the marsh were included in the 1996 Crissy Field Plan Environmental Assessment and Finding of No Significant Impact.

The inlet channel has closed 19 times between May 2001 and November 2004 (Table 2). See "Inlet Channel Dynamics" on p. 13. Of the 19 closures that have occurred to date, four have been re-opened mechanically, including two conducted by GGNRA maintenance staff (March 2003, June 2004).

An adaptive management plan for addressing tidal closures was adopted by GGNRA in January 2002**.** This plan calls for a meeting of key GGNRA and Parks Conservancy staff when an inlet closure reaches two weeks. At this time, staff review conditions in the marsh and discuss whether mechanical excavation is appropriate. Season, weather, marsh water levels, tide conditions, and monitoring results are all considered in order to evaluate 1) the likelihood of a natural reopening, and 2) whether conditions potentially stressful to marsh organisms are likely to develop. Given the many combinations of tides, weather, season, water levels and monitoring data possible, defining precise conditions (i.e., thresholds) that trigger mechanical excavation has not been possible.

During inlet closures, the regular monitoring program is adapted in order to track marsh conditions and attempt to identify stressful conditions soon after they develop. The primary factors that have been monitored during closures include water quality, plant health, and soil conditions. Each long-term closure (Dec. 2001 - Jan. 2002 ; Jan.– Mar. 2003; Sep. – Oct. 2003, Apr. - Jun. 2004) has provided an opportunity to re-evaluate the efficacy of "closure monitoring". Consequently, monitoring during inlet closures has evolved as our understanding of the system has improved and as the usefulness and/or feasibility of various monitoring techniques has been evaluated. Table 13 provides a summary of the monitoring approach conducted during the long-term closures through 2004.

Water Quality

Although water temperature and salinity are considered during closure, dissolved oxygen levels are of particular concern. Decreased circulation and decomposition of organic material (e.g., algae) can lead to declines in DO. As described previously (p. 16), declines in DO can be stressful to aquatic organisms and at levels below ~3 mg/L, the risk of mortality increases.

Although sharp declines in DO have not been observed during most long-term closures (Figure 9, Figure 10), declines in DO were evident during the spring 2004 inlet closure (Figure 11). Mean dissolved oxygen levels at nine sampling stations during the spring 2004 closure remained below 4.0 mg/L for the duration of the closure with brief increases attributed to spring tides overwashing the ebb bar (Figure 23). Declining DO levels were one of the factors that led to a decision to mechanically excavate in June 2004.

Water salinity declines during most long-term closures (Figure 7, Figure 15, Figure 16). However, this is not generally considered stressful and has not contributed to decisions to mechanically excavate. In fact, declines in salinity may provide some relief for submerged plants by decreasing stress related to maintaining osmotic balance.

In cooperation with the San Francisco Public Utilities Commission (SF PUC), water samples are collected in the marsh inlet during some closures. Samples are tested against public standards for recreational contact for *e. coli, enterococcus* and total coliforms. If concentrations exceed public health standards the area is posted with a "No Swimming" sign. The sign is left in place until subsequent samples are below contact levels.

Bacteria levels in the marsh inlet during the spring 2004 closure exceeded public health standards on three sampling dates, leading to concerns about the health and safety of recreational users of the beach and inlet. Bacteria levels in the inlet have not exceeded public health standards during any other closure events.

Plants

Quantifying the impacts of inlet closures to marsh plants is difficult. Although adapted to daily inundation by the tides, salt marsh plants are likely to die or be replaced by alternate vegetation if tidal action is eliminated. While we know that the risk to plants is greatest during the active growing season, tolerance to prolonged inundation is likely to vary among species and life stages. Stress may manifest itself through reduced growth rates, reduced seedling recruitment and/or mortality; measuring these parameters and relating them to a single cause is difficult.

To date, we have been using simple observations to detect plant stress. If a closure extends beyond 30 days during the active growing season (spring-fall) we begin collecting stems from submerged plants. Stem cross-sections are examined under a microscope for signs of waterlogging stress. Ideally these samples are compared to samples collected at nearby marshes with good tidal exchange. Using a camera attached to the microscope, photos of the stem cross-sections are taken and maintained for future comparisons.

Observations of plant stem cross sections was first initiated during the winter 2003 inlet closure and was repeated during the spring 2004 closure. There were obvious differences between plants collected from Crissy Field after one month of closure relative to plants collected from Richardson Bay; however differences varied between species. Observations from later collections appeared to indicate increasing signs of stress, but there was still significant variability between individuals. No plants appeared waterlogged or necrotic when collected two weeks after mechanical excavation and many appeared very healthy. However, many plants appeared dessicated; the prolonged closure may have impacted their ability to acquire water and nutrients following excavation.

Attempts to find reliable indicators of stress in plants and relate those effects to prolonged inundation continues. Until then, simple observations of plant response to inlet closures will be used to refine decision-making related to inlet management.

Soil Conditions

In fall 2003, we began monitoring soil redox potential in an attempt to determine its usefulness as an easily-measured field indicator of stress to plants. We expected soil redox potentials to decline following closure as oxygen and other terminal electron acceptors became depleted in the soil, creating conditions stressful to plants.

Soil redox potentials were measured during two time periods leading up to closure events (Aug. 2003, Feb. – May 2004) and for the duration of the Sep. – Oct. 2003 closure. Results from these sampling periods showed no strong differences in soil redox potential with respect to tidal flushing or tidal range. Rather, soils were fairly reduced at all times, regardless of tides. Because of the lack of differences during open and closed inlet conditions, this monitoring was dropped.

Physical Monitoring

In addition to the annual topographic surveys conducted in the fall, a set of smaller scale surveys is generally conducted before and after a mechanical excavation (Table 13). These surveys have documented the rapid response of the inlet channel and the ebb shoal to mechanical excavation (see PWA 2005 and GGNRA for more detail). Following mechanical excavation the elevation of the inlet channel thalweg generally downcuts by 2-4 feet. Downcutting usually continues for several weeks following excavation. The position of the inlet channel at the mouth also changes rapidly following mechanical excavation, deflecting eastward 20-30 meters within a few days following excavation. It then repeats its cycle of eastward migration and gradual infilling until the next closure event. (See "Inlet Channel Dynamics", p. 13.)

Small Erosion Events

Following restoration, gullies formed in several locations along the marsh upland north and in the dune swale where rainwater runoff from the promenade and adjacent paths found low spots. These were successfully mitigated with willow mattresses. The need for willow mattressing has decreased as vegetation has filled in.

OTHER RESEARCH AT CRISSY FIELD

Beyond the regular monitoring program, several independent research studies have been initiated to guide management decisions at Crissy Field.

Marsh Expansion Technical Study

In 2004, Philip Williams and Associates (PWA) completed a technical study to re-examine the relationship between tidal prism and inlet dynamics at Crissy Field (PWA 2004). This study used monitoring data collected at Crissy Field from 2000-2003 to create and calibrate a model to estimate the minimum tidal prism necessary to maintain a continuously open inlet. The model also predicted the number of inlet closures per year, as well as the number of closures requiring mechanical intervention for several intermediate-sized wetlands. Additionally, the study summarized the potential effects of marsh expansion on sand dynamics at East Beach. This study was peer-reviewed by several coastal geomorphologists and/or hydrologists. Several of the key findings from this report are presented here.

The model predicts that in order to achieve continuous tidal action, the marsh would need to be expanded from its current volume of 17 acre-feet to approximately 56 acre-feet. However, even small increases in tidal prism are likely to lead to a decreased frequency of closure and need for mechanical intervention. For example, a 39 acre-foot marsh would close on average less than three times a year, requiring mechanical intervention less than once a year.

The study also made observations with respect to changes in sand volumes and morphologic conditions that could result from marsh expansion. Both the flood shoal and the ebb shoal are expected to enlarge with an expanded marsh, with greater increases expected with larger expansions. This led to a recommendation that expansion should occur radially around the flood shoal in order to avoid pinching off portions of the marsh to tidal circulation.

As was true during the original marsh creation, marsh expansion would lead to both temporary and permanent changes at East Beach. A period of erosion, similar to that experienced following the original restoration, would be likely as sand delivery to the beach is disrupted by the evolution of the ebb and tidal shoals. These features, in turn, would affect local wave dynamics that would lead to changes in the orientation of the beach. The exact magnitude of these changes and the time required to reach equilibrium is uncertain.

Although PWA provided rough estimates of the changes in sand volume likely and the time required to reach equilibrium as well as qualitative descriptions of the shoreline adjustments, monitoring data collected since the report was finalized indicate that these estimates may be conservative. At the time that the study was completed, monitoring data appeared to indicate that the marsh had reached a dynamic equilibrium with respect to the volume of sand that had accumulated on the ebb and tide shoals and on East Beach. However, data from topographic and bathymetric surveys conducted in fall 2004 indicates that the system is still accumulating sand. This is especially true on the north edge of the ebb shoal and on East Beach. This should be considered when interpreting the report.

Emerging Contaminants Study

In summer 2004, a study was initiated in collaboration with Dr. Roger Hothem of USGS-BRD to establish baseline concentrations of emerging contaminants of concern in the water column in Crissy marsh and in San Francisco Bay just offshore of the marsh. This study was funded by the National Park Services' Water Resources Division and was initiated in anticipation of a wastewater treatment plant planned by the Presidio Trust. When constructed, this treatment plant will provide recycled wastewater (primarily for irrigation) on the Presidio. The restored airfield, adjacent to the marsh has been identified as one of the major users of the recycled water.

This project was designed to evaluate concentrations of contaminants not completed removed during tertiary treatment including hormones, pharmaceuticals, and personal care products. Many of these contaminants, including steroid hormones, have been documented to cause endocrine disruption in fish and other wildlife and may bioaccumulate in tissues. USGS employed the use of an innovative new technique: polar organic compound integrative samplers (POCIS) to evaluate the concentrations of these compounds in the marsh water column. Sample analysis has not been completed at the time of this writing; results will be presented in subsequent reports.

Sampling of the marsh's benthic macroinvertebrate community was also initiated in order to enable comparisons after irrigation with treated wastewater begins. The benthic macroinvertebrate community was sampled following Environmental Monitoring and Assessment Program (EMAP) protocols for collection, processing, reporting, and quality control (U.S. EPA 1995, 2001a, 2001b). Benthic macroinvertebrate specimens identified from samples collected as part of this study are included in Table 11.

Pending the availability of additional funding, follow-up studies are planned to evaluate the concentration of contaminants in the sewage influent and treated effluent once the wastewater treatment plant becomes operational. Likewise, additional benthic community samples will be collected from Crissy marsh for comparison to baseline concentrations.

Table 1. Crissy Field Monitoring Parameters, Objectives, and Linkage to Restoration and Management Objectives

Monitoring Parameter	Objective	Commitments	Mgmt Concerns	Pre-project objectives	Baseline and/or or comparision data
Hydrology/Geomorphology	1. Develop an understanding of the Crissy Field tidal wetland physical processes in order to guide adaptive management and future marsh expansion planning processes. 2. Document the long-term morphological changes of the Crissy Field tidal wetland.	Crissy Field Environmental Assessment and Finding of no Significant Impact (FONSI)	Inlet closures, future habitat plans	Crissy Field Environmental Assessment (EA) 2.1; "reestablishing an ecologically viable self-sustaining tidal marsh requiring a minimum of human intervention"	√
Water Quality (d.o., salinity, temp)	1. Document salinity, temperature, and dissolved oxygen (DO) levels in the Crissy Field wetland for purposes of establishing the seasonal temperature thermocline, salinity gradient, and DO range within the wetland, and for comparisons with other tidal wetlands within San Francisco Bay. 2. Detect short-term fluctuations in water quality associated with storm events and/or inlet closures in order to guide management decisions	FONSI	Inlet closures	E.A. 2.1 (see above)	√
Soils	1. Track changes in key soil properties (salinity, sediment texture, soil organic content, and total kjeldahl nitrogen (TKN)) associated with tidal wetland development			EA 2.3; "restoring and enhancing native plant communities"	√
Nutrients and Pollutants	1. Establish baseline information on gross inputs of inorganic nutrients and pollutants from each of four storm drains emptying into the tidal marsh at Crissy Field. 2. Detect potential sources of non-point source pollutants which could adversely affect the newly restored ecosystem.		Airfield Mgmt; Inputs from Watershed; inlet closures	EA 2.1 (see above)	√
Fish	1. Establish a community profile of fish and macrocrustaceans within subtidal and intertidal habitats of the project area for purposes of gaining information and tracking changes in the community composition associated with tidal wetland development		Inlet closures, mosquitoes, airfield mgmt	EA 2.4; providing adequate protection for wildlife currently on the site and anticipated to occur as a result of planned improvements E.A. 2.1 (see above)	√
Birds	1. Conduct bird surveys within the Crissy Field project wetland and adjacent upland, dunes, dune swale, and beach and nearshore habitats for purposes of documenting the seasonal distribution, abundance, species richness, and diversity of birds, and documenting changes over time.			E.A. 2.4 (see above)	√

Vegetation	1. Tidal marsh: Characterize and assess trends in vegetation species diversity, relative and total percent cover within each of three subhabitats (low marsh, marsh plain, and high marsh) in the restored tidal marsh at Crissy Field. 2. Dunes: Characterize and assess trends in vegetation species diversity, relative and total percent cover within each of three substrate types (remnant, beach sand, and dredge) in the restored dunes at Crissy Field.		Inlet closures	EA 2.3 (see above) EA 2.1 (see above) Crissy Field Restoration Action Plan (RAP) 8; " maintain the site by removing 90% of the non-native invasive plants during the first year of revegetation and 75% over the next four years of active restoration…"	√
Benthic invertebrates	1. Establish a benthic macro-invertebrate community profile for the Crissy Field Restoration Area tidal wetland in each of three habitats (marsh plain, low marsh and subtidal), and in areas subject to different hydrologic conditions; 2. Track changes in invertebrate species composition associated with tidal wetland development.			Same as Fish	√

Table 2. Observed closures and breaches of inlet channel (November 1999 – November 2004)

1	5/01/2001 – 5/04/2001	Intermittent closures and small mechanical breaches.
2	5/12/2001 – 5/20/2001	Neap closure and natural re-opening during rising spring tide.
3	6/14/2001 – 6/16/2001	Neap closure and natural re-opening during rising spring tide.
4	8/09/2001 - 8/16/2001	Closure and natural re-opening during rising spring tide. (based on partial tide record)
5	10/21/2001 – 11/05/2001	
6	11/21/2001 – 11/24/2001	High swell during neap tides closed inlet, unusually high tides (storm surge).
7	12/05/2001 – 12/14/2001	Partial closure (less than 0.5 ft tide range in marsh)
7	12/14/2001 – 12/28/2001	Full closure during spring tides due to greatly reduced effective tidal prism. Natural re-opening during unusually large tides (storm surge).
8	1/02/2002 – 1/16/2002	Closure due to reduced effective tidal prism, unauthorized mechanical breaching by Wayne.
9	7/01/2002 – 7/08/2002	Neap closure and spring re-opening
10	7/31/2002 – 8/06/2002	Neap closure and spring re-opening. Step-wise filling at high water over six days.
11	8/27/2002 – 9/04/2002	Neap closure and spring re-opening, following a few days of partial re-opening (~ 1 ft range).
12	9/28/2002 – 10/09/2002	Neap closure and spring re-opening.
13	10/21/2002 - 11/05/2002	Partial closure through 10/28, then full, spring re-opening. Photodocumentation of breach.
14	1/07/2003 – 1/10/2003	Partially closed
15	1/13/2003 – 3/18/2003	mechanical breach conducted to relieve stress on marsh plants at beginning of growing season
16	9/04/2003 – 10/27/2003	partial closure through 9/30/03, then full closure at 2.5 ft NGVD; high incoming tide cut channel through ebb bar directly north of promenade bridge on 10/27/03. Marsh filled and scour continued on outgoing tide; photodocumentation.
17	3/27/04 – 4/5/04	Neap closure, spring re-opening; mouth 130 meters east of stairs
18	4/11/04 – 6/3/04	Neap closure. Mechanical excavation 6/2/04.
19	10/6/04 – 10/16/04	Neap closure, spring re-opening. Inlet re-directed to north-south alignment during storm 10/19

adapted from table in Philip Williams and Associates (2004)

Table 3. 2002 Data Inventory and Descriptive Statistics, Hydrolab® Minisonde

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deployment Summary													
Number of days deployed		16	13	26	17	28	30	26	30	27	14	28	30
Sampling Interval (min)		60	60	60	60	60	60	60	60	60	60	60	60
Descriptive Statistics													
Temperature (^{o}C)	n	369	236	601	415	681	718	641	724	637	329	684	713
	mean	10.5	13.4	12.7	14.2	15.1	16.5	17.7	17.8	17.8	17.9	14.4	12.7
	max	14.3	16.6	17.9	20.1	21.9	26.4	24.9	23.6	23.9	22.4	16.8	14.4
	min	6.1	10.5	7.6	11.3	11.6	12.2	14.1	14.7	15.4	14.4	12.1	10.2
Salinity (ppt)	n	369	236	601	415	681	718	641	724	637	329	684	713
	mean	26.6	28.6	27.1	30.2	32.3	31.2	31.6	31.6	31.4	30.2	30.8	28.8
	max	31.0	30.6	31.2	31.9	35.1	32.7	32.9	32.8	32.5	32.5	32.4	31.8
	min	12.9	3.2	3.4	24.9	23.7	27.2	28.3	28.6	26.3	24.6	23.8	10.9
Dissolved Oxygen (mg/l)	n	238	236	457	415	596	589	438	639	637	296	684	713
	mean	9.39	3.88	4.65	7.53	8.58	8.22	7.80	5.97	4.27	5.68	6.60	6.60
	max	14.16	7.17	7.21	11.94	14.25	17.39	19.58	16.17	10.08	10.60	11.44	8.64
	min	2.74	2.82	2.89	3.35	4.67	1.42	1.38	0.15	0.93	1.58	3.44	3.05

* Measurements of percent saturation (%) and conductivity, and specific conductance are also taken but not included in table.

Table 4. 2003 Data Inventory and Descriptive Statistics, Hydrolab® Minisonde

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deployment Summary													
Number of days deployed		28	25	29	28	29	28	23	28	27	25	4	24
Sampling Interval (min)		60	20	60	60	60	60	60	60	60	60	60	60
Descriptive Statistics													
Temperature (°C)	n	693	1652	688	668	632	670	559	601	637	133	103	579
	mean	13.1	14.1	15.1	13.9	15.3	16.5	17.5	19.3	19.4	16.4	12.0	11.9
	max	15.4	16.7	20.2	20.5	22.1	25.3	23.5	25.2	24.7	19.3	12.8	13.8
	min	10.3	11.2	12.3	11.7	11.5	11.5	13.6	15.8	16.4	14.9	11.1	8.9
Salinity (ppt)	n	693	1652	688	668	632	670	559	601	637	133	103	579
	mean	24.8	18.2	20.0	29.0	28.1	31.2	31.4	31.9	31.6	27.6	30.5	28.6
	max	29.3	22.3	31.8	31.2	32.0	33.1	32.9	33.2	33.3	28.8	31.4	31.3
	min	7.7	13.0	11.8	15.7	21.8	22.6	29.6	30.2	28.3	26.4	22.9	9.2
Dissolved Oxygen (mg/l)	n	655	1652	272	134	387	670	559	601	637	133	103	258
	mean	6.25	6.88	9.91	7.39	7.10	6.95	6.74	5.87	5.29	4.97	7.58	7.10
	max	15.19	14.48	13.36	11.54	10.89	11.47	12.63	9.92	8.44	7.43	8.44	8.24
	min	2.43	1.21	7.14	4.83	4.56	3.41	2.72	2.61	1.86	2.59	6.71	5.58

* Measurements of percent saturation (%) and conductivity, and specific conductance are also taken but not included in table.

Table 5. 2004 Data Inventory and Descriptive Statistics, Hydrolab® Minisonde

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deployment Summary													
Number of days deployed		23	28	29	24	28	27	28	29	23	20	22	30
Sampling Interval (min)		60	60	60	60	60	60	60	60	60	60	60	60
Descriptive Statistics													
Temperature (^{o}C)	n	545	672	572	550	583	320	383	691	549	486	528	728
	mean	11.2	12.5	15.1	17.2	18.7	16.5	17.3	17.9	17.8	15.0	13.2	11.7
	max	13.1	15.7	21.0	25.0	24.2	23.0	23.4	24.6	24.8	18.4	18.5	14.3
	min	7.5	10.5	8.8	11.6	13.2	12.6	14.7	15.7	14.6	13.0	9.0	9.4
Salinity (ppt)	n	257	672	572	550	583	320	383	691	549	486	528	728
	mean	27.1	30.6	20.6	24.1	25.9	28.8	33.3	32.4	32.8	31.1	30.3	31.0
	max	33.3	35.3	27.4	28.6	31.6	33.2	35.7	35.8	35.6	32.3	31.6	35.9
	min	14.3	17.2	0.4	20.8	2.6	12.4	25.7	11.2	30.6	19.0	17.7	6.0
Dissolved Oxygen (mg/l)	n	73	672	572	550	299	179	154	0	0	112	327	728
	mean	6.0	6.10	7.11	5.26	4.96	4.77	6.19	N/A	N/A	5.45	5.91	7.07
	max	7.47	7.93	10.84	10.02	9.73	8.81	7.48	N/A	N/A	7.26	7.73	9.09
	min	3.87	3.62	3.98	1.85	0.44	0.39	5.01	N/A	N/A	3.98	3.57	5.10

- Measurements of percent saturation (%) and conductivity, and specific conductance are also taken but not included in table.

Table 6. Average percent (%) cover and percent frequency of occurrence of algae and plant cover along 18 permanent transects at low elevation s of Crissy Field Tidal Marsh, 2002-2004. (Species are listed in decreasing frequency of occurrence as measured in 2004.)

Low Elevation Transects (~5 feet MLLW)		**2002**		**2003**		**2004**	
Scientific Name	Common Name	Average % Cover	% Frequency Occurrence	Average % Cover	% Frequency Occurrence	Average % Cover	% Frequency Occurrence
	bare ground	72	100	67	100	53	100
Ulva and *Enteromorpha sp.*	algae	8	100	19	100	22	89
Sarcornia pacifica	pickleweed	6	72	3	78	18	78
Spartina foliosa	Pacific cordgrass	8	61	10	56	9	67
Distichlis spicata	salt grass	2	11	5	22	10	39
Jaumea carnosa	salt marsh daisy	3	11	<1	17	2	33
Spergularia macrotheca	beach sand spurry	<1	6	<1	6	3.5	17
Frankenia salina	alkali heath	<1	6	<1	6	<1	17
Spergularia marina	salt marsh sand spurry	--	--	<1	16	<1	17
Juncus leseurii	salt rush	--	--	<1	6	2	11
Schoenoplectus pungens		5	6	--	--	1	6
Limonium californicum	sea lavender	<1	6	--	--	<1	6
Scirpus maritimus		--	--	--	--	<1	6
Non-native forbs		2	33	<1	6	<1	6
Carex obnupta	slough sedge	--	--	1	6	--	--
Salicornia europaea	annual pickleweed	<1	17	<1	6	--	--
Plantago maritima		<1	6	--	--	--	--
Triglochin concinna	arrow grass	<1	6	--	--	--	--
Native Species Richness (Mean ± S.E.)		2.0 ± 0.4		2.2 ± 0.4		2.9 ± 0.5	
Species Richness Range		0-8		0-6		0-8	

Table 7. Average percent (%) cover and percent frequency of occurrence of algae and plant cover along 18 permanent transects at mid elevations of Crissy Field Tidal Marsh, 2002-2004. (Species are listed in decreasing frequency of occurrence as measured in 2004.)

Mid Elevation Transects (~5.25 – 6 feet above MLLW)		**2002**		**2003**		**2004**	
Scientific Name	Common Name	Average % Cover	% Frequency Occurrence	Average % Cover	% Frequency Occurrence	Average % Cover	% Frequency Occurrence
---	bare ground	70	100	61	100	45	100
Sarcocornia pacifica	pickleweed	3	83	7	89	11	100
Frankenia salina	alkali heath	12	83	15	72	21	83
Jaumea carnosa	salt marsh daisy	7	56	8	56	11	72
Distichlis spicata	salt grass	6	44	8	72	20	67
Ulva and *Enteromorpha sp.*	algae	2	78	5	83	1	50
Spergularia marina	salt marsh sand spurry	--	--	<1	33	<1	44
Limonium californicum	sea lavender	<1	17	<1	11	<1	28
Spergularia macrotheca	beach sand spurry	<1	28	<1	17	<1	22
Plantago maritima		<1	22	--	--	<1	17
Juncus leseurii	salt rush	3	11	4	11	7	11
Salicornia europaea	annual pickleweed	<1	11	<1	17	<1	6
Schoenoplectus pungens		1	6	2	6	<1	6
Atriplex leucophylla	beach saltbush	--	--	--	--	<1	6
Cordylanthus maritimus ssp. palustris	Point Reyes bird's beak	--	--	--	--	<1	6
Triglochin concinna	arrow grass	<1	11	<1	11	<1	6
---	non-native forbs	3	33	<1	6	<1	6
Atriplex triangularis	spearscale	<1	11	<1	11	--	--
Spartina foliosa	Pacific cordgrass	--	--	<1	11	--	--
Heliotropium curassavicum	salt heliotrope	<1	6	--	--	--	--
Native Species Richness (Mean ± S.E.)		3.7 ± 0.5		4.2 ± 0.6		4.6 ± 0.5	
Species Richness Range		1-9		1-9		1-9	

Table 8. Average percent (%) cover and percent frequency of occurrence of algae and plant cover along 18 permanent transects at high elevations of Crissy Field Tidal Marsh, 2002-2004. (Species are listed in decreasing frequency of occurrence as measured in 2004.)

High Elevation Transects **(~6.5 - 7 feet above MLLW)** *Scientific Name*	Common Name	**2002** Average % Cover	% Frequency Occurrence	**2003** Average % Cover	% Frequency Occurrence	**2004** Average % Cover	% Frequency Occurrence
	bare ground	69	100	66	100	62	100
Distichlis spicata	salt grass	10	78	13	83	18	89
Sarcornia pacifica	pickleweed	3	67	2	83	4	83
--	non-native forbs	3	89	<1	6	1	67
Spergularia macrotheca	beach sand spurry	5	72	2	78	2	61
Spergularia marina(salina?)	salt marsh sand spurry	--	--	2	44	1	56
Jaumea carnosa	salt marsh daisy	1	22	3	44	2	50
Frankenia salina	alkali heath	5	44	3	50	1	50
Plantago maritima	goose tongue	<1	33	<1	11	<1	50
Limonium californicum	sea lavender	2	17	<1	22	<1	39
Ambrosia chamissonis	beach bur	<1	11	--	--	1	17
Atriplex triangularis	spearscale	1	22	<1	44	<1	17
Grindelia stricta	marsh gumplant	3	17	<1	17	<1	11
--	non-native grasses	<1	17	--	--	<1	17
Atriplex californica	Ca. saltbush	<1	6	--	--	<1	11
Schoenoplectus pungens		--	--	<1	6	5	6
Baccharis pilularis	coyote brush	--	--	--	--	<1	6
Armeria maritima ssp. *californica*	Ca. sea pink	--	--	--	--	<1	6
Triglochin concinna	arrow grass	<1	6	<1	6	<1	6
Juncus bufonius	toad rush	<1	17	--	--	<1	6
Heliotropium curassavicum	salt heliotrope	<1	6	--	--	<1	6
Festuca rubra	Red fescue	<1	6	--	--	<1	6
Ulva and *Enteromorpha sp.*	algae	3	50	3	83	--	--
Fragaria chiloensis	beach strawberry	<1	11	<1	11	--	--
Atriplex leucophylla	beach saltbush	--	--	<1	6	--	--
Spartina foliosa	Pacific cordgrass	<1	6	<1	6	--	--
Lupinus arboreus	yellow bush lupine	<1	6	--	--	--	--
Rumex occidentalis		<1	6	--	--	--	--
Epilobium brachycarpum	willow herb	<1	6	--	--	--	--
Native Species Richness (Mean ± S.E.)		4.2 ± 0.6		5.0 ± 0.6		5.2 ± 0.6	
Species Richness Range		0-9 species		0-9 species		1–9 species	

Table 9. Summary of special status plant species introductions and monitoring results from Crissy Field, 1999-2004.

Species				**Reintroduction**		**Monitoring**	
Scientific Name	**Common Name**	**Status**	**Year**	**Location**	**Amount**	**Methods**	**Results**
Chorizanthe cuspidata var. *cuspidate*	San Francisco spineflower	FSC CNPS 1B	1999	throughout site Dune A	1 envelope (?) 11 grams (~16,000 seeds)	none	
			2000	Dunes D, F, G, H, R/S, dune swale upland, shellmound	254.5 grams (~370,000 seeds)	mapping, observations	plants appeared small and clumped
			2001	shellmound	missing data	mapping, observations	plants appeared to increase in size; possibly due to leaking irrigation line
			2002	none		none	
			2003	none		none	
			2004	none		mapping, census	~3,000 – 5,000 individuals
Collinsia corymbosa	round-headed Chinese houses	FSC CNPS 1B	2003	Dune R/S	12.5 grams	survey, observations	0 individuals
			2004	none		survey, observations	0 individuals
Cordylanthus maritimus ssp. *palustris*	Point Reyes bird's beak	FSC CNPS 1B	2001	west shore of marsh	5,400 seeds into one 1-sq. meter plot	survey, observations	1 individuals

Species				Reintroduction		Monitoring	
Scientific Name	**Common Name**	**Status**	**Year**	**Location**	**Amount**	**Methods**	**Results**
Cordylanthus maritimus ssp. *palustris*	Point Reyes bird's beak	FSC CNPS 1B	2002	none		mapping, census	10 individuals
			2003	none		mapping, census	122 on west shore, one on east shore
			2004	west shore of marsh	12,811 seeds into six 1-sq. meter plots;	mapping, census, reproductive information (number flowering and fruiting)	2,363 individuals (268 outside of seeding plots, 2,095 within the plots); some individuals were found at the east and south side of marsh; 73% flowered & 47% fruited
Erysimum franciscanum	San Francisco wallflower	FSC CNPS 4	1999	marsh upland north	40 plants	none	
			2000	dune swale upland, shellmound, marsh uplands (north, south, west)	466 plants	mapping, census	412 total; 268 in marsh uplands, 66 in shellmound, 78 in dune swale upland
			2001	marsh upland (south), shellmound	33 plants	mapping, population estimate	~30-40% survival from previous year; very few seedlings
			2002	dune swale upland, shellmound, marsh uplands (south, west)	112 plants	none	

Species				Reintroduction		Monitoring	
Scientific Name	**Common Name**	**Status**	**Year**	**Location**	**Amount**	**Methods**	**Results**
Erysimum franciscanum	San Francisco wallflower	FSC CNPS 4	2003	Dune swale upland, shellmound, marsh upland (south)	75 plants	mapping, census, survivorship monitoring for 2003 plantings	123 total; 16 in marsh uplands, 2 in shellmound, 105 in dune swale upland, 68 of 2003 plantings survived.
			2004	none		mapping, census, survivorship monitoring for 2003 plantings	88 total; 31 in marsh uplands, 12 in shellmound, 45 in dune swale upland; 0% survival for 2003 plantings
Gilia capitata ssp. *chamissonis*	dune gilia	CNPS 1B	1999	throughout site, Dune A	90.1 grams (~247,000 seeds)	none	
			2000	Dunes D, F, G, H, R/S, dune swale upland, shellmound	98.1 grams (~270,000 seeds)	mapping, observations	Plants appeared small and clumped
			2001	none		mapping, observations	Plants appeared to have increased in size, possibly due to leaking irrigation line
			2002	shellmound	10 grams (~27,000 seeds)	none	population appears stable/increasing
			2003	none		none	

Species				Reintroduction		Monitoring	
Scientific Name	**Common Name**	**Status**	**Year**	**Location**	**Amount**	**Methods**	**Results**
Gilia capitata ssp. *chamissonis*	dune gilia	CNPS 1B	2004	none		mapping, population size estimated	~10,000 individuals
Lessingia germanorum	San Francisco Lessingia	FE CNPS 1B	2000	none		observations	2? individuals
			2001	none		mapping, census	80 individuals
			2002	none		mapping, census	655 individuals
			2003	none		mapping, census	315 individuals
			2004	none		mapping, census	145 individuals
Silene verecunda spp. *verecunda*	San Francisco campion	FSC CNPS 1B	2000	shellmound	46 plants	none	
			2001	none		mapping, population estimate	~35% of plantings from 2000 surviving
			2002	none		mapping, census	13 individuals

Species				Reintroduction		Monitoring	
Scientific Name	Common Name	Status	Year	Location	Amount	Methods	Results
Silene verecunda spp. *verecunda*	San Francisco campion	FSC CNPS 1B	2003	dune swale upland, shellmound, marsh upland (west)	51 plants	mapping, census, survivorship monitoring fro 2003 plantings	76 individuals, 47 of the 2003 plantings surviving
			2004	shellmound	23 plants	mapping, census, survivorship for 2003 plantings	63 individuals, 3 of the 2003 plantings surviving
Suaeda californica	California sea-blite	FE CNPS 1B	2001	tidal marsh (east, west, and south shores)	28 plants	mapping, census	27 individuals
			2002			mapping, census	13 individuals
			2003			census	0 individuals
			2004			none	0 individuals
Tanacetum camphoratum	dune tansy	FSC	2000	Dunes A-L, P-T, dune swale upland, shellmound, marsh uplands	1,759 plants	none	
			2001	none		none	
			2002	none		none	

Species				Reintroduction		Monitoring	
Scientific Name	**Common Name**	**Status**	**Year**	**Location**	**Amount**	**Methods**	**Results**
Tanacetum camphoratum	dune tansy	FSC	2003	none		census and map	542 plants
			2004	none		none	

Table 10. Fish taxa collected in Crissy field marsh (June 2000 – July 2004)

Family	Scientific Name	Common Name
AMMODYTIDAE	*Ammodytes hexapterus*	Pacific sand lance
ATHERINOPSIDAE	*Atherinops affinis*	Topsmelt
BOTHIDAE	*Citharichthys stigmaeus*	Speckled sanddab
CLINIDAE	*Gibbonsia elegans*	Spotted kelpfish
COTTIDAE	*Leptocottus armatus*	Pacific staghorn sculpin
	Scorpaenichthys marmoratus	Cabezon
EMBIOTOCIDAE	*Cymatogaster aggregata*	Shiner surf perch
FUNDULIDAE	*Luciana parva*	Rainwater killifish*
GASTEROSTEIDAE	*Gasterosteus aculeatus*	Threespine stickleback
GOBIIDAE	*Acanthogobius flavimanus*	Yellowfin goby*
	Clevelandia ios	Arrow goby
	Ilypnus gilberti	Cheekspot goby
PHOLIDAE	*Apodichthys flavidus*	Penpoint gunnel
	Pholis ornata	Saddleback gunnel
PLEURONECTIDAE	*Isopsetta isolepsis*	Butter sole
	Hypsopsetta guttulata	Diamond turbot
	Platichthys stellatus	Starry flounder
	Psettichthys melanosticus	Sand sole
SYNGNATHIDAE	*Syngnathus leptorhynchus*	Bay pipefish

* non-native to San Francisco Bay

Table 11. Invertebrate Taxa Collected at Crissy Field, 2000-2004

	Phylum/Class	Order/Family	Species	Collection Method	Habitat	Station	Notes
1	**Cnetopohora**	Cydippida	*Pleurobrachia bachei*	Seine: ¼ inch		F-4	
2	**Cnidaria**		*Polyorchis* spp.	Seine: ⅛ inch		F-1	
3	Anthozoa		unid. Actiniaria	Core depth: 10 cm	S	I-4, 7	
4	**Nematoda**	Trichuridae	unid. nematode	Core depth: 20 cm, 10 cm	S	I-2, 4, 5, 6, 7	
5	**Nemertea**		*Micrura spp.*	Core depth: 10 cm	S	I-5	collected once, October 2004
			unid. Nemertea	Core depth: 10 cm	S	I-4	
6	**Sipuncula**	Golfingiidae	*Golfingia* spp.	Core depth: UNK	S	I-2	collected once, April 2002
	Annelida						
7	Oligochaeta	Tubificidae	many	Core depth: 5, 10, 20 cm	S, L, M	All	
8	Polychaeta	Polynoidae	*Harmothoe imbricata*	Core depth: 20 cm, 10 cm & UNK Seine: ⅛ & ¼ inch	S	F-1, 2, 5 I-1, 2, 3, 7	
9		Phyllodocidae	*Eteone lighti*	Core depth: 10 cm	S	I-7	collected once, October 2004
10			*Hesionura coineau difficilis*	Core depth: 10 cm	S	I-5	collected once, October 2004
11			*Phyllodoce multipapillata*	Core depth: 10 cm	S	I-5	collected once, October 2004
12		Syllidae	*Syllis nipponica* (synonym: *Typosyllis nipponica**)	Seine: ⅛ inch Core depth: 20 cm & UNK	S, L, M	F-1 I-1, 2, 3	introduced from Japan
13			*Sphaerosyllis californiensis*	Core depth: 10 cm	S	I-4, 5, 7	
14		Nereidae	*Neanthes brandti*	Core depth: 20 cm & UNK	S	I-1, 2, 3	
15			*Platynereis bicanaliculata*	Core depth: 10 cm	S	I-4, 6,7	
			unid. Nereidae	Core depth: UNK	S	I-1	
16		Goniadidae	*Glycinde polygnatha*	Core depth: 20 cm, 10 cm & UNK	S, L	I-1, 2, 3, 4, 7	
			Glycinde spp.	Core depth: 20 cm, 10 cm	S	I-1, 3, 4	
17		Nephtyidae	*Nephtys caecoides*	Core depth: 20 cm & UNK Shovel	S, FS	I-1, 2, 3 FS	
18		Glyceridae	*Glycera americana*	Shovel	FS	FS	
19			*Hemipodus borealis*	Core depth: 10 cm	S	I-5	collected once, October 2004
20		Onuphidae	*Onuphis elegans* (synonym: *Nothria elegans)*	Core depth: UNK	S	I-1	
21		Dorvilleidae	*Dorvillea rudolphi*	Core depth: UNK, 10 cm Seine: ⅛ inch	S	I-1, 4, 6, 7 F-1, 2	
22		Orbiniidae	*Leitoscoloplos elongatus*	Core depth: 10 cm	S	I-7	
23		Spionidae	*Boccardia proboscidea*	Core depth: 5 cm & UNK	L, M	I-3 F-UNK	
24			*Dipolydora socialis*	Core depth: 10 cm	S	I-4, 7	
25			*Polydora cornuta* (synonym: *Polydora ligni)*	Core depth: UNK, 10 cm	S, L	I-1, 4, 5, 6, 7	first collected SF Bay 1933; introduced from northern Atlantic

	Phylum/Class	Order/Family	Species	Collection Method	Habitat	Station	Notes
26	**Annelida** Polychaeta (continued)		*Streblosopio benedicti*	Core depth: 10 cm	S	I-4	
27			*Pseudopolydora kempi*	Core depth: 10 cm	S	I-4, 5, 6, 7	
28			*Pseudopolydora paucibranchiata*	Core depth: 20 cm, 10 cm	S	I-1, 2, 4, 5, 6 7	first collected SF Bay 1973; introduced from Japan
			unid. Spionidae	Core depth: 10 cm	S	I-4, 7	
29		Opheliidae	*Armandia brevis*	Core depth: 10 cm	S	I-4, 5, 6, 7	
30		Cirratulidae	*Cirriformia spirabrancha*	Core depth: UNK, 10 cm	S, FS	I-1, 6, 7 FS	
31			*Tharyx parvus*	Core depth: 10 cm	S	I-4, 5, 6, 7	
			unid. Cirratulidae	Core depth: 20 cm & UNK	S	I-1, 2, 3	
32		Capitellidae	*Capitella capitata* complex	Core depth: 5, 10, 20 cm	S, L	I-1, 2, 3, 4, 5 6, 7	
33			*Heteromastus filiformus*	Core depth: 10 cm	S	I-7	collected once, October 2004
34			*Mediomastus spp.*	Core depth: 10 cm & UNK	S, L	I-1, 2, 3, 4 5, 7	
35		Pectinaridae	*Pectinaria californiensis*	Core depth: 10 cm	S	I-4	collected once, October 2004
36		Sabellidae	*Euchone liminicola*	Core depth: 10 cm	S	I-4, 6	
	Arthropoda Crustacea (subphylum)						
37	Cirripedia (subclass)	Balanidae	*Balanus crenatus*	Core depth: 20 cm	S	I-1	
38	Copepoda (subclass)	**Harpacticoida**		Core depth: 10 cm	S	I-4, 7	
39	Malacostraca	**Nebaliacea**	*Nebalia pugettensis* (may be an unidentified *Epinebalia* sp)	Seine: ⅛ inch		F-1, 2	
40		**Mysidacea**	*Holmesimysis macropsis* (synonym: *Neomysis macaropsis)*	Seine: ⅛ inch		F-1	
41			*Neomysis mercedis*	Seine: ⅛ inch		F-2	
42			*Neomysis rayii*	Seine: ¼ inch		F-4	
			Neomysis spp.	Seine: ⅛ inch		F-1	
43		**Cumacea**	*Cumella vulgaris*	Core depth: UNK	S, L	I-1, 2, 3	758 collected in 2002, all but one from subtidal habitat
44			*Nippoleucon hinumensis* (synonym: *Hemileucon hinumensis)*	Core depth: 20 cm, 10 cm & UNK	S, M	I-1, 2, 3, 4, 7	first collected SF Bay 1986; native to Japan: only one individual caught in marsh plain

45	**Arthropoda Crustacea** (continued)	**Tanaidacea**	***Sinolobus sp.*** (synonym: ***Sinolobus stanfordi, Tanais sp.)***	Core depth: UNK	L	I-3	first reported SF Bay 1968; introduced; origin unknown collected once in April 2002
46		**Isopoda**	unid. Cymothoidae	Core depth: 20 cm Seine: ⅛ & ¼ inch	S	I-2 F-1, 2, 4	
47		**Amphipoda** (sub-order) **Gammaridea**	*Ampelisca abdita* (synonym: *Ampelisca milleri* *)	Core depth: 20 cm & UNK	S	I-1	first collected SF Bay 1966; native to northwest Atlantic
48			*Ampithoe lacertosa*	Hand collected, and core depth: 10 cm	S	I-4	
49			*Anisogammarus pugettensis*	Core depth: 5 cm & UNK Seine: 1/8 inch	S	I-1, 3 F-1, 2	
50			*Anisogammarus confervicolus*	Core depth: 20 cm Seine: ⅛ inch	S	I-2 F-1	
51			*Grandidierella japonica*	Core depth: 5, 10, 20 cm Seine: ⅛ inch	S	I-All F-1, 2	first collected SF Bay 1966; native to Japan
52			*Corophium acherusicum*	Core depth: 20 cm Seine: ⅛ inch	S	I-1 F-1	males only; early records in SF Bay 19 prob. introduced from Atlantic
53			*Corophium insidiosum*	Core depth: 5 cm, 10 cm & UNK	S, L, FS	I-1, 2, 3, 4 6, 7, FS	males only; first collected 1931 in Lake Merritt; north Atlantic species
			Corophium spp.	Core depth: 5, 10, 20 cm Seine: ⅛ inch	S	I- All, FS F-2	females/juveniles
			unid. Gammaridea	Core depth: 10 cm	S	I-7	
54		**Caprellidea** (sub-order)	*Caprella laeviuscula*	hand collected			
			Caprella spp.	Seine: ⅛ inch		F-1	
55		Talitridae	*Orshestoidea* spp.	Core depth: 5 cm & UNK	L, M	I-3	
		Decapoda					
56	+	**Caridea** (sub-order)	*Crangon franciscorum*	Seine: 1/8 inch		F-1	
57	+		*Crangon nigricauda*	Seine: ⅛ & ¼ inch		F-1, 3, 4, 5	
58	+		*Heptacarpus brevirostris*	Seine: ⅛ inch		F-1, 2,6	
59	+		*Heptacarpus paludicola*	Seine: ⅛ inch		F-1, 2, 6	
60	+		*Heptacarpus sitchensis*	Seine: ⅛ inch		F-1	collected once in July 2003
61	+		*Palaemon macrodactylus*	Seine: ⅛ inch		F-1,2	first collected SF Bay 1957; native to Korea, Japan, north China
62	+	**Brachyura** (sub-order)	*Cancer antennarius*	Core depth: 20 cm &UNK	L	I-1, F-1,3	
63	+		*Cancer gracilis*	Seine: ⅛ inch		F-1, 2	collected once in July 2002
64	+		*Cancer jordani*	Seine: ⅛ inch		F-1, 2, 3,4	

65	**Arthropoda Crustacea** (continued) **+**		***Carcinus maenas***	Seine: ⅛ inch		F-5,6	first collected SF Bay 1989-1990; introduced from Europe, probably via Atlantic
66	+		*Hemigrapsus oregonensis*	Core depth: 5, 20 cm	S, L	I-1, 2 F-1,2,3,4,5,6	
67	+		*Pugettia producta*	Seine: ⅛ inch		F-1,2,6	
68		**Anomura** (sub-order)	*Neotrypaea californiensis* (synonym.: *Callianassa californiensis)*	Core depth: 20 cm Shovel	S, FS	I-1, 4 FS	
69	+		*Pagurus hirsutiusculus*	Seine: ⅛ inch		F-1	collected once in July 2003
			Pagurus spp.	Core depth: 20 cm	S	I-1	collected once in July 2003
70	**Chelicerata (subphylum)** Arachnida	**Acari**		Core depth: 10 cm	S	I-7	
	Insecta	**Coleoptera** Staphylinidae		Core depth: 5, 20 cm Seine: UNK	L, M	I-2, 3 F-UNK	
71			*Bledius* spp	Core depth: 5	M	I-3	
72		**Hemiptera** Saldidae	*Saldula comatula*	Core depth: 20 cm	M	I-2	
73		**Diptera**	unid. Diptera larvae	Core depth: 20 cm	L	I-1	
74		**Brachycera** (sub-order) Tabanidae		Core depth: 5 cm	M	I-2	
75		Ceratopogonidae	unid. spp.	Core depth: 5 cm	L	I-1	
76		Dolichopodidae		Core depth: 20 cm & UNK	M, L	I-2, 3	
77		Ephrydridae	Ephrydridae *spp.*	Core depth: 5, 20 cm	M, L, S	I-1, 2, 3	
78		Muscidae	*Lispe* spp.	Core depth: 20 cm Seine: UNK	L	I-2, 3 F- UNK	
79		Tipulidae	*Ormosia* spp.	Core depth: 5 cm	M	I-2	
80	**Mollusca** Scaphopoda		*Cadulus fusiformis*	Core depth: UNK	S	I-2	collected once in April 2002
81	Gastropoda		*Hermissenda crassicornus*	Seine: 1/8th inch		F-3	collected once, October 2004
82			*Haminoea vesicular*	Core depth: UNK Seine: ⅛ & ¼	S	I-1 F-1, 4	
83			*Philine auriformis*	hand collected	Intertidal		first identified SF Bay 1993 hand collected once in May 2004
			Philine spp.	Core depth: 10 cm	S	I-5	
			unid. gastropod	Core depth: UNK	S	I-3	

84	**Mollusca** Bivalvia		***Clinocardium nuttalli***	Core depth: 20 cm	S	I-1	collected once in fall 2000
85			*Cryptomya californica*	Core depth: 20 cm	S	I-4	
86			*Lyonsia californica*	Core depth: 10 cm	S	I-4	Collected once, October 2004
87			*Macoma inquinata*	Core depth: 20 cm, 10 cm	S	I-2, 6, 7	
88			*Macoma nasuta*	Core depth: UNK	S	I-2	collected once in April 2002, but num Macoma sp. observed in marsh follow mechanical excavation of marsh inlet
89			*Macoma petalum*	Core depth: 20 cm	FS	FS	*M. balthica* of SF Bay authors*; introd from NW Atlantic (as early as 1869?) collected once in July 2003; but nume Macoma sp. observed in marsh follow mechanical excavation of marsh inlet
			Macoma sp.	Core depth: 10 cm	S	I-4,6	
90			*Musculista senhousia* (synonym: *Musculus senhousia)*	Core depth : 5, 10, 20 cm Seine: ⅛ inch	S, L	I-1, 2, 3, 4, 6 F- 1, 2	first collected SF Bay 1946
91			*Mya arenaria*	Core depth: 5, 10, 20 cm Seine: ⅛ inch Shovel	S ,L, FS	I-1, 2, 3, 5 6, 7, FS F-1, 2	first collected SF Bay 1874; introduced from Atlantic
92			*Mytilus* spp. (includes *M.galloprovincialis*, *M. trossulus*, and their hybrids)	Core depth: 20 cm	S	I- 3	introduced (see Cohen and Carlton 19 discussion) collected once in fall 2000
93			*Protothaca staminea*	Core depth: 20 cm	S	I- 3	collected once in fall 2000, but many observed in marsh following mechani excavation of marsh inlet 5/2005
94			*Theora lubrica*	Core depth: 20 cm	S	I- 2	first collected SF Bay 1982**
95			*Venerupis phillippanarum* (synonym: *Tapes japonica)*	Core depth: UNK Seine: ¼ inch Shovel	S, FS	I-1, 4, 7, FS F-5	first collected SF Bay 1946; introduced with Japanese oysters
			unid. Bivalvia	Core depth: 20 cm	S	I-1	

Source: *Smith, R. I. and J. T. Carlton (eds.). 1975. ; ** Cohen and Carlton (1995) unless otherwise specified. ***www.calacademy.org
\+ Indicates taxa caught in beach seines
All Cores 10 cm diameter
Key to Stations: F=Fish survey station, I=Benthic invertebrate survey station, FS= Flood Shoal, UNK= unknown core depth or station
Key to Habitats: M=Marsh plain, L=Low marsh, S= Subtidal marsh, FS= Flood shoal
Note: Invertebrate Stations 4-7 sample were established in October 2004 to complement a USGS research study undertaken in the marsh (see "Other Research" in body of document). These stations sample subtidal habitats below 0 feet NGVD only.

Table 12. Bird Species Detected at Crissy Field, 1999-2004.

	Group	Species (common name)	Species (scientific name)	Zone	Listing Status
1	Gaviformes (Loons)	Red-throated Loon	*Gavia stellata*	**W, B**	
2		Pacific Loon	*Gavia pacifica*	**B**	
3		Common Loon	*Gavia immer*	**B**	
4	Podicepiformes (Grebes)	Pied-billed Grebe	*Podilymbus podiceps*	**B**	
5		Horned Grebe	*Podiceps auritus*	**W**	
6		Red-necked Grebe	*Podiceps grisegena*	**W, B**	
7		Eared Grebe	*Podiceps nigricollis*	**W**	
8		Western Grebe	*Aechmophorus occidentalis*	**W,B**	
9		Clark's Grebe	*Aechmophorus clarkii*	**B**	
10	Procillariformes (Tubenoses)	Sooty Shearwater	*Puffinus griseus*	**B**	
11		Black Storm-petrel	*Oceanodroma tethys*	**B**	
12	Pelicaniformes (Pelicans)	American White Pelican	*Pelecanus erythrorhynchos*	**W**	
13		Brown Pelican	*Pelecanus occidentalis californicus*	**W,F,S,B**	**SE, FE**
14	Phalacrocoraciformes (Cormorants)	Double-crested Cormorant	*Phalacrocorax auritus*	**W,F,S,B**	
15		Brandt's Cormorant	*Phalacrocorax penicillatus*	**B**	
16		Pelagic Cormorant	*Phalacrocorax pelagicus*	**B**	
17	Ciconiformes (Herons)	Black–crowned Night-Heron	*Nycticorax nycticorax*	**W,F,B**	
18		Green Heron	*Butorides virescens*	**W**	
19		Snowy Egret	*Egretta thula*	**W,F,S,B**	**FSC**
20		Great Egret	*Ardea alba*	**W,S**	
21		Great Blue Heron	*Ardea herodias*	**W,B**	
22	Anatidae (Swans, Geese, and Ducks)	Mallard	*Anas platyrhynchos*	**W,F,S,B**	
23		Northern Pintail	*Anas acuta*	**W**	
24		Northern Shoveler	*Anas clypeata*	**W**	
25		Green-winged Teal	*Anas crecca*	**W**	
26		American Wigeon	*Anas americana*	**W**	
27		Ring-necked Duck	*Aythya collaris*	**W**	
28		Greater Scaup	*Aythya marila*	**W,B**	
29		Lesser Scaup	*Aythya affinis*	**W**	
30		Oldsquaw	*Clangula hyemalis*	**B**	
31		Black Scoter	*Melanitta nigra*	**W,B**	
32		Surf Scoter	*Melanitta perspicillata*	**W,B**	

	Group	Species (common name)	Species (scientific name)	Zone	Listing Status
33		Common Goldeneye	*Bucephala clangula*	**W,B**	
34		Bufflehead	*Bucephala albeola*	**W,F**	
35		Red-breasted Merganser	*Mergus serrator*	**B**	
36		Ruddy Duck	*Oxyura jamaicensis*	**W,B**	
37		Canvasback	*Aythya valisineria*	**W**	
38		Canada Goose	*Branta canadensis*	**W,F,S,B**	
39	Cathartidae (American Vultures)	Turkey Vulture	*Cathartes aura*	**W,F,B**	
40	Accipitridae (Hawks, Eagles, and Harriers)	Osprey	*Pandion haliaetus*	**flyover**	
41		Northern Harrier	*Circus cyaneus*	**O**	
42		Sharp-shinned Hawk	*Accipiter striatus*	**F**	
43		Cooper's Hawk	*Accipiter cooperii*	**S**	
44		Red-shouldered Hawk	*Buteo lineatus*	**W,F,S**	
45		Red-tailed Hawk	*Buteo jamaicensis*	**W,F,S**	
46	Falconidae (Falcons)	American Kestrel	*Falco sparverius*	**W**	
47		Merlin	*Falco columbarius*	**O**	
48		American Peregrine Falcon	*Falco peregrinus*	**O**	**SE, FE**
49	Rallidae (Rails,Gallinules, and Coots)	American Coot	*Fulica americana*	**W**	
50	Charadriidae (Plovers)	Black-bellied Plover	*Pluvialis squatarola*	**W,S,B**	
51	Charadriidae (Plovers)	Snowy Plover	*Charadrius alexandrinus*	**B**	**FT**
52		Semipalmated Plover	*Charadrius semipalmatus*	**W**	
53		Killdeer	*Charadrius vociferus*	**W,F,S,B**	
54	Recurvirostridae (Stilts and Avocets)	American Avocet	*Recurvirostra americana*	**W**	
55	Scolopacidae (Sandpipers and relatives)	Willet	*Cataptrophorus semipalmatus*	**W,B**	
56		Greater Yellowlegs	*Tringa melanoleuca*	**W**	
57		Solitary Sandpiper	*Tringa solitaria*	**S**	
58		Spotted Sandpiper	*Actitis macularia*	**W**	
59		Whimbrel	*Numenius phaeopus*	**W,S,B**	
60		Long-billed Curlew	*Numenius americanus*	**W,B**	
61		Marbled Godwit	*Limosa fedoa*	**W,B**	
62		Ruddy Turnstone	*Arenaria interpres*	**B**	
63		Black Turnstone	*Arenaria melanocephala*	**W,B**	
64		Sanderling	*Calidris alba*	**W,B**	

	Group	Species (common name)	Species (scientific name)	Zone	Listing Status
65		Dunlin	*Calidris alpina*	**W**	
66		Semipalmated Sandpiper	*Calidris pusilla*	**W**	
67		Western Sandpiper	*Calidris mauri*	**W**	
68		Least Sandpiper	*Calidris minutilla*	**W,F**	
69		Baird’s Sandpiper	*Calidris bairdii*	**W**	
70		Pectoral Sandpiper	*Calidris melanotos*	**W**	
71		Short-billed Dowitcher	*Limnodromus griseus*	**W,B**	
72		Long-billed Dowitcher	*Limnodromus scolopaceus*	**W**	
73		Common Snipe (Wilson's Snipe)	*Gallinago gallinago*	**W**	
74		Red-necked Phalorope	*Phalaropus lobatus*	**W**	
75		Red Phalorope	*Phalaropus fulicaria*	**W**	
76		Wilson’s Phalarope	*Phalaropus tricolor*	**W**	
77	Laridae (Gulls and Terns)	Parasitic Jaeger	*Stercorarius parasiticus*	**B**	
78		Bonaparte's Gull	*Larus philadelphia*	**B**	
79		Heerman's Gull	*Larus heermanni*	**W,F,S,B**	
80		Mew Gull	*Larus canus*	**W,F,S,B**	
81		Ring-billed Gull	*Larus delawarensis*	**W,F,S,B**	
82		California Gull	*Larus californicus*	**W,F,S,B**	
83		Herring Gull	*Larus argentatus*	**B**	
84		Thayer's Gull	*Larus thateri*	**W,B**	
85		Western Gull	*Larus occidentalis*	**W,F,S,B**	
86		Glaucous-winged Gull	*Larus glaucescens*	**W**	
87		Black-legged Kittiwake	*Rissa tridactyla*	**B**	
88		Glaucous Gull	*Larus hyperboreus*	**B**	
89		Caspian Tern	*Sterna caspia*	**W,F,S,B**	
90		Elegant Tern	*Sterna elegans*	**W,F,S,B**	**FSC**
91		Common Tern	*Sterna hirundo*	**B**	
92		Arctic Tern	*Sterna paradisaea*	**B**	
93		Forster's Tern	*Sterna forsteri*	**B**	
94		California Least Tern	*Sterna antillarum*	**B**	**SE, FE**
95	Alcidae (Auks, Murres, and Puffins)	Common Murre	*Uria aalge*	**B**	
96		Pigeon Guillemot	*Cepphus columba*	**B**	

	Group	Species (common name)	Species (scientific name)	Zone	Listing Status
97		Marbled Murrelet	*Brachyramphus marmoratus*	**B**	**SE, FT**
98	Columbidae (Doves and Pigeons)	Rock Dove	*Columba livia*	**W,F,S,B**	
99		Band tailed Pigeon	*Columba fasciata*	**flyover, O**	
100		Mourning Dove	*Zenaida macroura*	**W,F,S,B**	
101	Trochilidae (Hummingbirds)	Anna's Hummingbird	*Calypte anna*	**W,F,S**	
102		Rufous Hummingbird	*Selasphorus rufus*	**F**	
103	Trochilidae (Hummingbirds)	Allen's Hummingbird	*Selasphorus sasin*	**W,S**	
104	Alecidinidae (Kingfishers)	Belted Kingfisher	*Ceryle alcyon*	**W,S,B**	
105	Picidae (Woodpeckers)	Downy Woodpecker	*Picoides pubescens*	**F,S,B**	
106		Hairy Woodpecker	*Picoides villosus*	**F**	
107		Northern Flicker	*Colaptes auratus*	**F**	**SE**
108	Tyranidae (Tyrant Flycatchers)	Pacific-slope Flycatcher	*Empidonax difficilis*	**S**	
109		Stellar's Jay	*Cyanocitta stelleri*	**F**	
110		Black Phoebe	*Sayornis nigricans*	**W,F,S,B**	
111		Say's Phoebe	*Sayornis saya*	**W,F,S,B**	
112		Western Kingbird	*Tyrannus verticalis*	**W,F,S**	
113	Hirundinidae (Swallows)	Tree Swallow	*Tachycineta bicolor*	**W,F,S,B**	
114		Violet-green Swallow	*Tachycineta thalassina*	**W,F,S,B**	
115		N. Rough-winged Swallow	*Steigidopteryx serripennis*	**W**	
116		Cliff Swallow	*Hirundo pyrrhonota*	**W,F,S,B**	
117		Barn Swallow	*Hirundo rustica*	**W,F,S,B**	
118		Bank Swallow	*Riparia riparia*	**O**	**ST**
119	Corvidae (Jays, Magpies, Crows and Ravens)	American Crow	*Corvus brachyrhynchos*	**W,F,S,B**	
120		Common Raven	*Corvus corax*	**W,F,S,B**	
121	Paridae (Chickadees and Titmice)	Chestnut-backed Chickadee	*Parus rufescens*	**W**	
122	Aegithalidae (Bushtits)	Bushtit	*Psaltriparus minimus*	**F**	
123	Sittidae (Nuthatches)	Pygmy Nuthatch	*Sitta pygmaea*	**F**	
124		House Wren	*Troglodytes aedon*	**F**	
125		Marsh Wren	*Cistothorus palustris*	**W**	
126	Muscicapidae(Kinglets, Gnatcatchers and Thrushes)	Ruby-crowned Kinglet	*Regulus calendula*	**F**	
127		Hermit Thrush	*Catharus guttatus*	**F**	
128		American Robin	*Turdus migratorius*	**W,F,S**	

	Group	Species (common name)	Species (scientific name)	Zone	Listing Status
129	Mimiidae (Mimic Thrushes)	Northern Mockingbird	*Mimus polyglottos*	**F**	
130	Motacillidae (Pipits)	American Pipit	*Anthus rubescens*	**F**	
131	Bombycillidae (Silky Flycathers)	Cedar Waxwing	*Bombycilla cedrorum*	**O**	
132	Sturnidae (Starlings)	European Starling	*Sturnus vulgaris*	**W,F,S,B**	
133		Orange-crowned Warbler	*Vermivora celata*	**S**	
134	Parulinae (Wood Warblers)	Yellow Warbler	*Dendroica petechia*	**F,S**	
135		Yellow-rumped Warbler	*Dendroica coronata*	**W,F,S**	
136		Townsend's Warbler	*Dendroica townsendi*	**F,S,**	
137	Thraupine (Tanagers)	Western Tanager	*Piranga ludoviciana*	**F**	
138		Brewer's Sparrow	*Spizella breweri*	**S**	
139		Fox Sparrow	*Passerella iliaca*	**S,B**	
140	Emberizinae (Sparrows)	Lark Sparrow	*Chondestes grammacus*	**O**	
141		Savannah Sparrow	*Passerculus sandwichensis*	**W,F,S,B**	
142		Song Sparrow	*Melospiza melodia*	**W,F,S**	
143		White-crowned Sparrow	*Zonotrichia leucophrys*	**W,F,S**	
144		Golden-crowned Sparrow	*Zonotrichia atricapilla*	**W,S**	
145		Dark-eyed Junco	*Junco hyemalis*	**W,S**	
146	Icterninae (Blackbirds and relatives)	Red-winged Blackbird	*Agelaius phoeniceus*	**F,S**	
147		Tricolored Blackbird	*Agelaius tricolor*	**O**	
148		Western Meadowlark	*Sturnella neglecta*	**W,F,S,B**	
149		Brewer's Blackbird	*Euphagus cyanocephalus*	**W,F,S,B**	
150		Brown-headed Cowbird	*Molothrus ater*	**W,F,B**	
151		Hooded Oriole	*Icterus cucullatus*	**F**	
152		Purple Finch	*Carpodacus purpureus*	**F**	
153	Fringillidae (Finches)	House Finch	*Carpodacus mexicanus*	**W,F,S,B**	
154		Pine Siskin	*Carduelis pinus*	**F**	
155		Lesser Goldfinch	*Carduelis psaltria*	**F**	
156		American Goldfinch	*Carduelis tristis*	**W,F,S**	
157	Passeridae (Old world Sparrows)	House Sparrow	*Passer domesticus*	**W,F,S,B**	

W = Wetland, F = Foredunes, S= Shellmound and Dune Swale, B = Beach and Nearshore, O = Other. Other Habitats may include the airfield, or trees in landscaped areas adjoining the restored areas of Crissy Field

Table 13. Additional monitoring implemented during long-term closures.

		Parameter			
Closure Date	**Duration (days)**	**Spatial Measurements of Water Quality**	**Visual Examinations of Plant Stem Cross-sections**	**Soil Redox Potential (eH)**	**Topographic Monitoring** (unless otherwise specified includes East Beach profiles, ebb bar crest elevation, thalweg orientation and elevation, and key cross-sections)
Dec. 2001 – Jan. 2002	37 days*	monthly	N/A	N/A	N/A
Jan. – Mar. 2003	64 days	weekly	biweekly beginning one month after closure and continuing to one week after breach	N/A	one week before and after excavation
Sep. – Oct. 2003	53 days	weekly		weekly in month preceding closure, biweekly during closure	Six weeks and two weeks prior to closure
Apr. - Jun. 2004	53 days	every 3-4 days	6 ½ weeks after closure, one month after breach	biweekly in month preceding full closure, then dropped	one month before and after excavation. Thawleg elevation and orientation also surveyed 2 days after excavation.

* This includes 23 days in December, followed by a brief re-opening for 5 days, and closure for another 14 days.

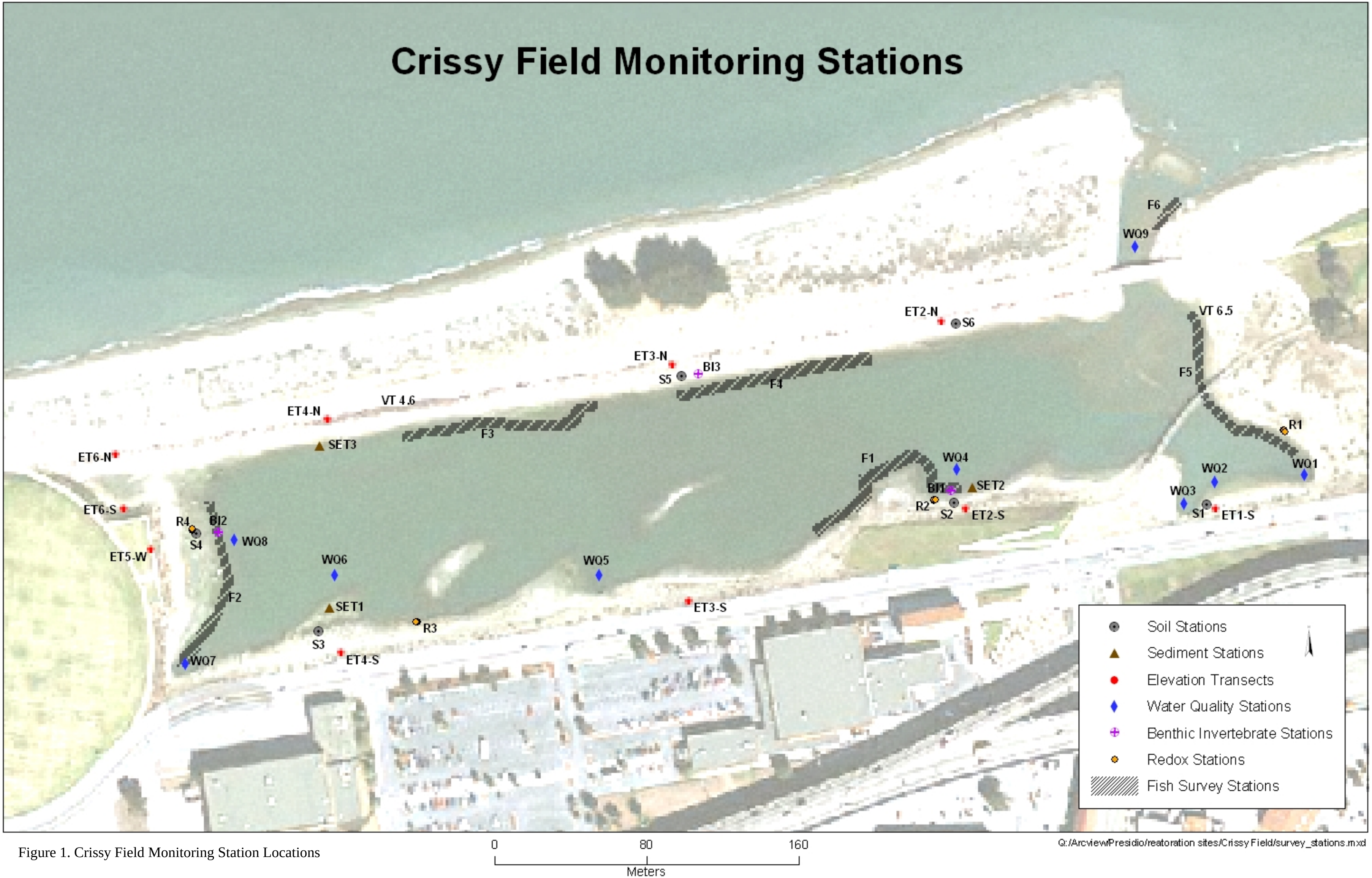


Figure 1. Crissy Field Monitoring Station Locations

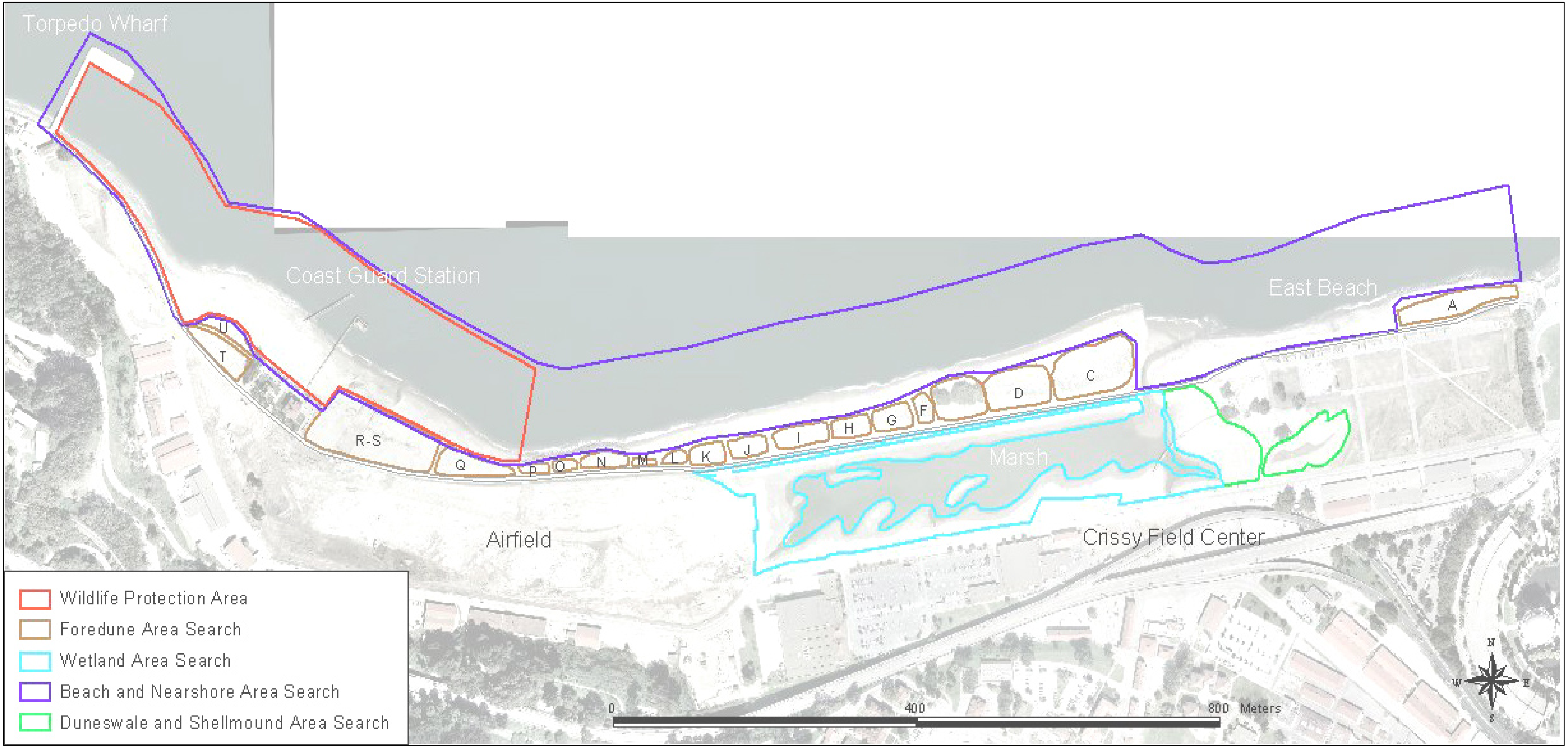


Figure 2. Crissy Field Bird Survey Search Areas

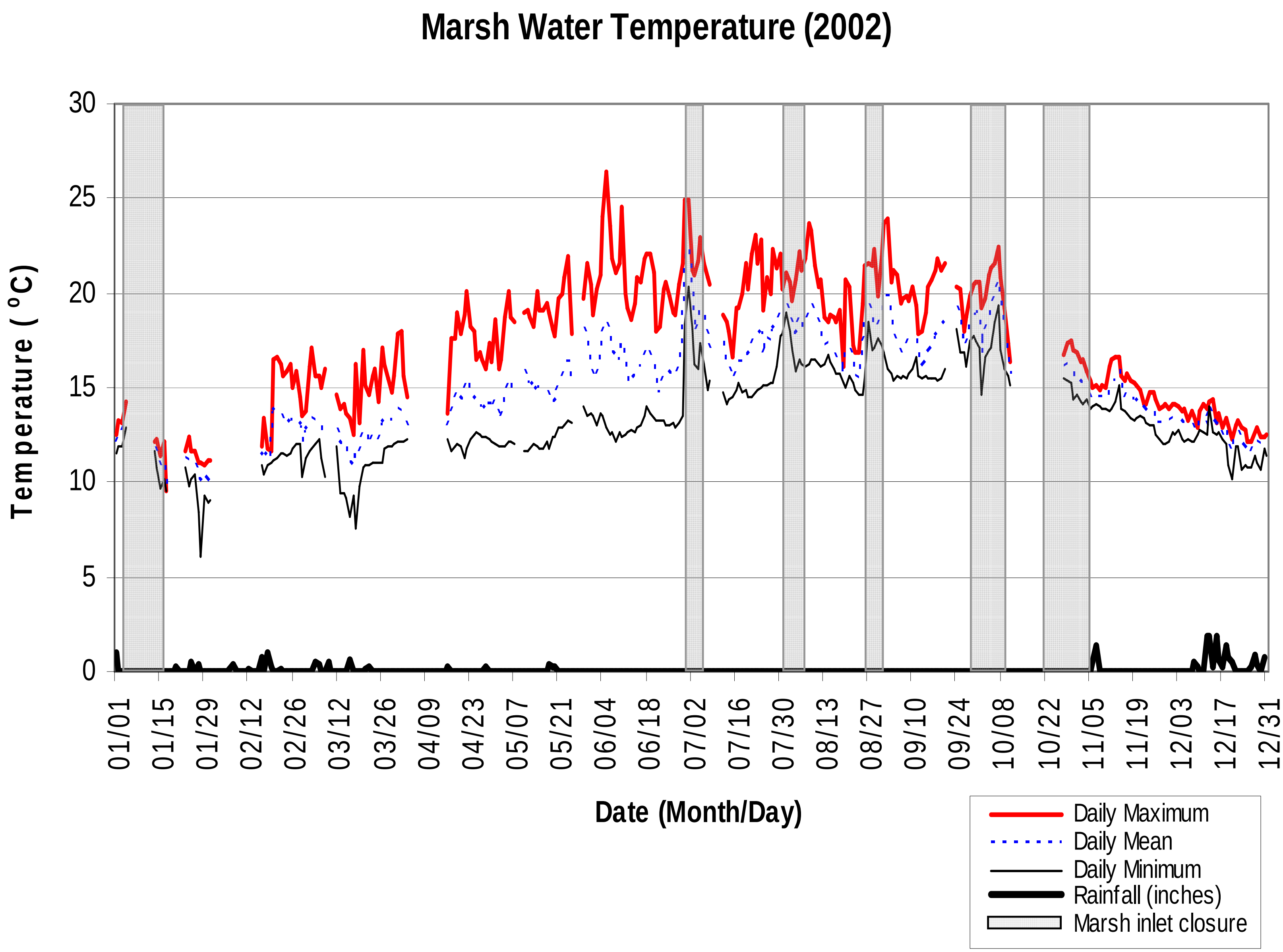


Figure 3. Daily Maximum, Mean, and Minimum Water Temperature, 2002

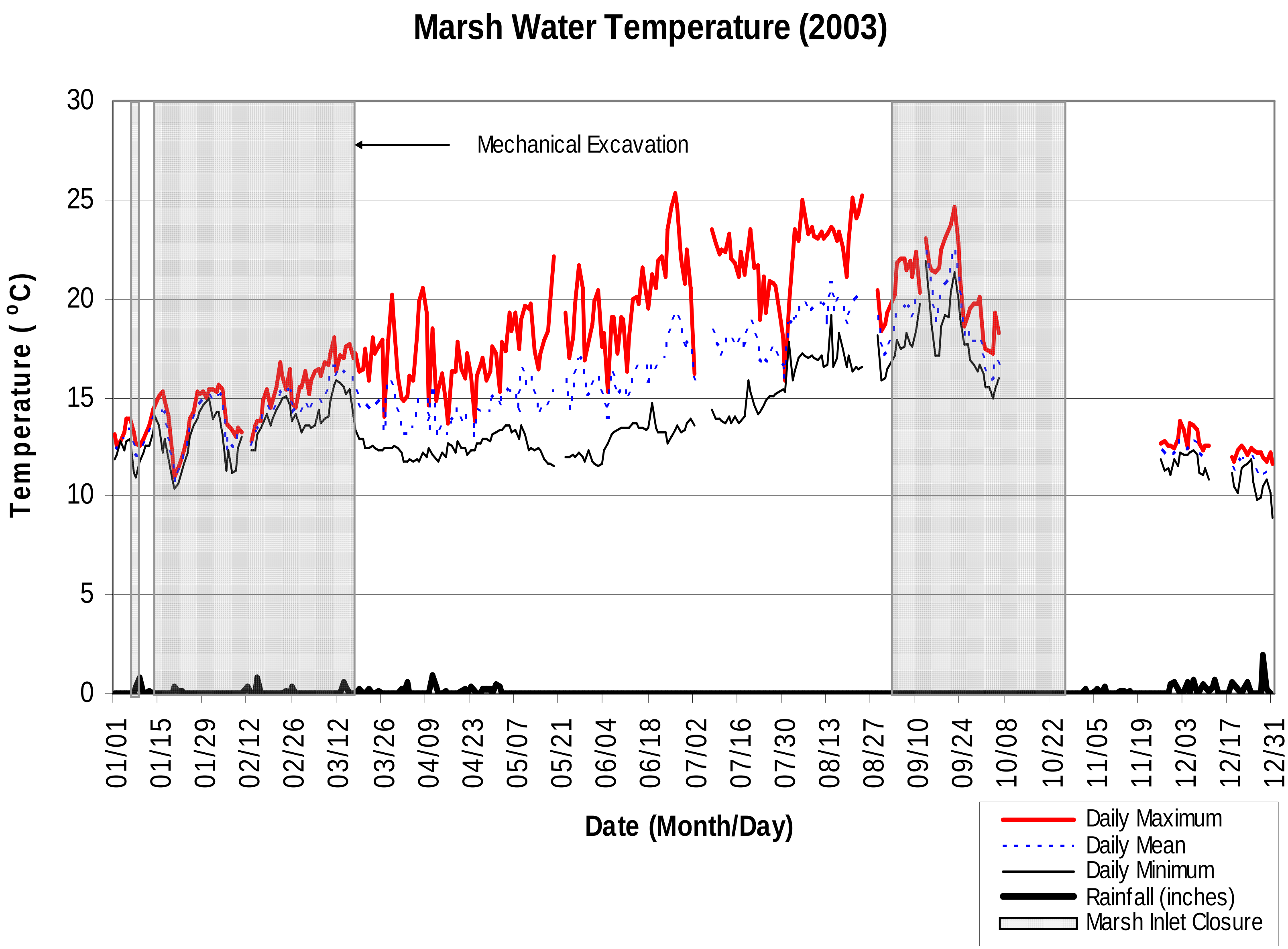


Figure 4. Daily Maximum, Mean, and Minimum Water Temperature, 2003.

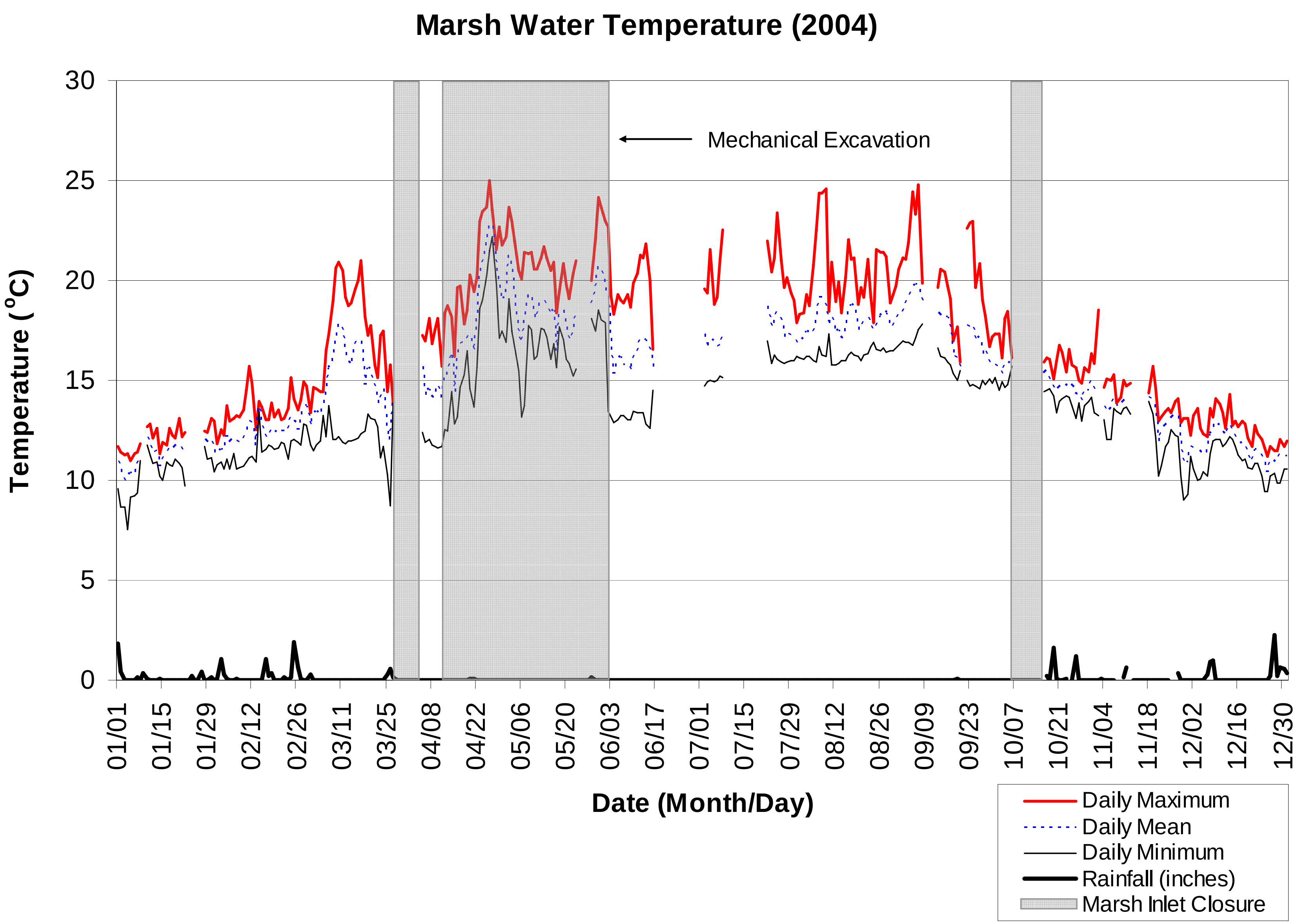


Figure 5. Daily Maximum, Mean, and Minimum Water Temperature, 2004

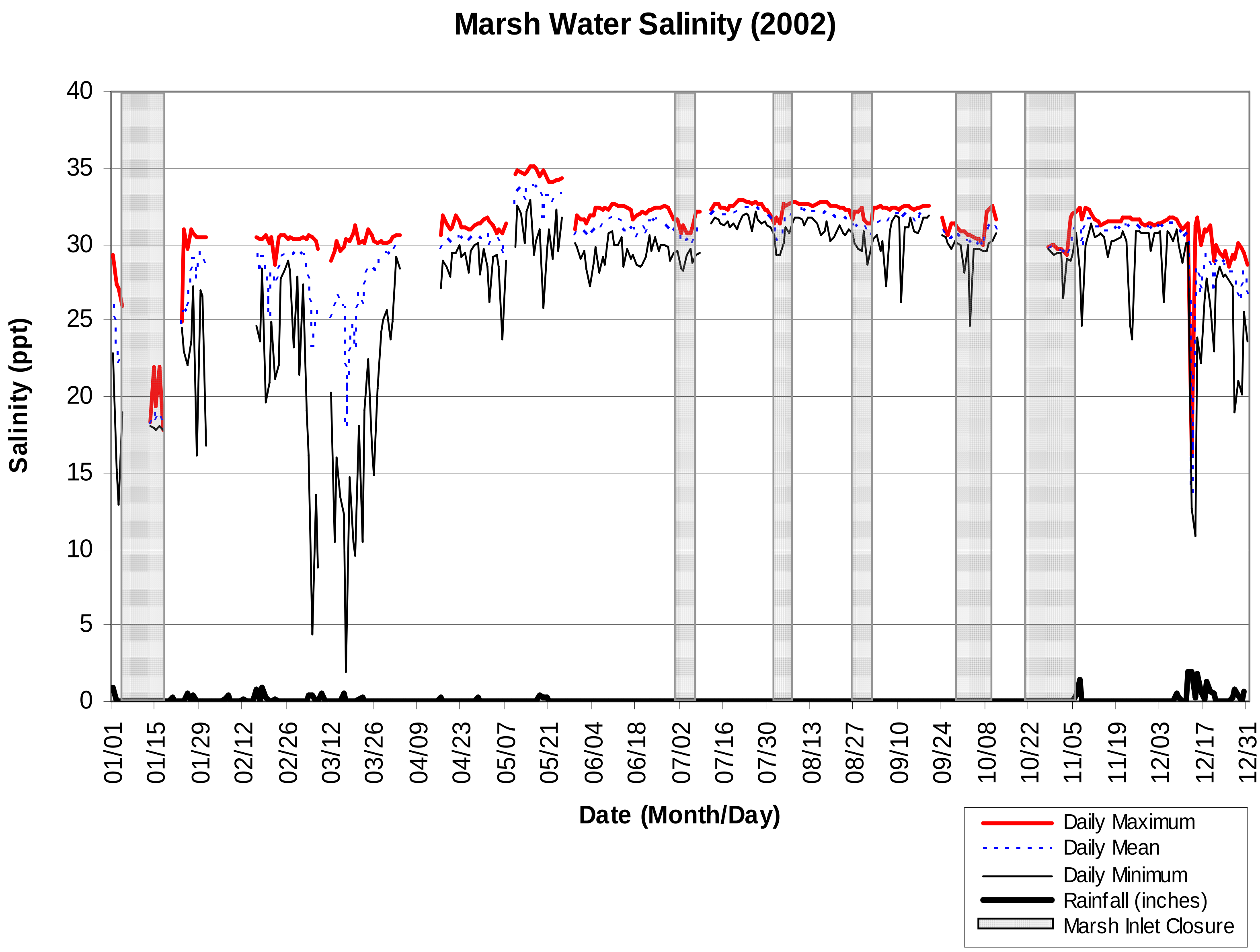


Figure 6. Daily Maximum, Mean, and Minimum Water Salinity, 2002.

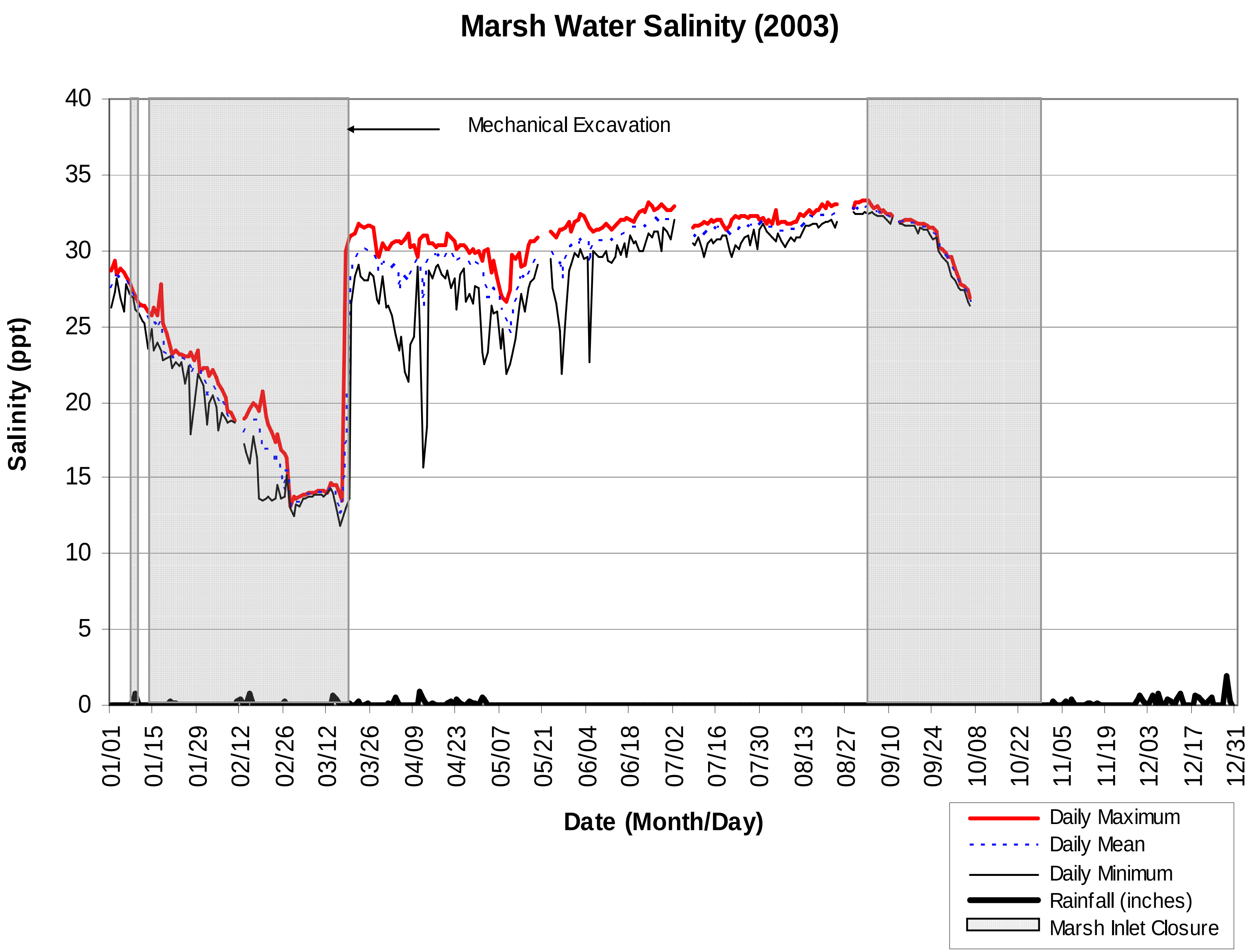


Figure 7. Daily Maximum, Mean, and Minimum Water Salinity, 2003.

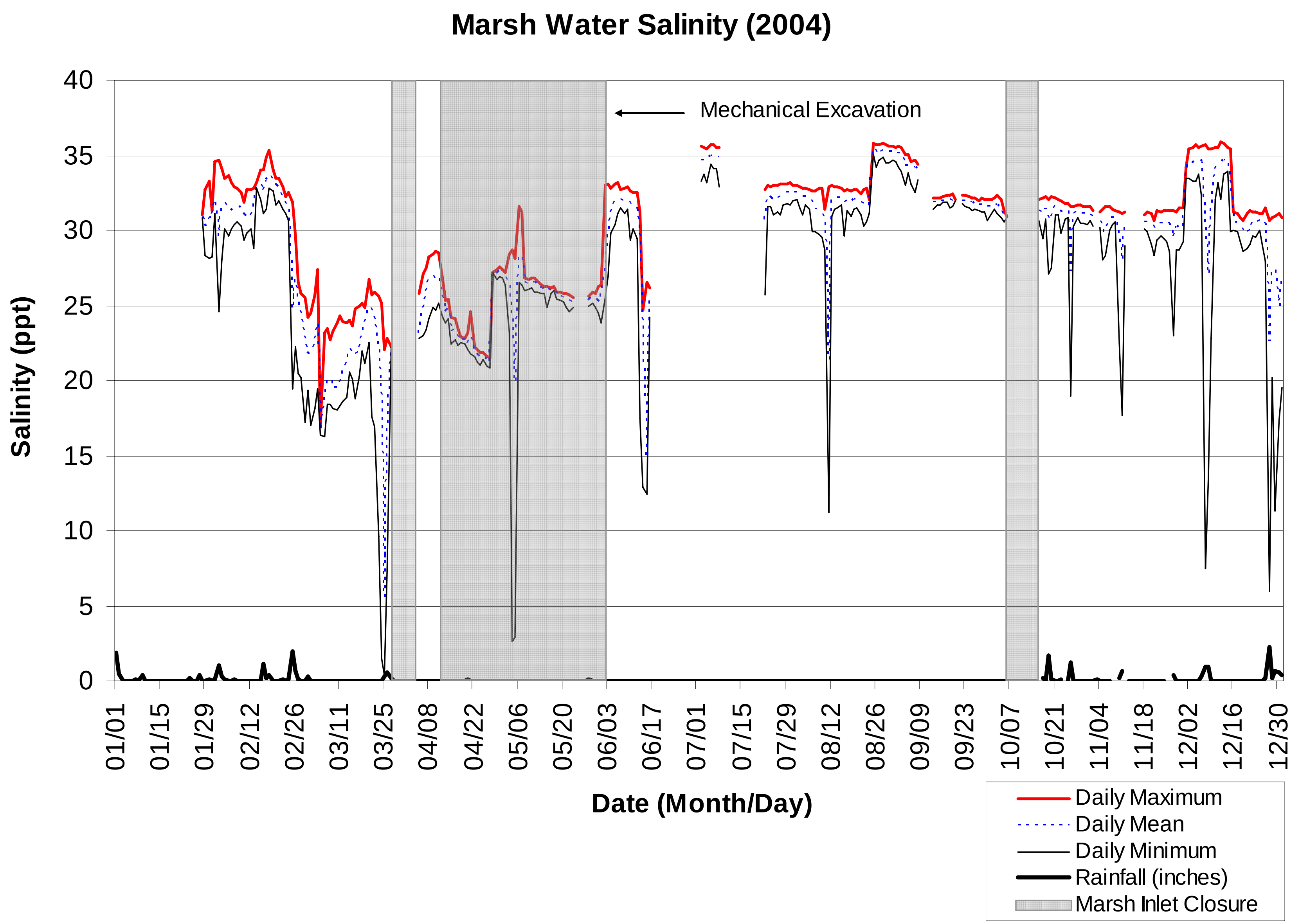


Figure 8. Daily Maximum, Mean, and Minimum Water Salinity, 2004.

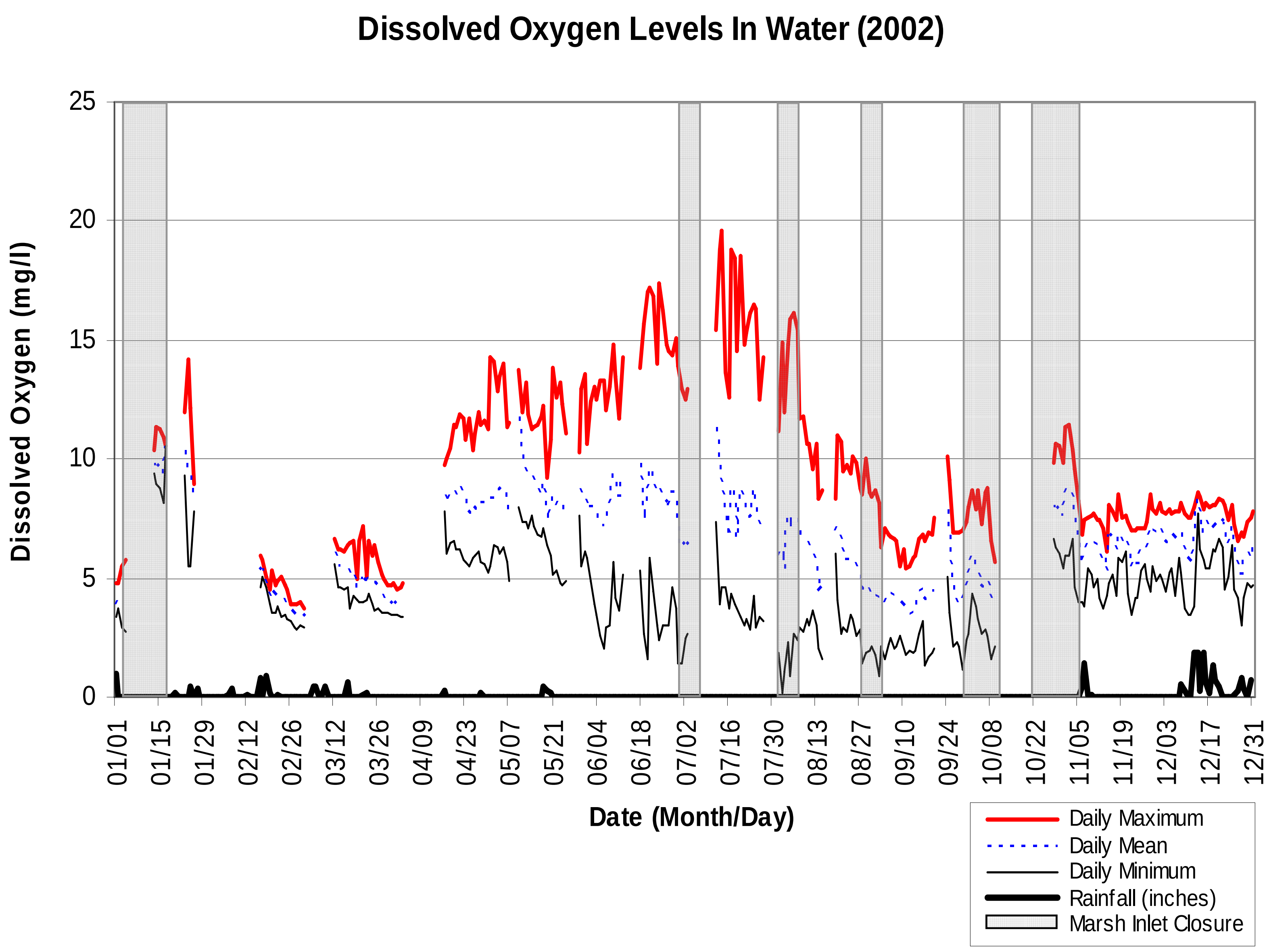


Figure 9. Daily Maximum, Mean, and Minimum Water Column Dissolved Oxygen, 2002

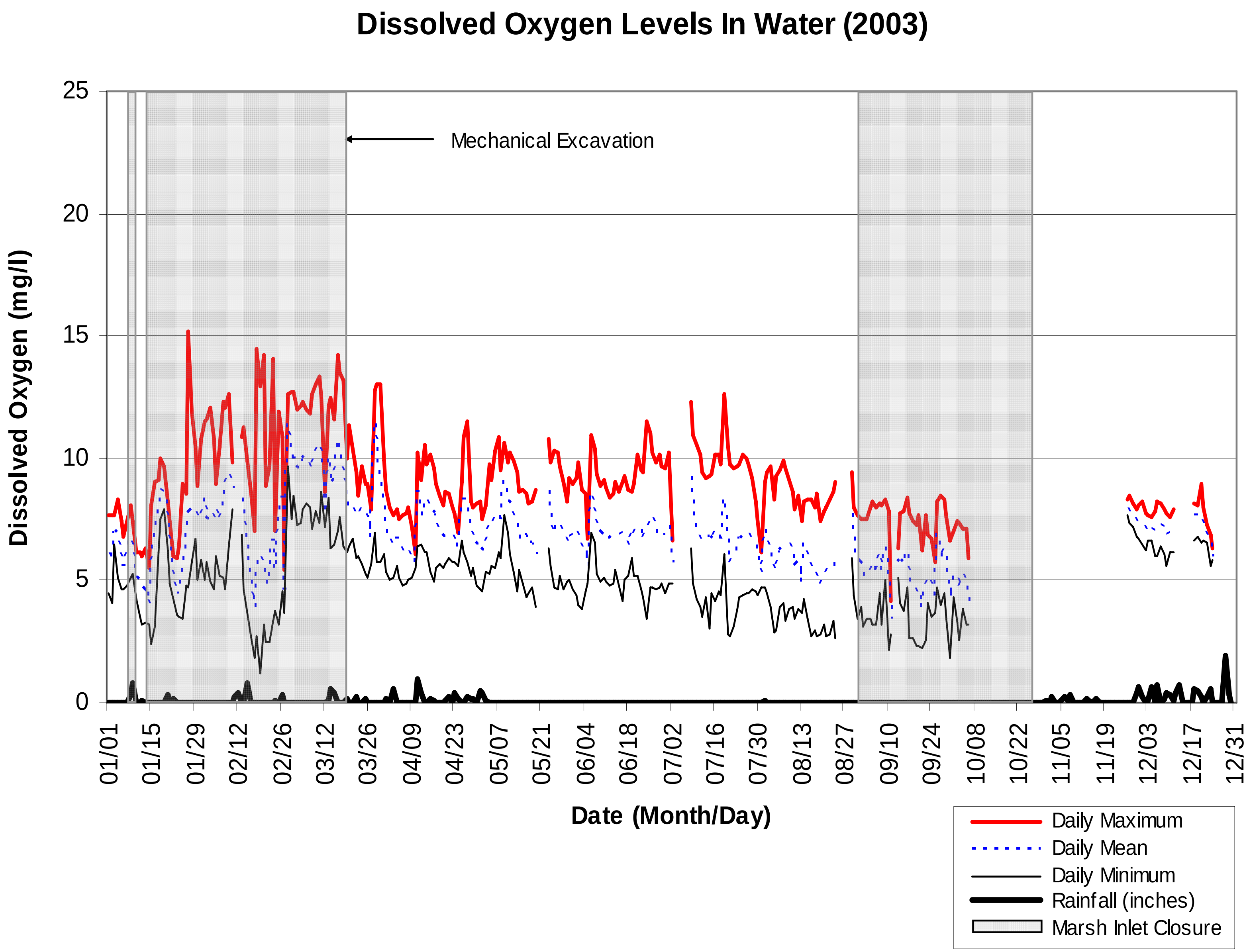


Figure 10. Daily Maximum, Mean, and Minimum Water Column Dissolved Oxygen, 2003.

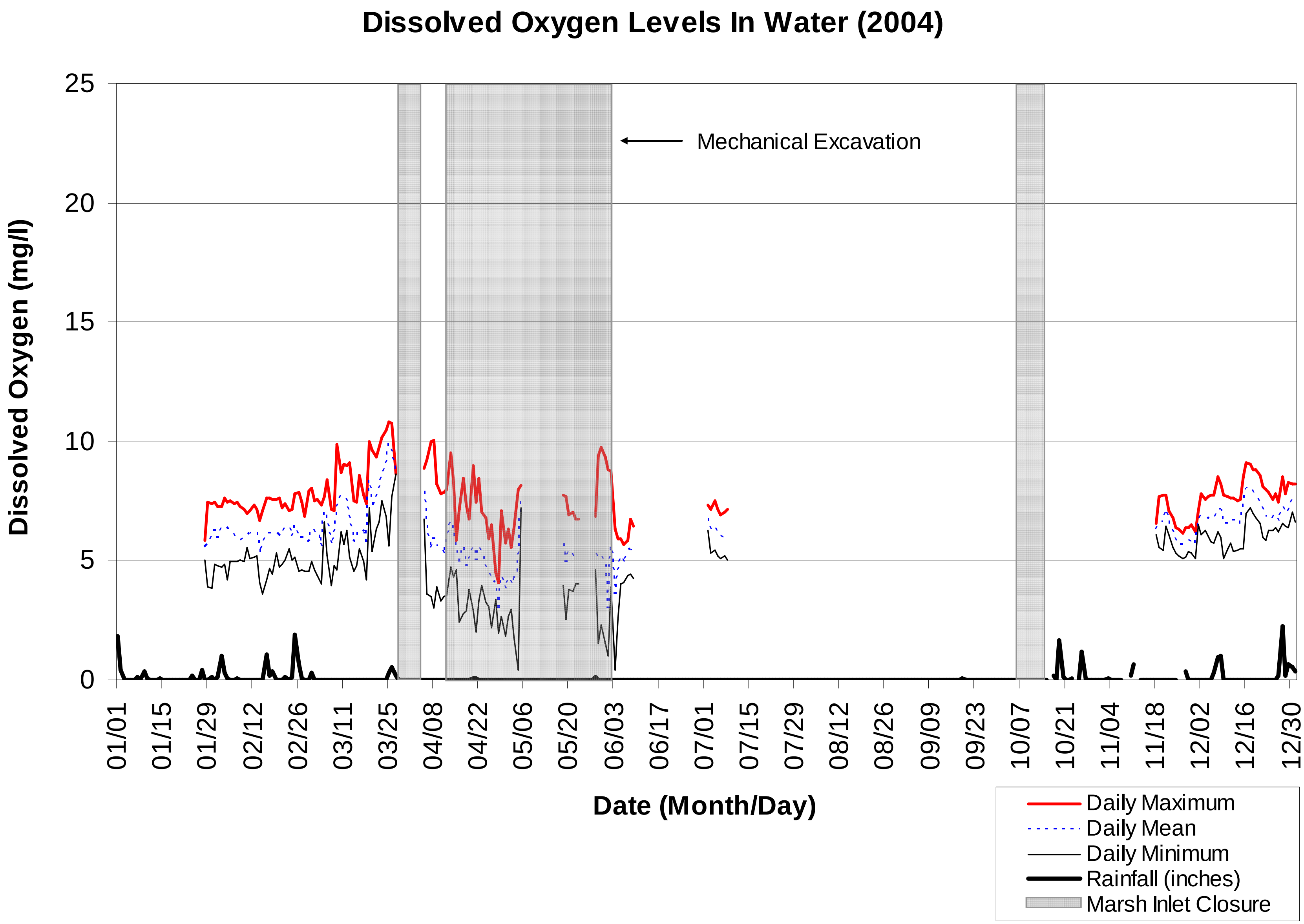


Figure 11. Daily Maximum, Mean, and Minimum Water Column Dissolved Oxygen, 2004. (Periods with missing data due to sensor malfunction.)

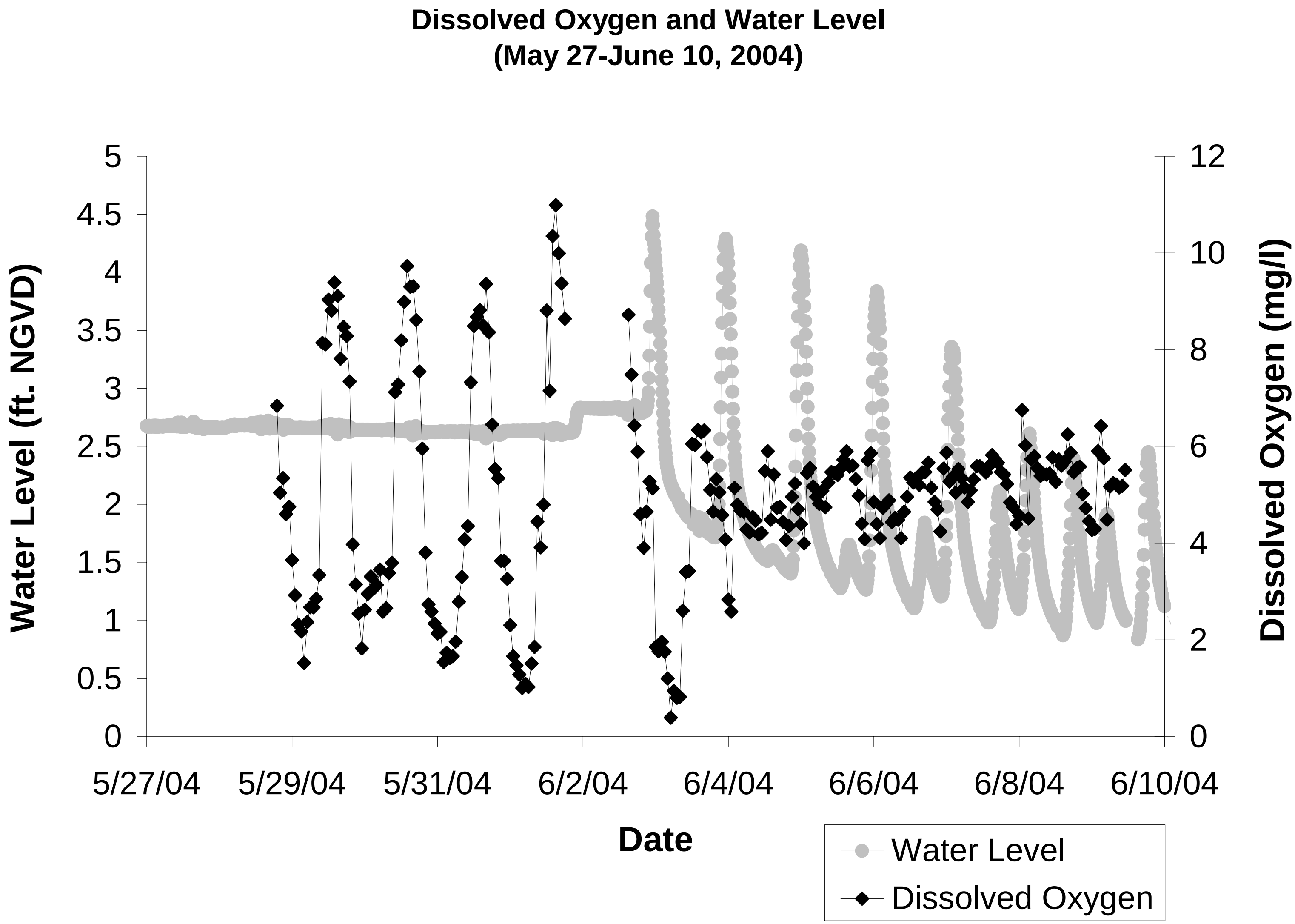


Figure 12. Dissolved oxygen and water levels in Crissy Field marsh during and after an inlet closure (May 27-June10, 2004).

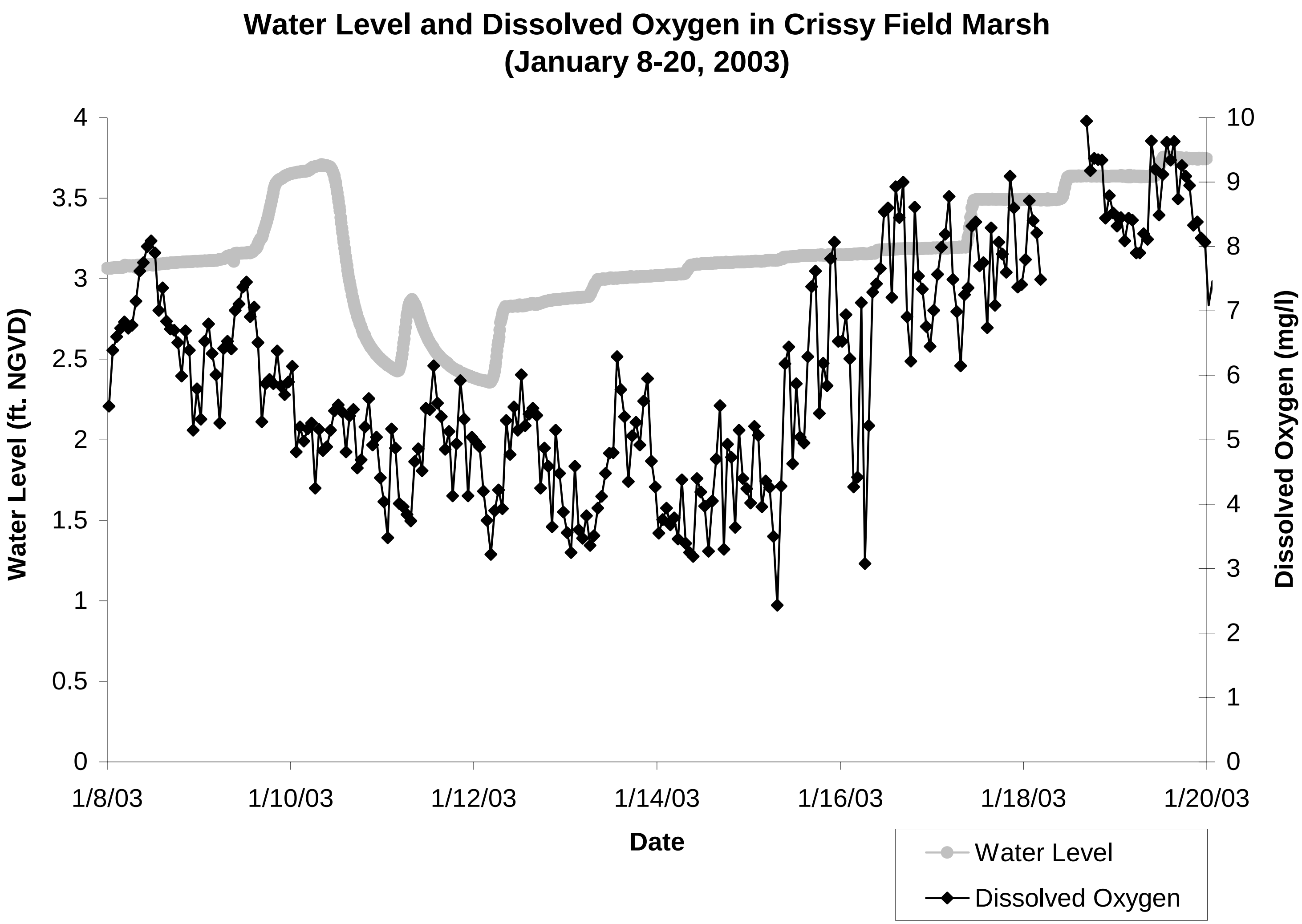


Figure 13. Dissolved oxygen and water levels in Crissy Field marsh leading up to and during an inlet closure (January 8-20, 2003).

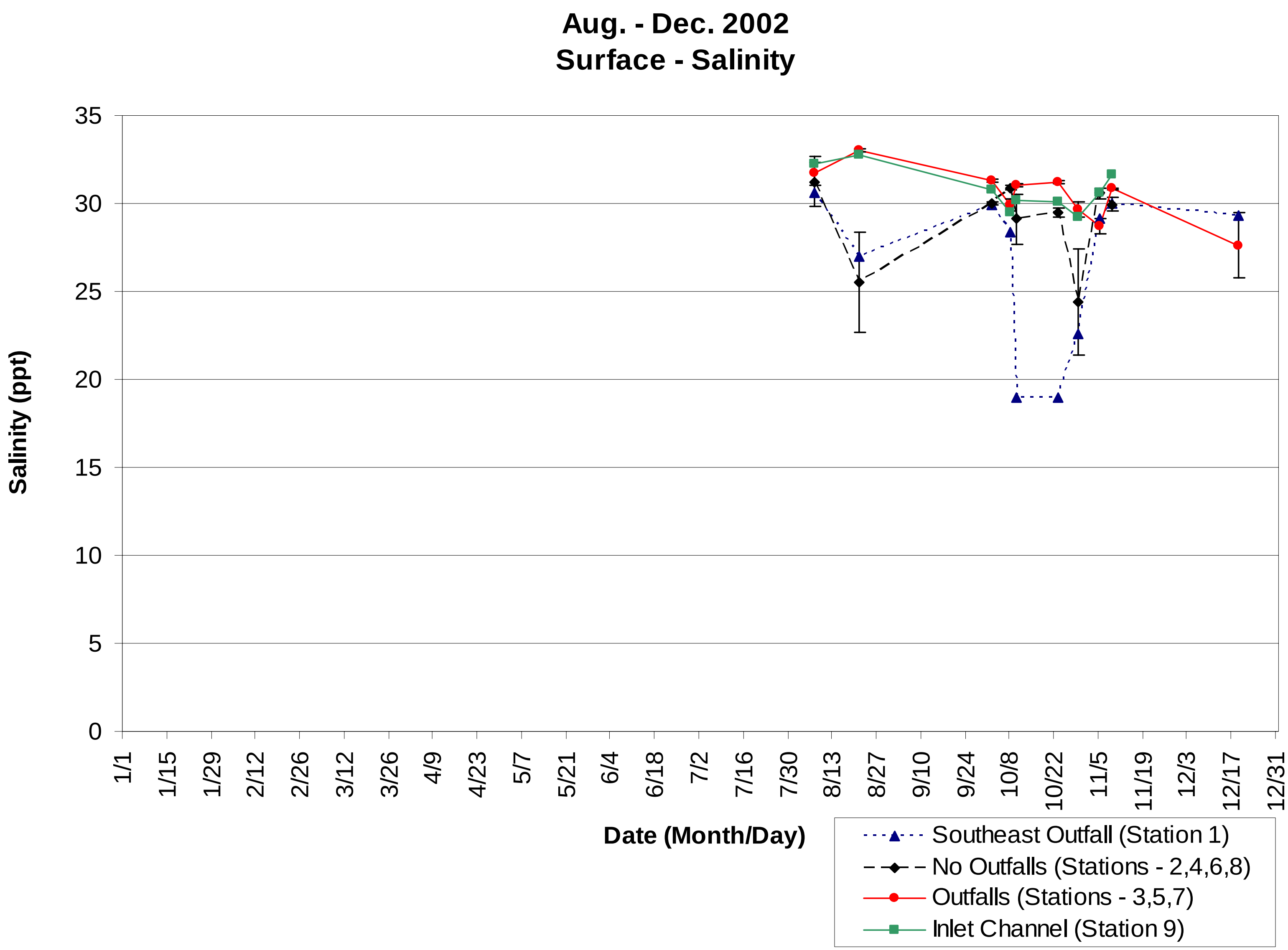


Figure 14. Crissy Field Marsh Water Surface Salinity from Nine Sampling Stations, August – December 2002

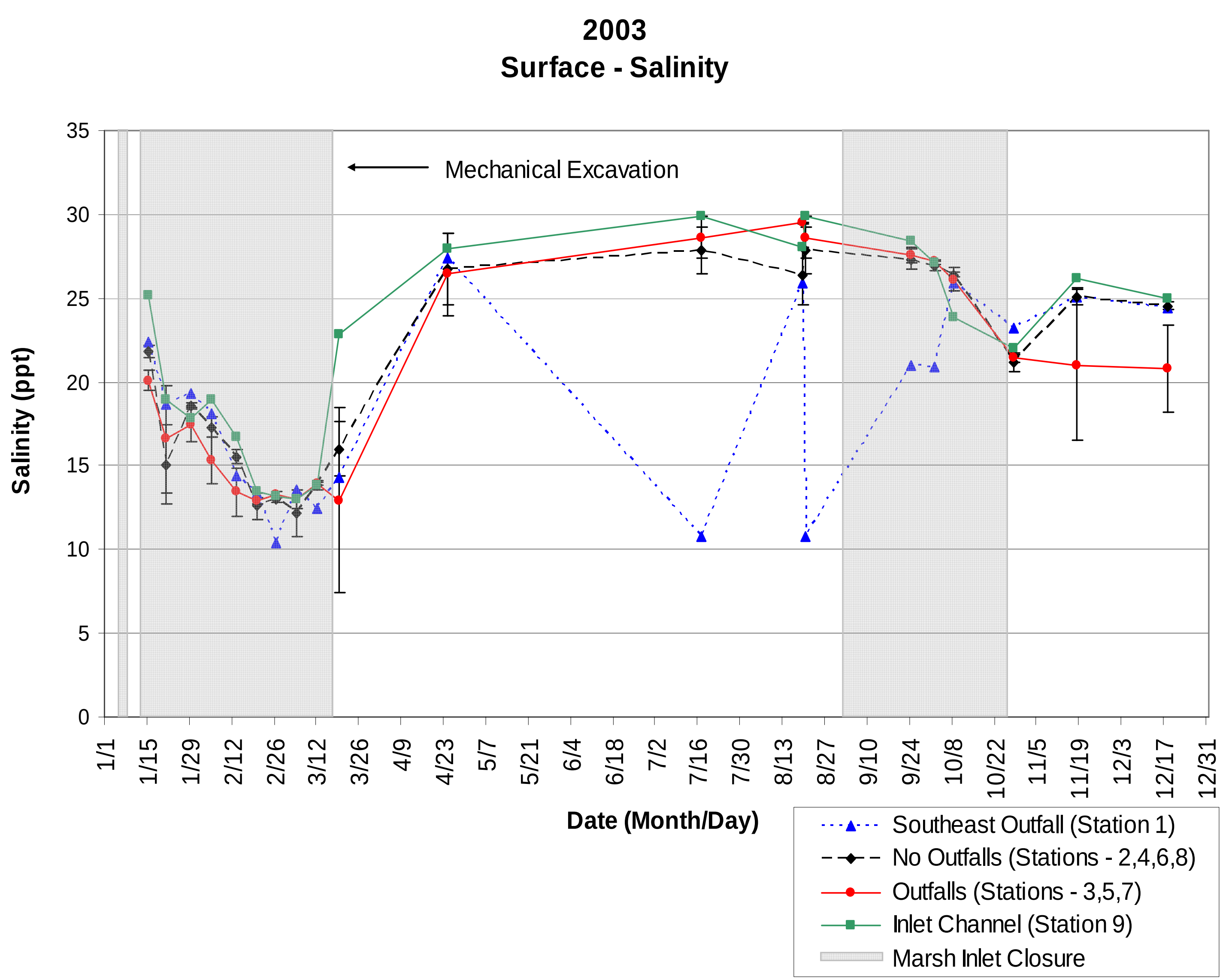


Figure 15. Crissy Field Marsh Water Surface Salinity from Nine Sampling Stations, 2003.

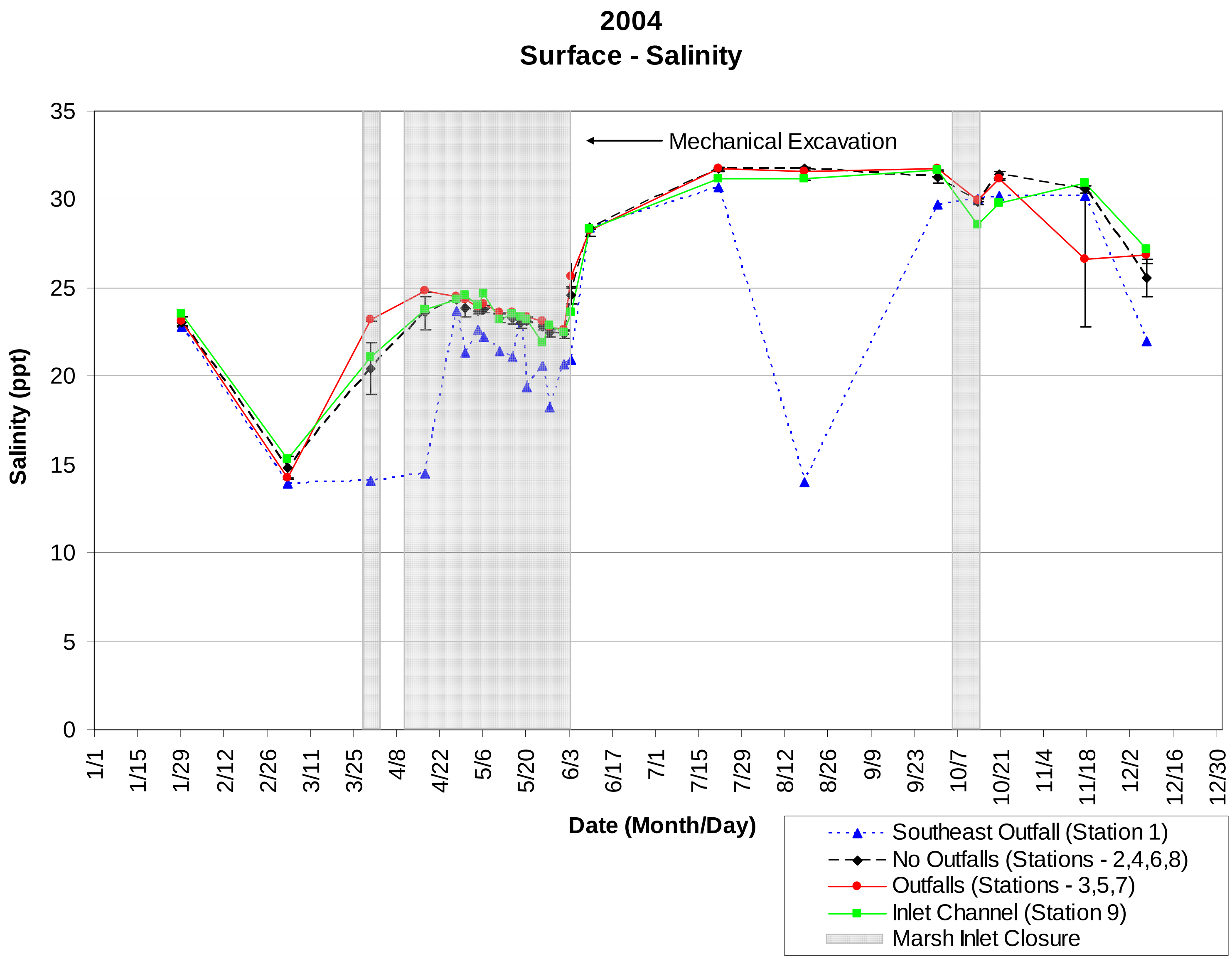


Figure 16. Crissy Field Marsh Water Surface Salinity from Nine Sampling Stations, 2004.

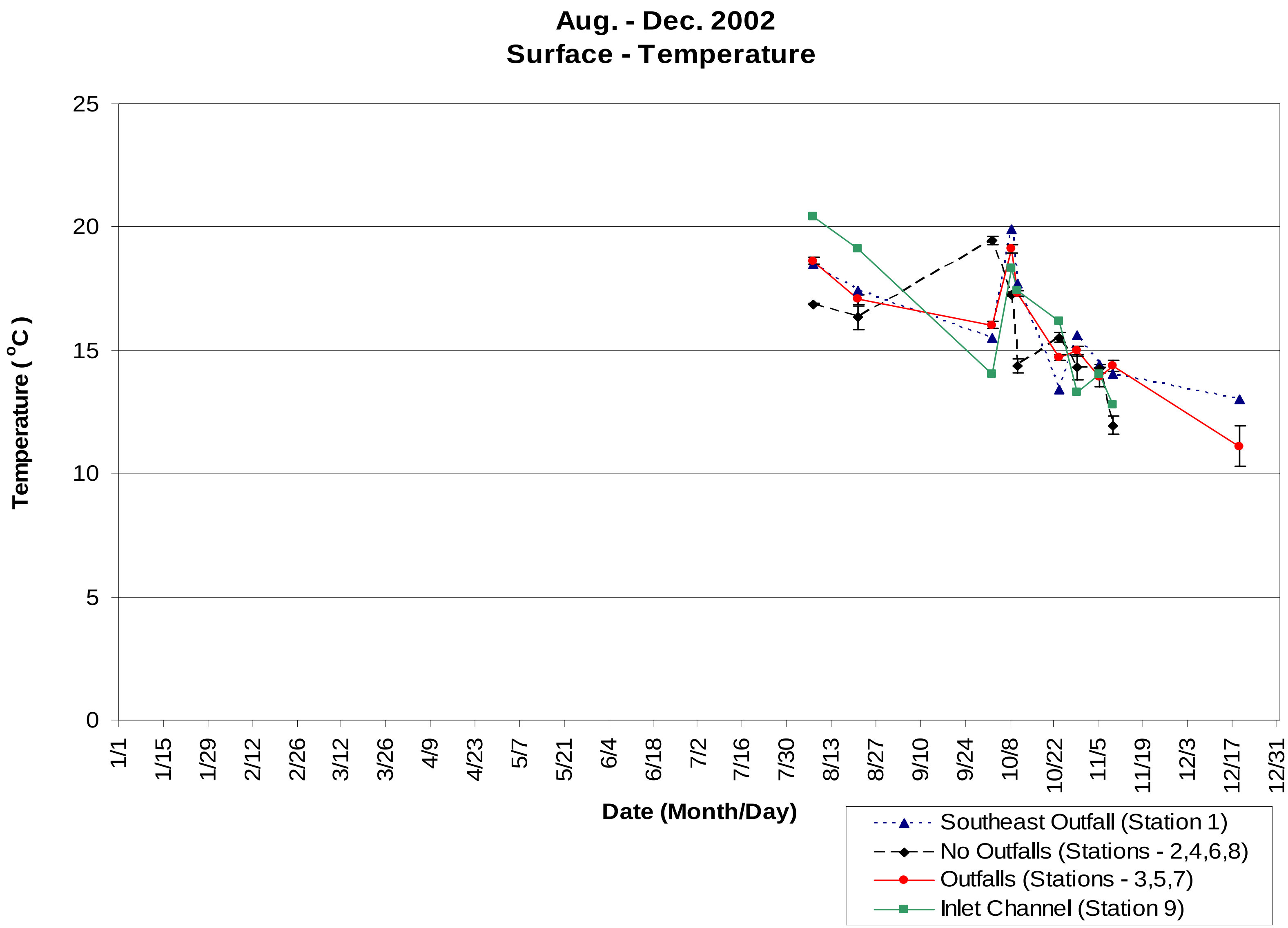


Figure 17. Crissy Field Marsh Water Surface Temperature from Nine Sampling Stations, August – December 2002.

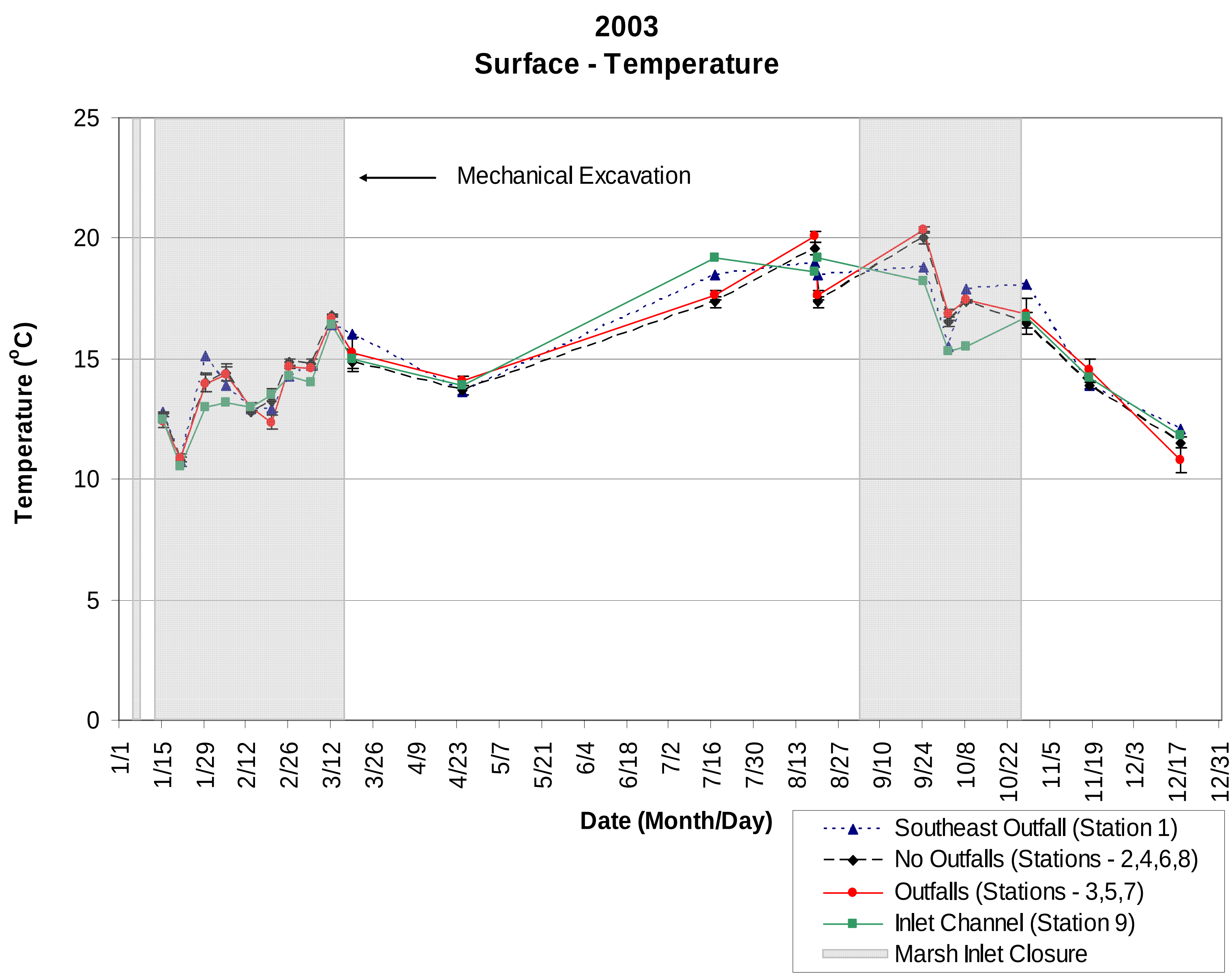


Figure 18. Crissy Field Marsh Water Surface Temperature from Nine Sampling Stations, 2003.

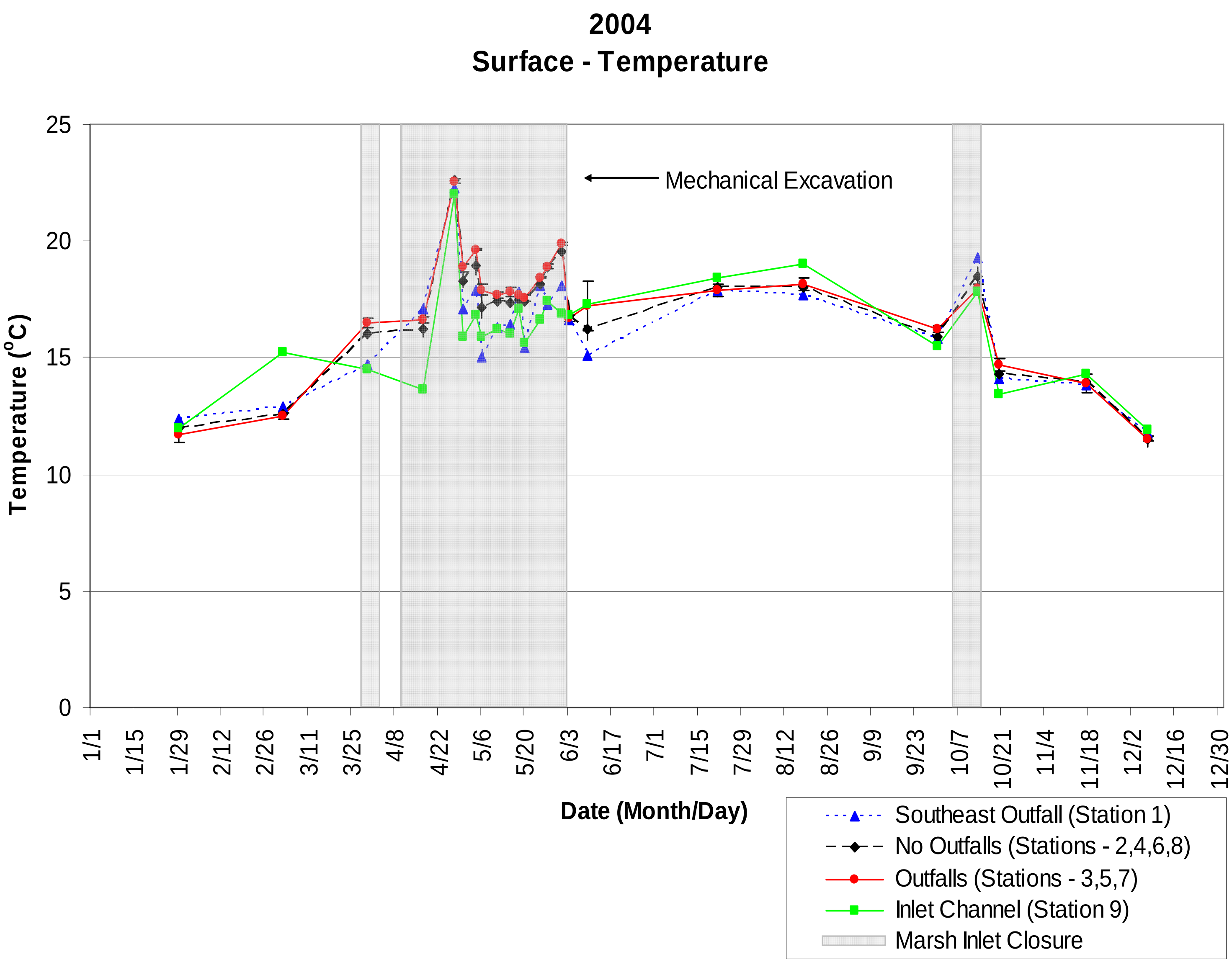


Figure 19. Crissy Field Marsh Water Surface Temperature from Nine Sampling Stations, 2004.

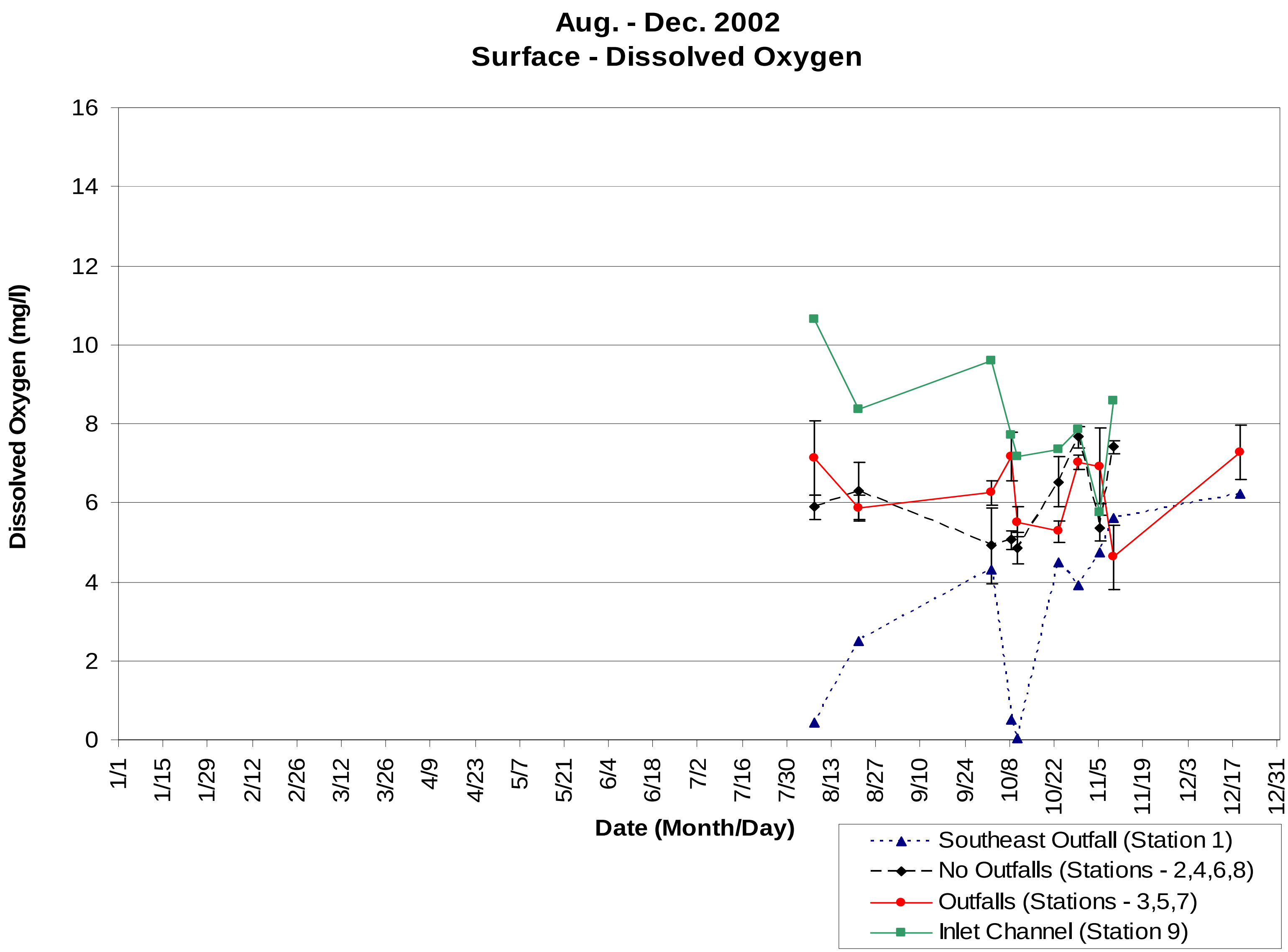


Figure 20. Crissy Field Marsh Water Surface Dissolved Oxygen from Nine Sampling Stations, August – December 2002.

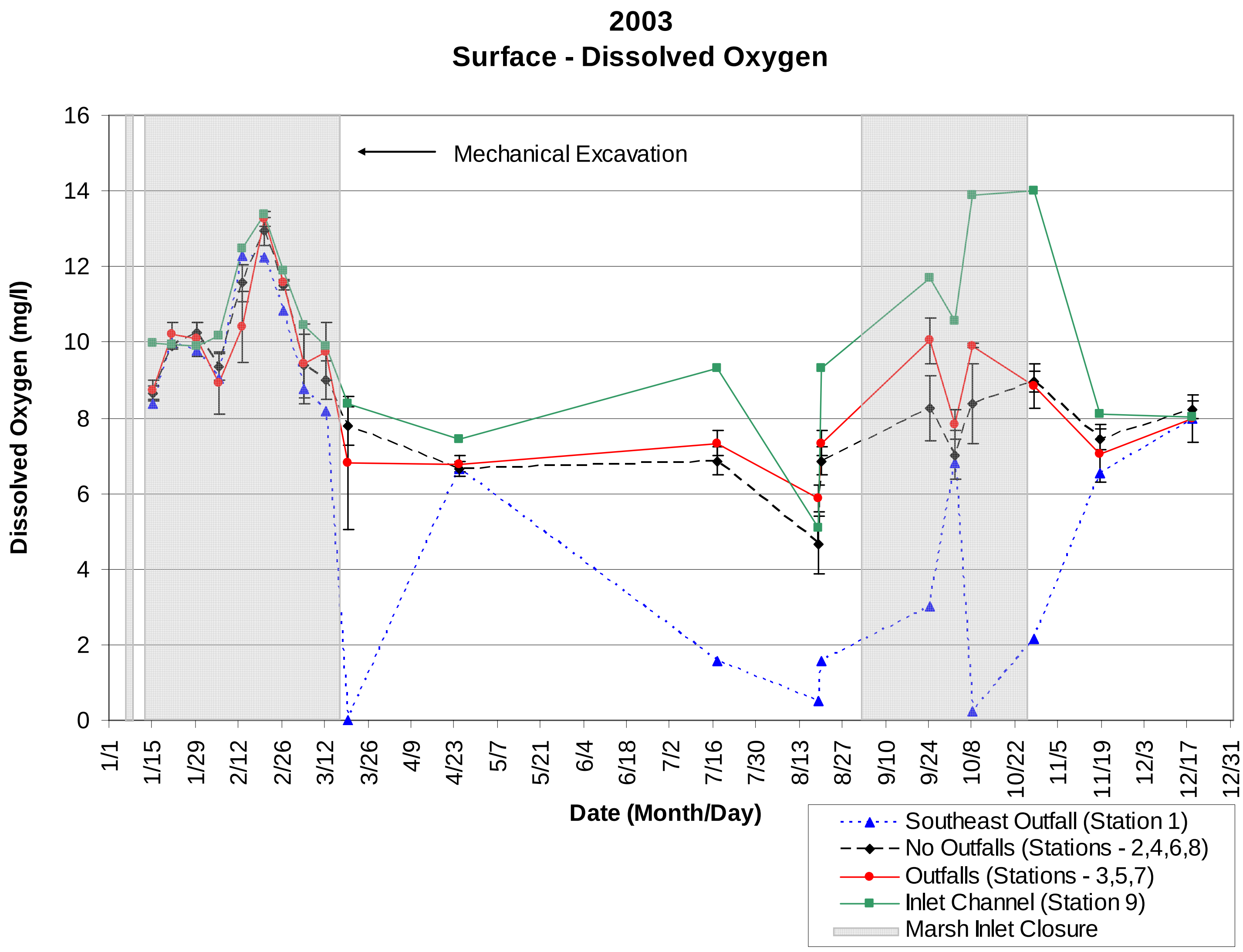


Figure 21. Crissy Field Marsh Water Surface Dissolved Oxygen from Nine Sampling Stations, 2003.

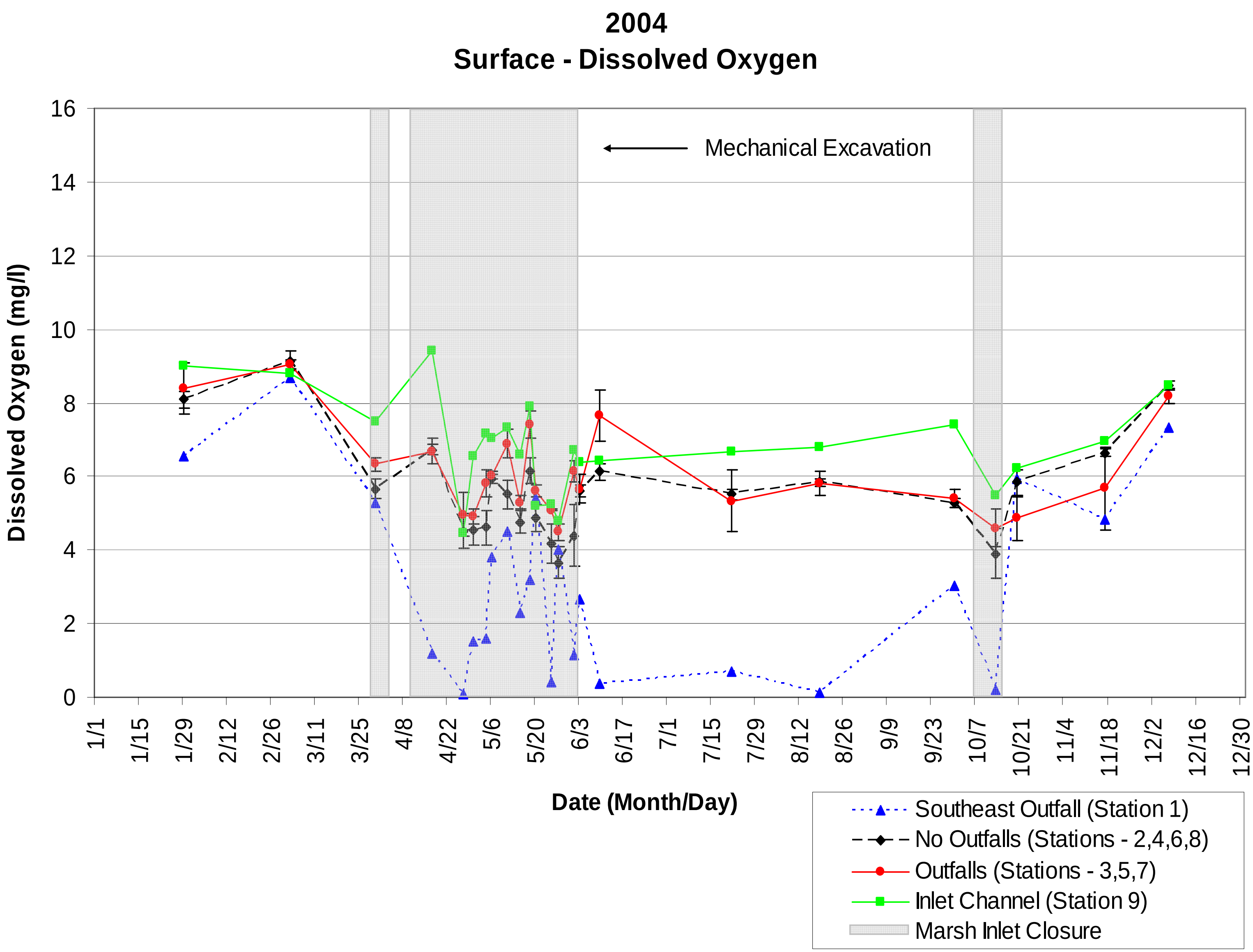


Figure 22. Crissy Field Marsh Water Surface Dissolved Oxygen from Nine Sampling Stations, 2004.

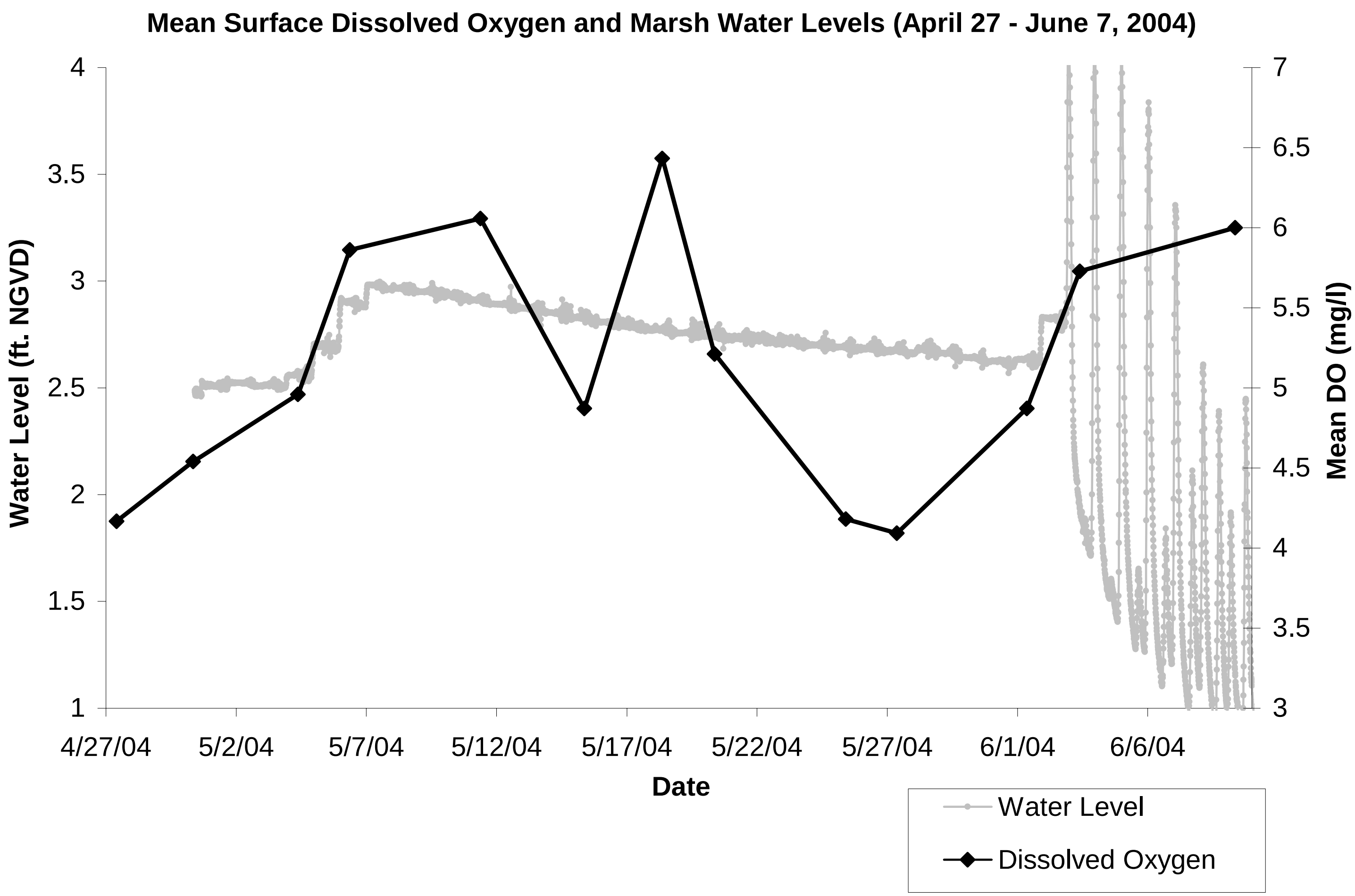


Figure 23. Mean surface dissolved oxygen (mg/L) from nine sampling stations during spring 2004 inlet closure.

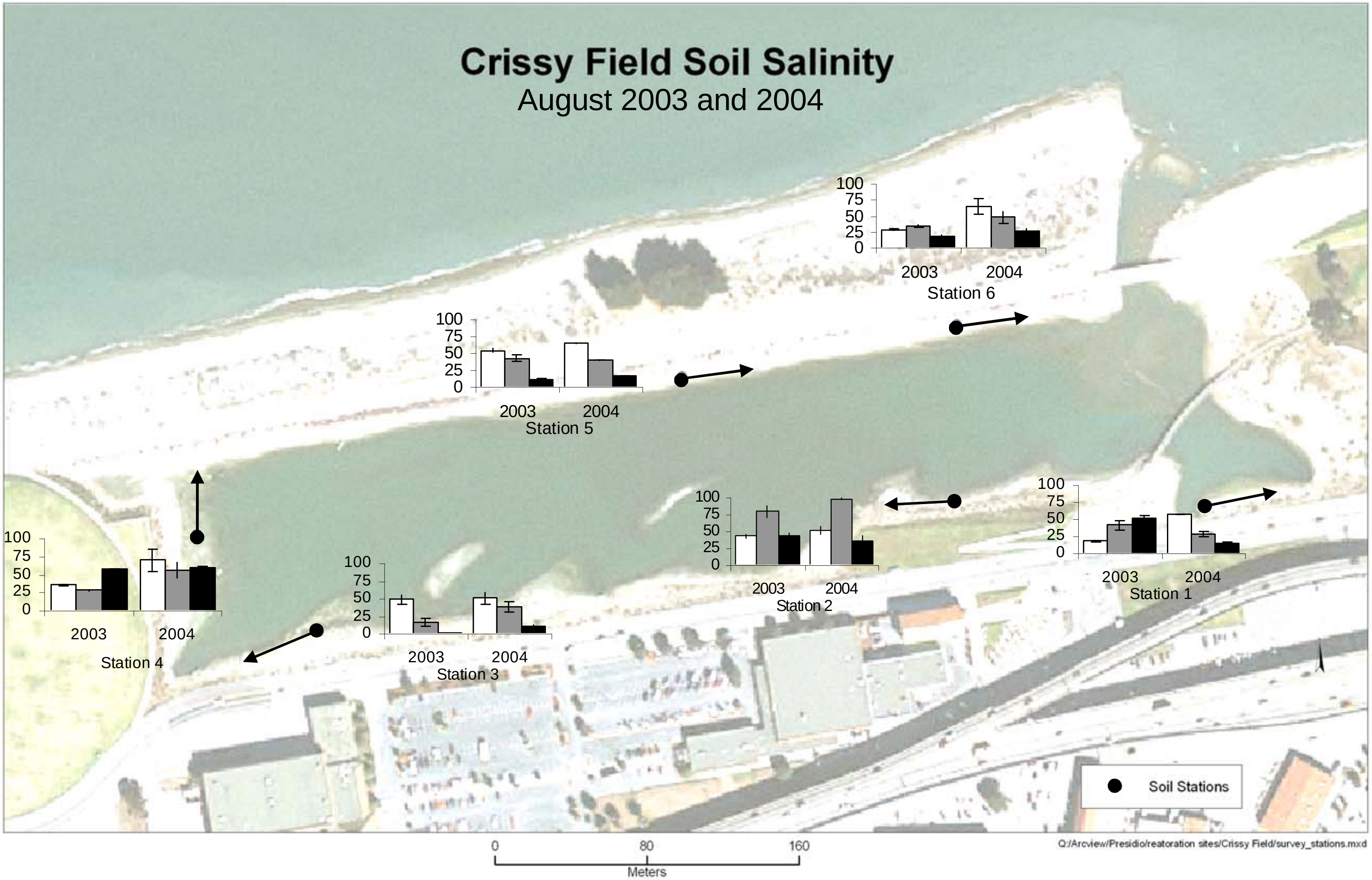


Figure 24. Mean soil porewater salinities (ppt) at six sampling stations, August 2003 and August 2004. (White bars represent low elevations, gray bars: mid elevations, black bars: high elevations.)

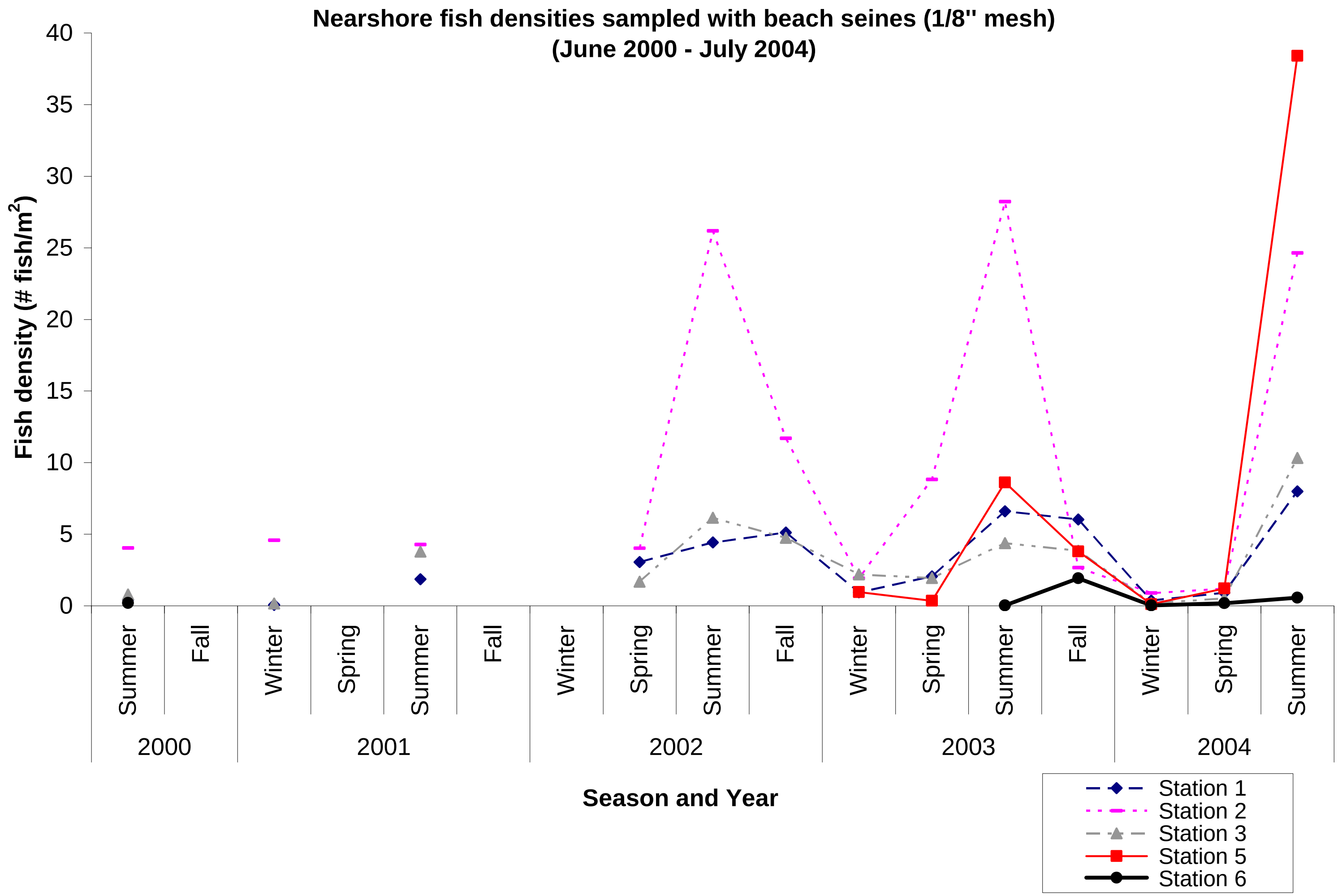


Figure 25. Nearshore fish densities in Crissy Field marsh from beach seine surveys (Summer 2000 – Summer 2004).

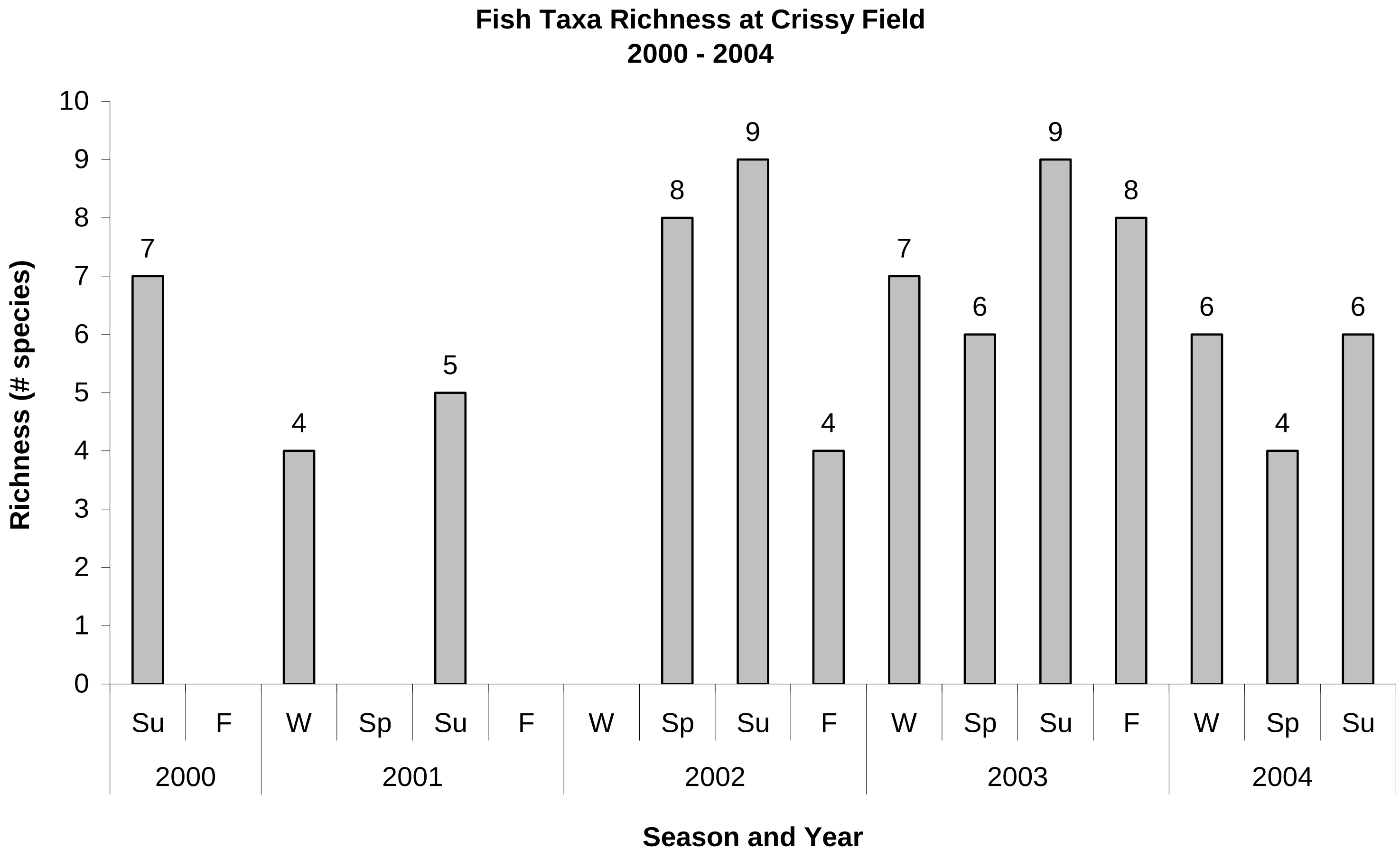


Figure 26. Fish taxa richness by season and year.

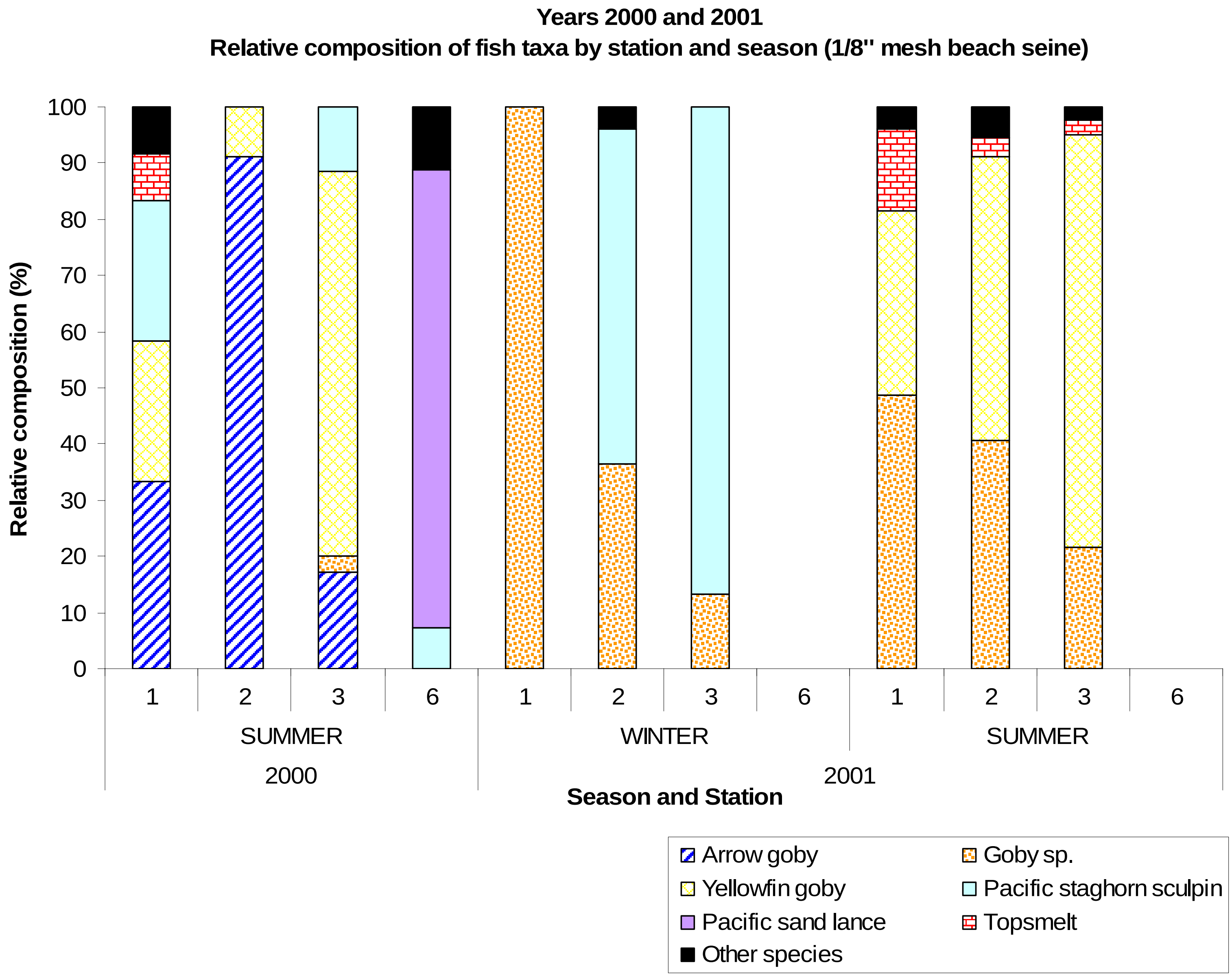


Figure 27. Relative percent composition of fish taxa collected by station and season, 2000 -2001. note: not all seasons were sampled.

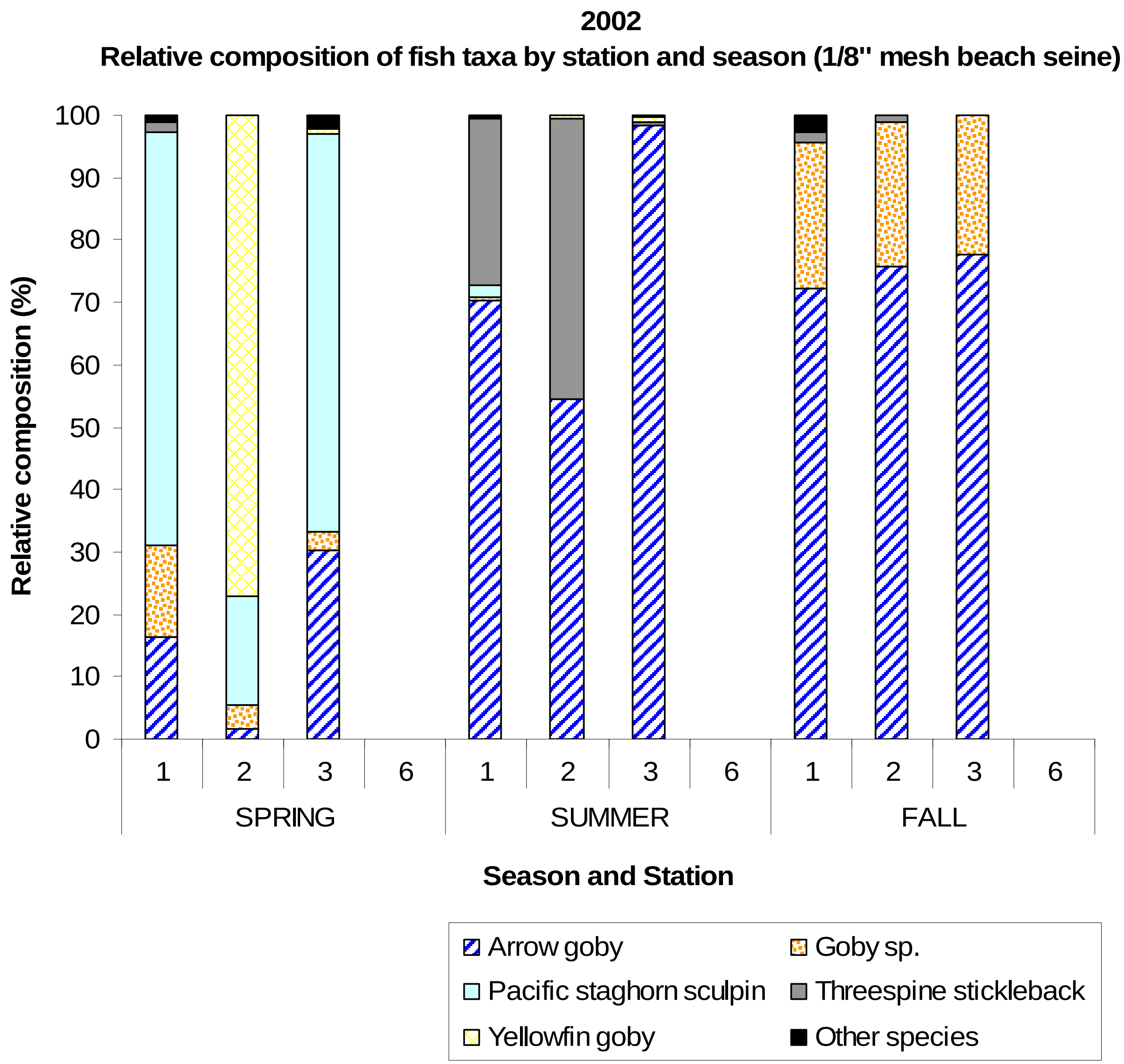


Figure 28. Relative percent composition of fish taxa collected by station and season, 2002. note: winter was not sampled.

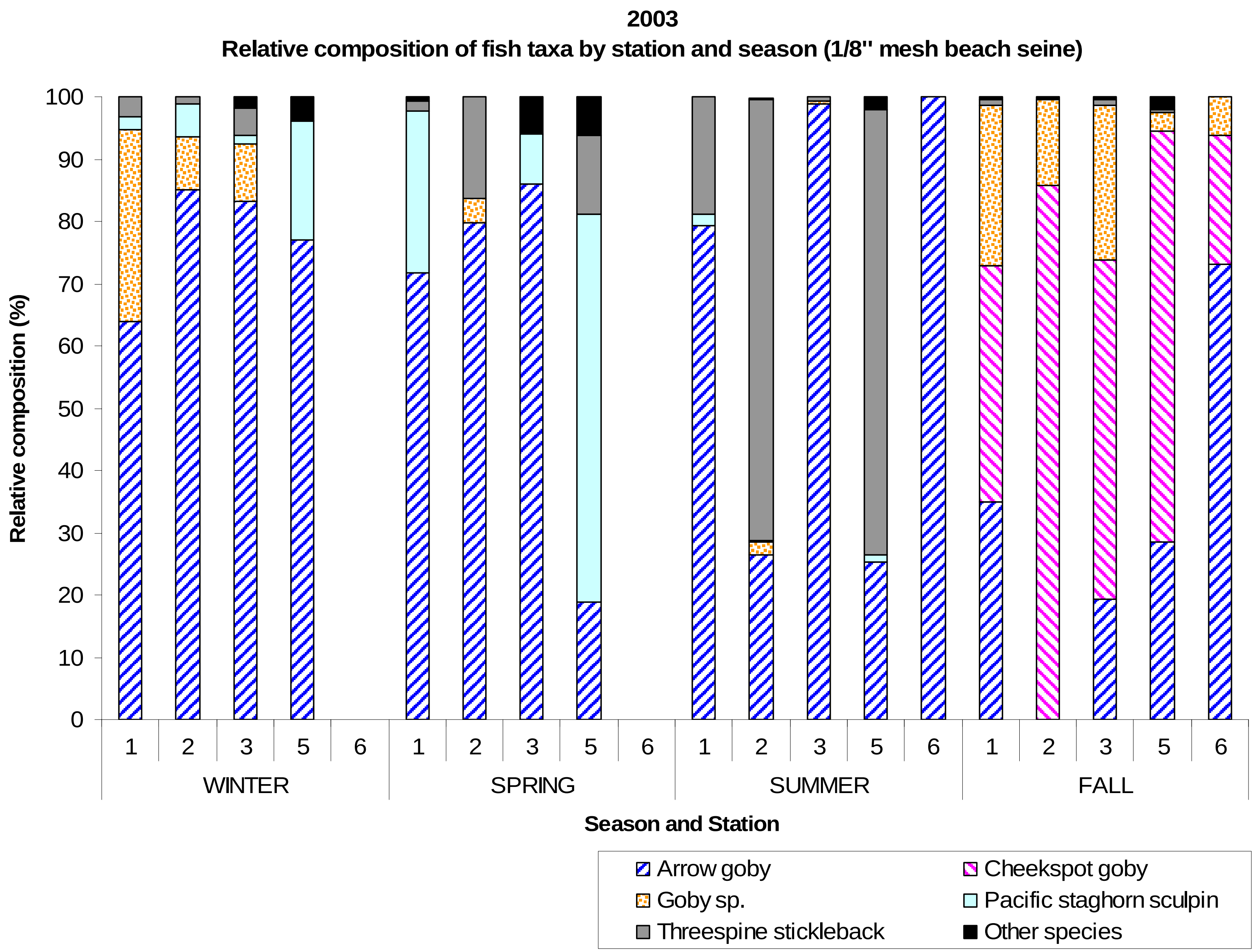


Figure 29. Relative percent composition of fish taxa collected by station and season, 2003.

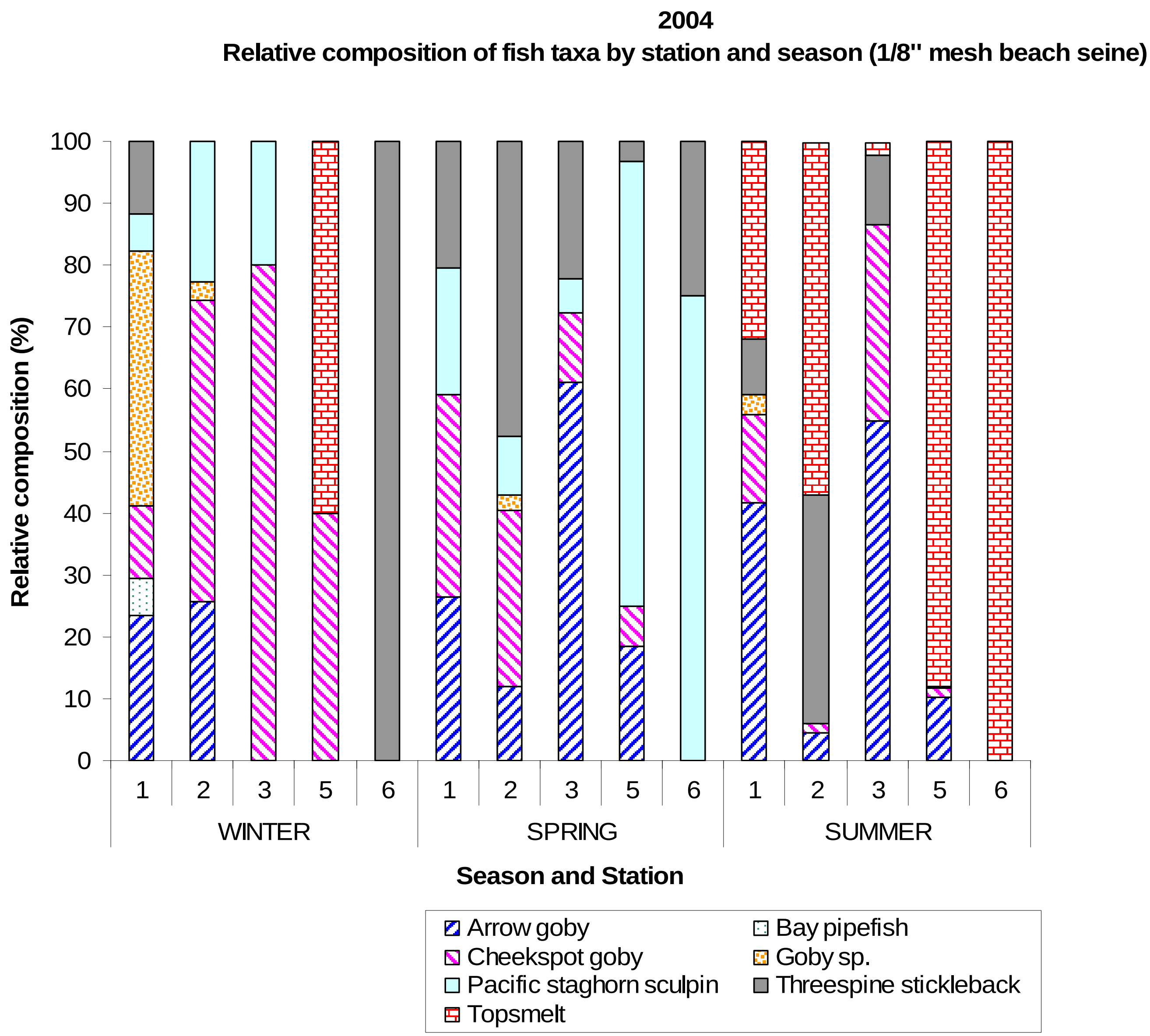


Figure 30. Relative percent composition of fish taxa collected by station and season, 2004.

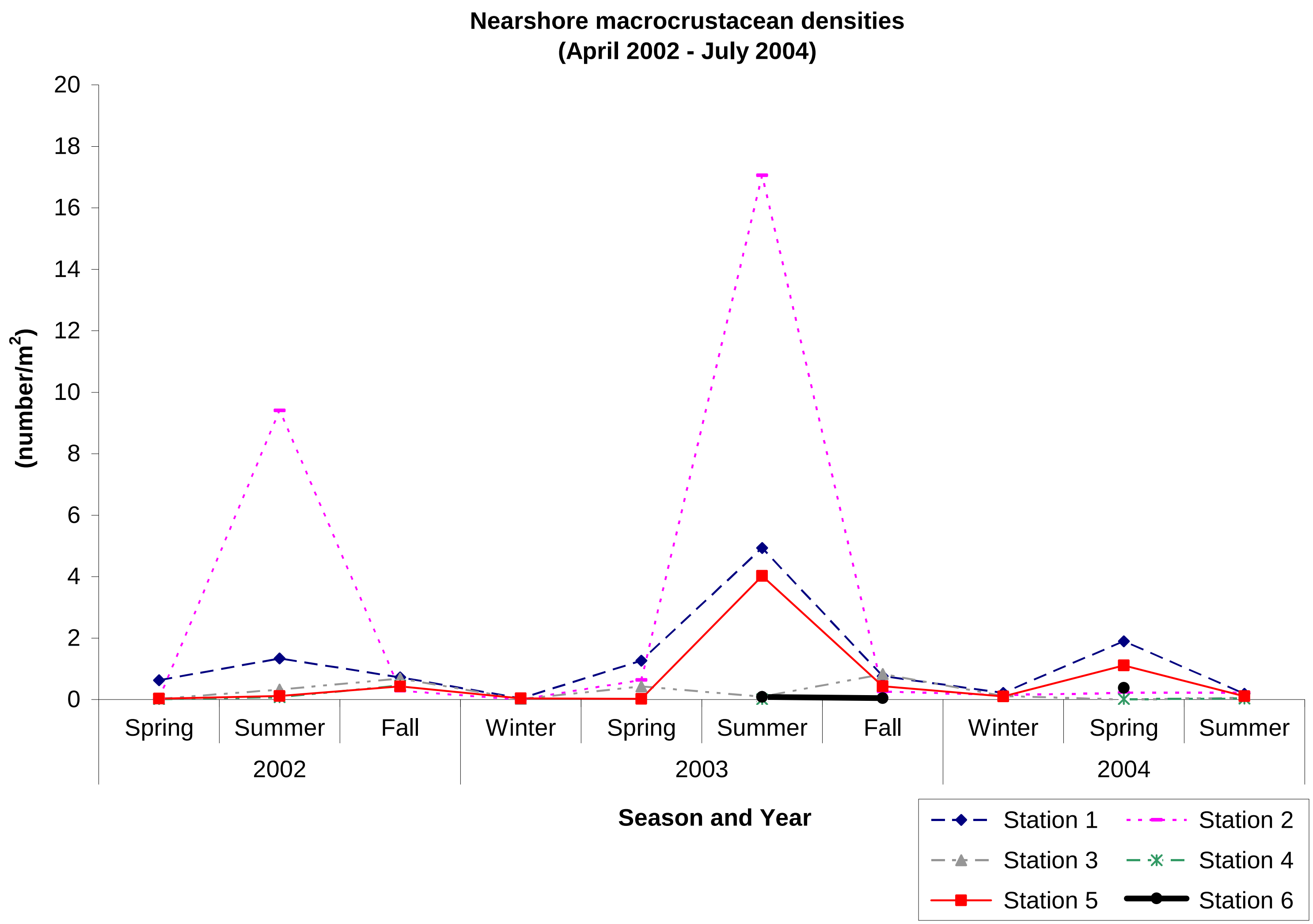


Figure 31. Nearshore macrocrustacean densities (number per m^2), caught in fish seines, 2002-2004.

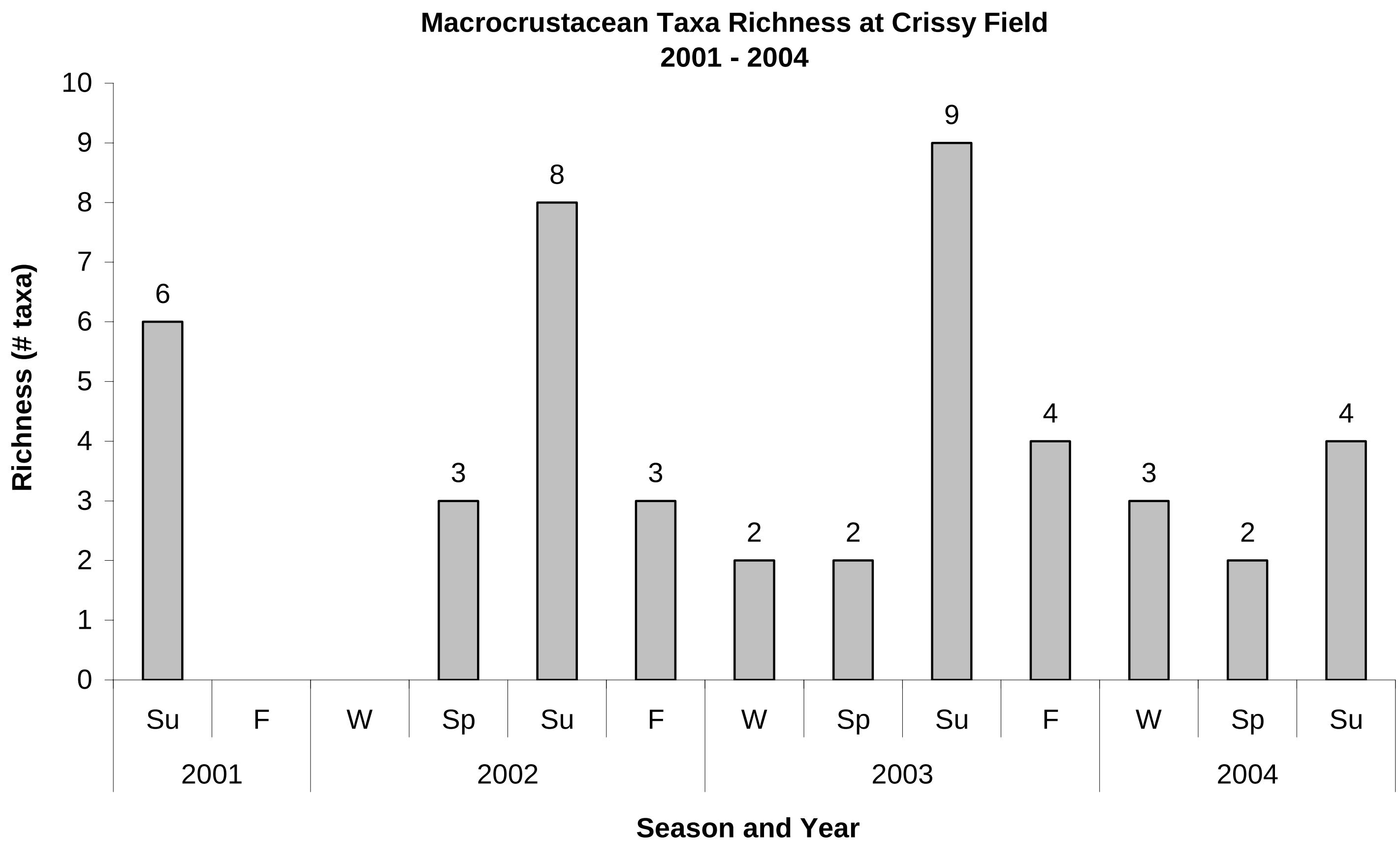


Figure 32. Nearshore macrocrustacean taxa richness at Crissy Field, by season and year, 2001-2004.

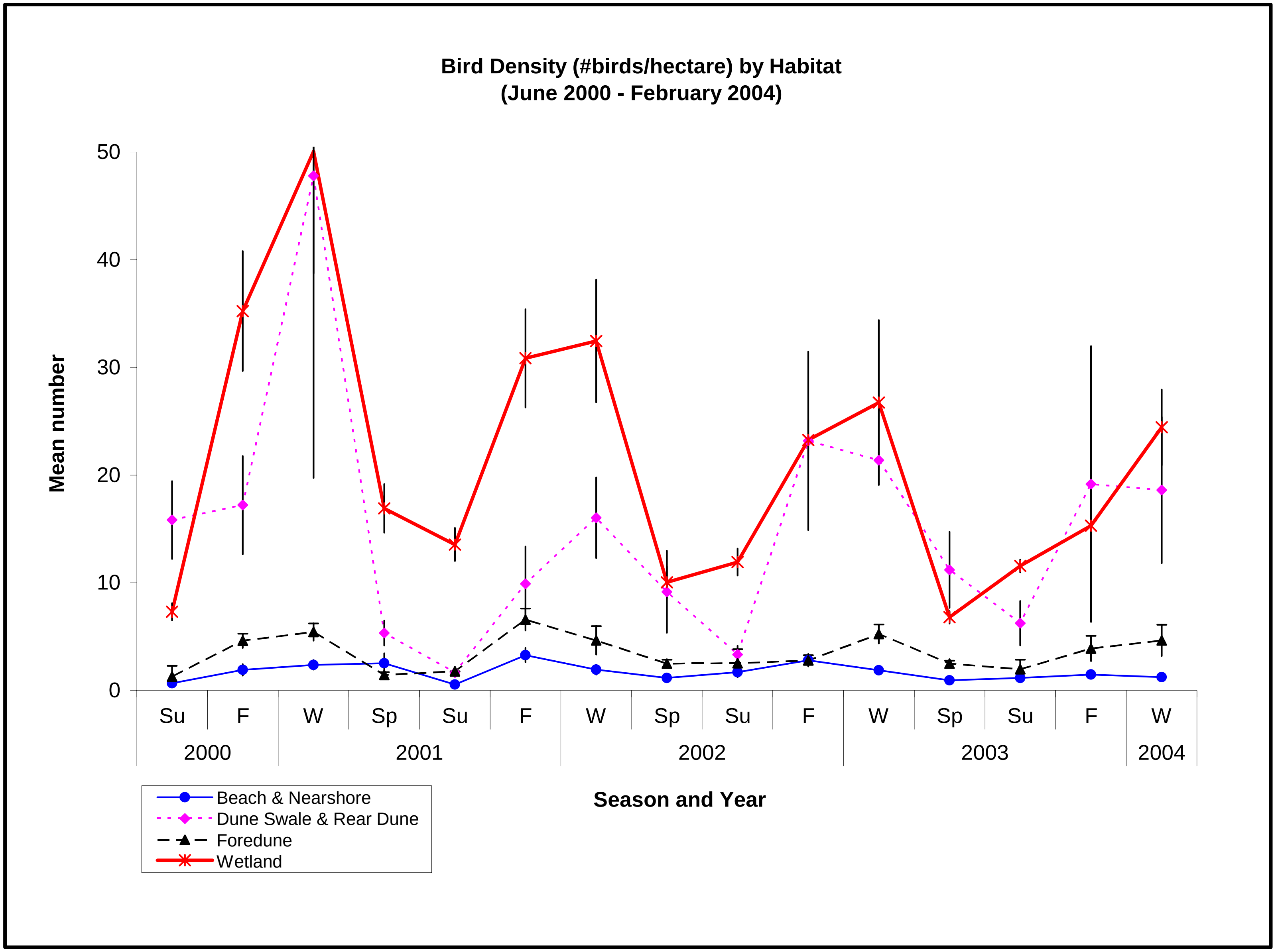


Figure 33. Mean number of birds/hectare found in each habitat by season and year, Summer 2000 – Winter 2004.

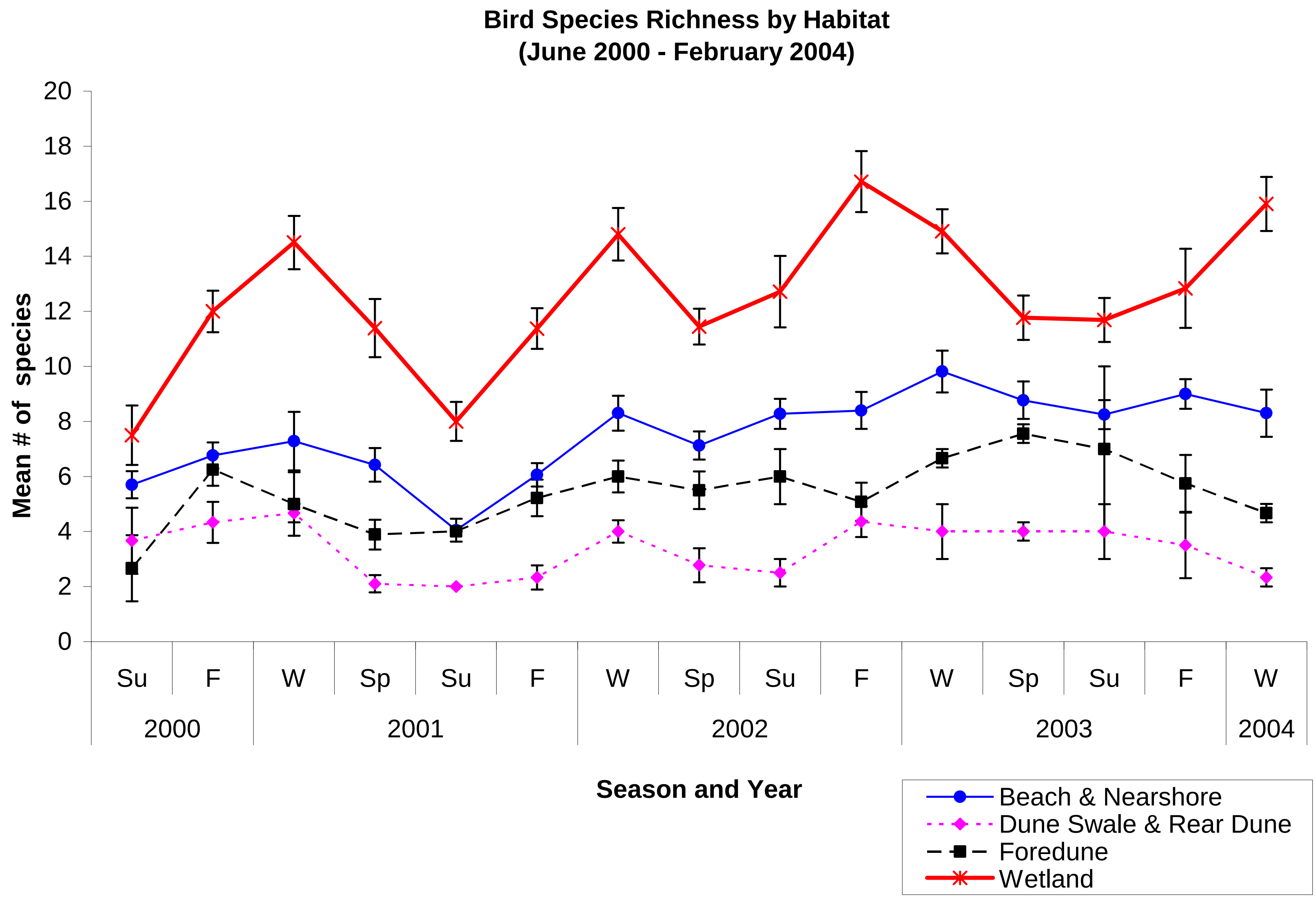
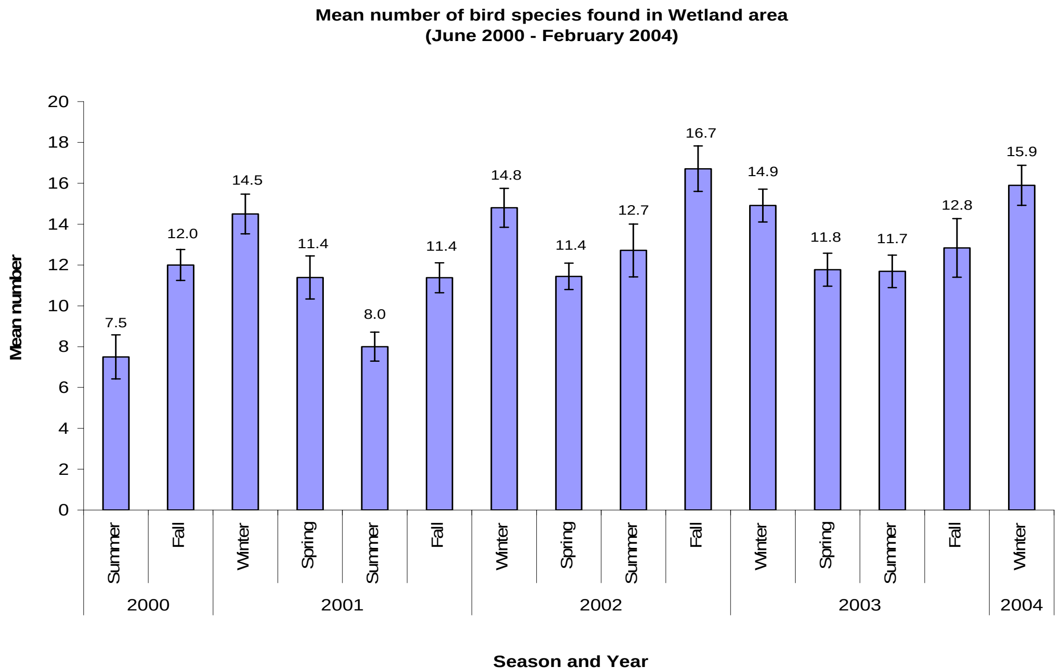


Figure 34. Mean number of bird species found in each habitat by season and year, Summer 2000 – Winter 2004.



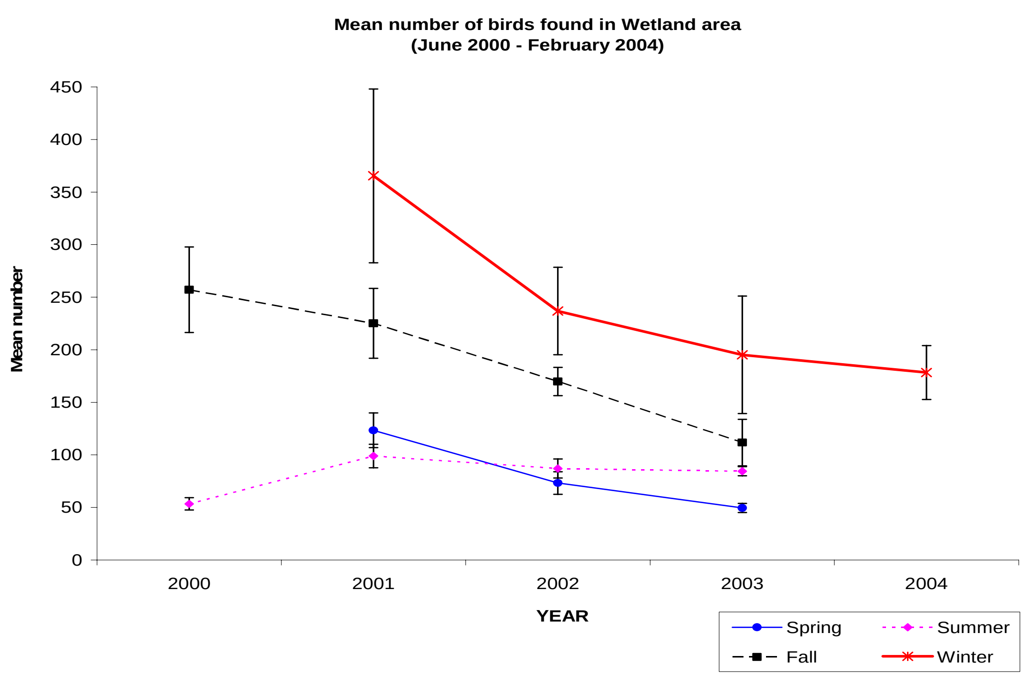
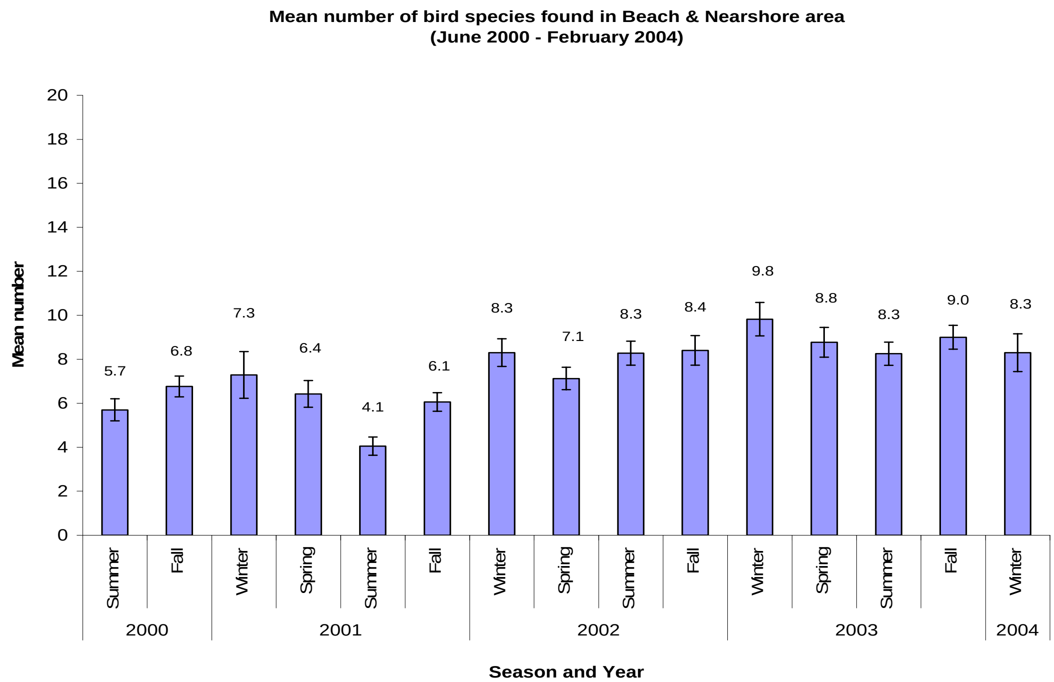


Figure 35. Bird species richness (top) and abundance (bottom) in the wetland, by season and year. (Area covered ≈ 18 acres)

Figure 36. Mean number of western and least sandpipers detected in Crissy marsh (Summer 2000 – Winter 2004).



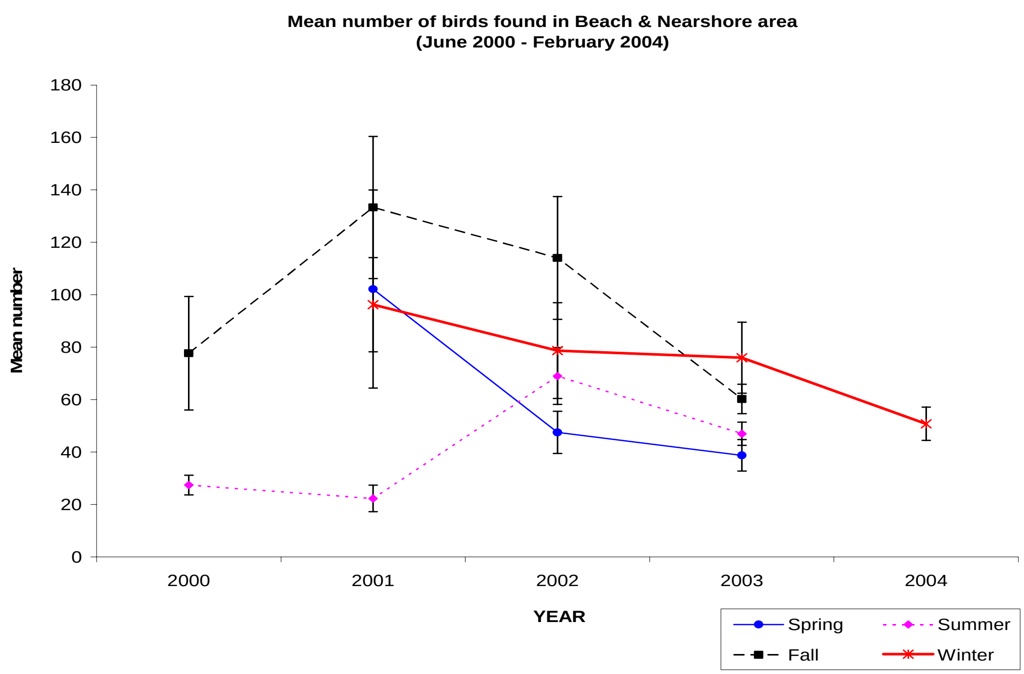
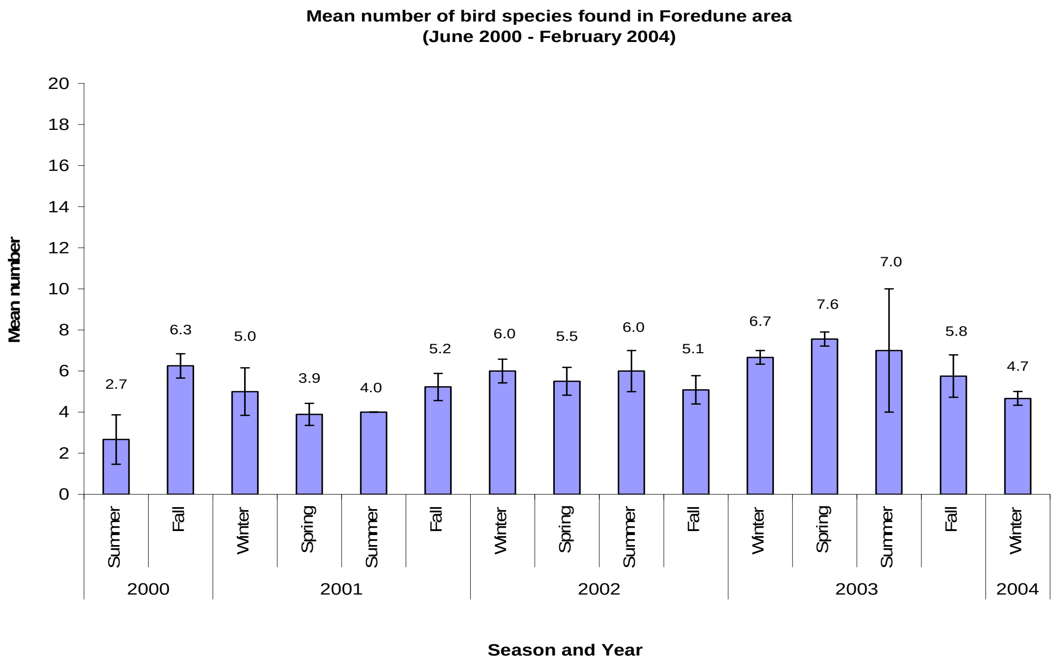


Figure 37. Bird species richness (top) and abundance (bottom) in the beach and nearshore area, by season and year. (Area covered ≈ 100 acres)



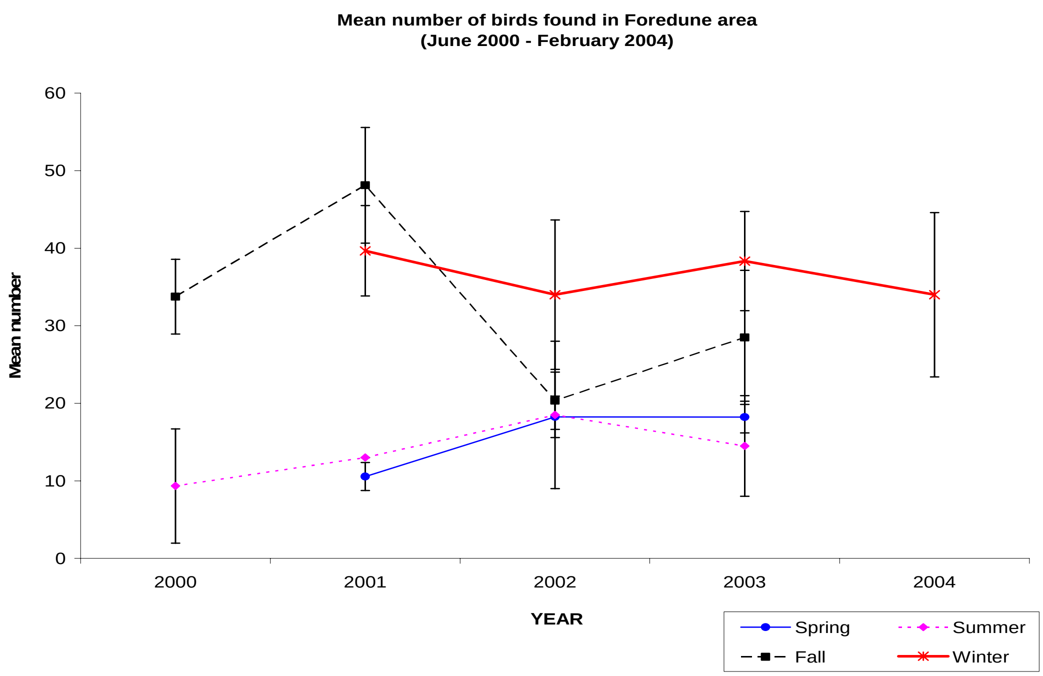
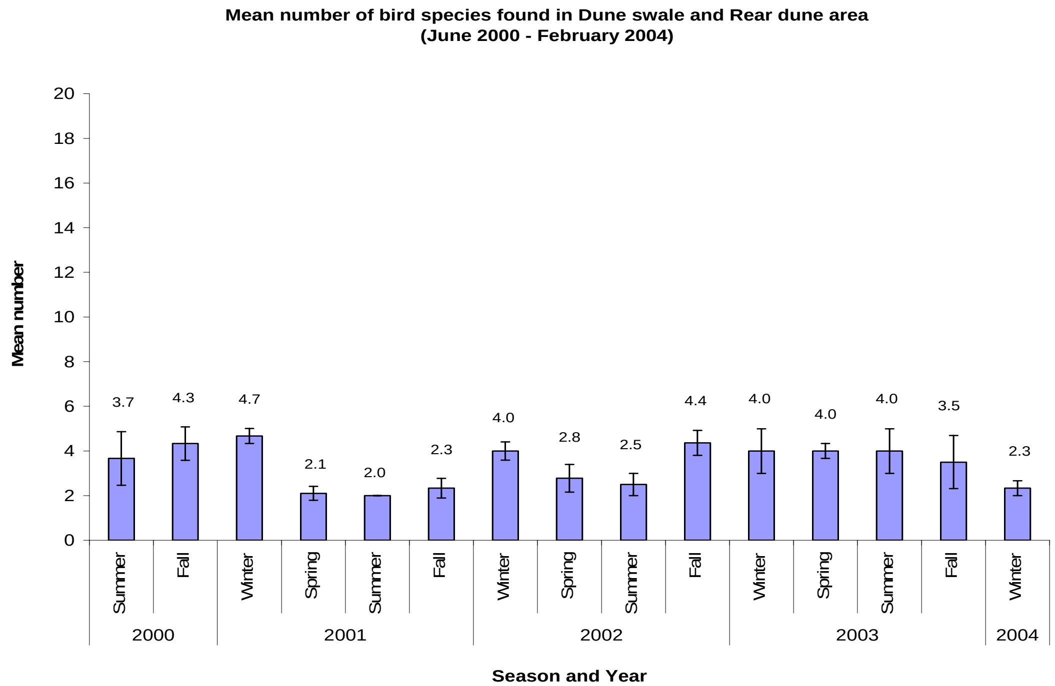


Figure 38. Bird species richness (top) and abundance (bottom) in the foredunes, by season and year. (Area covered ≈ 18 acres)



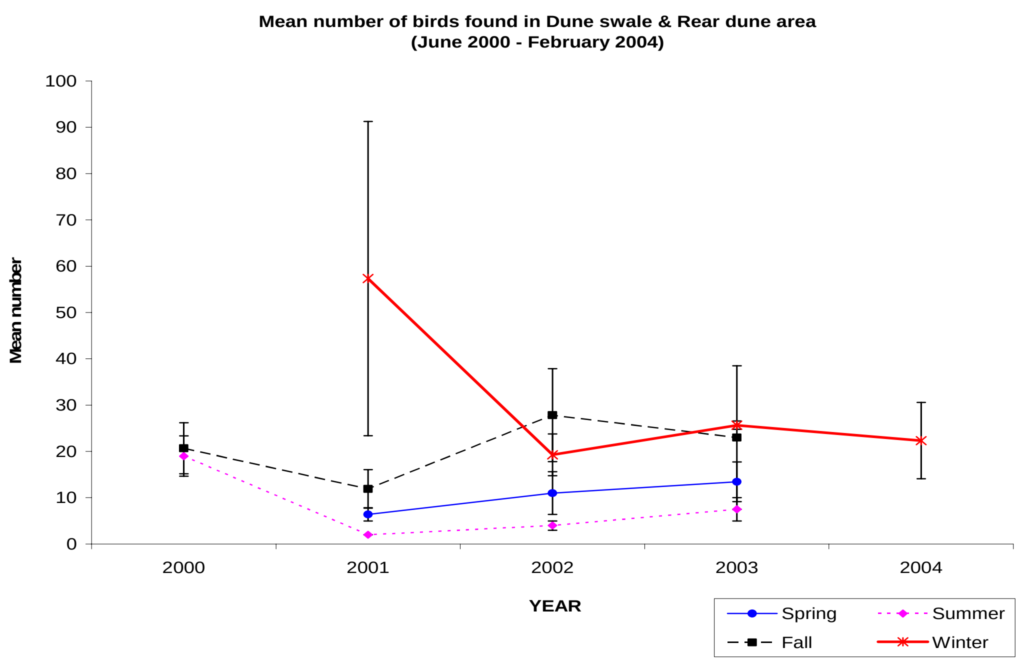


Figure 39. Bird species richness (top) and abundance (bottom) in the foredunes, by season and year. (Area covered ≈ 3 acres)

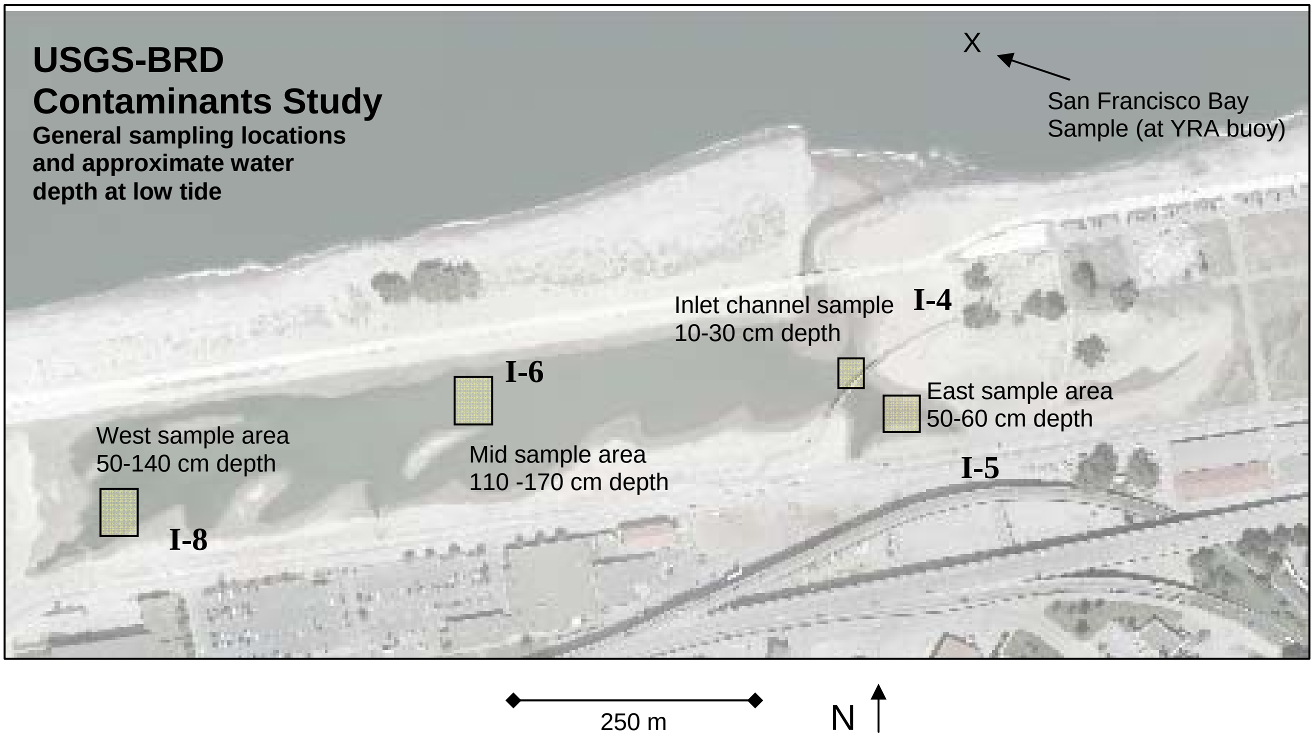


Figure 40. Location of sampling sites for USGS-BRD Contaminants Study. Benthic macroinvertebrate sampling stations established for the study are shown as I-4, I-5, I-6, and I-7 and correspond to stations referenced in Table 11.

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