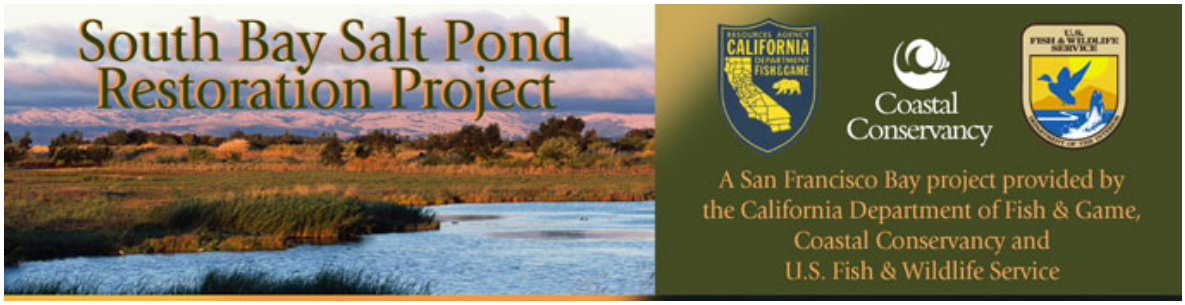

South Bay Science Symposium:
South Bay Salt Ponds, Bay and Watershed Research

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Poster Abstracts
(in alphabetical order based on first author)

Mercury Accumulation in Black-necked Stilt Chicks in San Francisco Bay

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We examined accumulation rates of total mercury (THg) in Black-necked Stilt chicks (*Himatopus mexicanus*) as they aged. We collected chicks of different ages during a two-week period from the same marsh (New Chicago Marsh, Alviso salt pond complex), to control for spatial and temporal variability in environmental Hg availability. We immediately necropsied chicks and analyzed THg levels in liver, kidney, muscle, blood, and head and breast feathers. We found a significant increase in THg concentrations as chicks aged; for example, THg concentrations in liver more than doubled from 1.61 ppm dw when chicks were young (about 17 days old) to 3.70 ppm dw when chicks had recently fledged (about 29 days old). Using culmen length as an index of chick age, liver THg increased in concentration at a rate of 0.19 ppm dw per day ($N=10$, $R^2=0.85$, $P<0.0001$). Similar positive relationships were found with culmen length and THg concentrations in kidney ($N=10$, $R^2=0.76$, $P=0.001$), and blood ($N=8$, $R^2=0.62$, $P=0.02$), but not breast feathers ($N=10$, $R^2=0.21$, $P=0.19$) likely because feathers represent short-term Hg burdens. Additional data from salvaged chicks and mark-released chicks further supports rapid Hg accumulation. Our results indicate that Black-necked Stilt chicks in the South San Francisco Bay rapidly accumulate Hg to concentrations approaching adult toxic thresholds and suggest that current Hg exposure may cause reproductive impairment in locally breeding birds.

Mercury Levels and Growth Rates of Forster's Tern Chicks in San Francisco Bay

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We examined mercury (Hg) concentrations and growth rates of Forster's tern chicks from four nesting colonies in the San Francisco Bay as part of a CalFed-supported study to examine Hg risks to avian reproduction. Using mark-recapture methods, we captured, banded, weighed, and measured 680 Forster's tern chicks and recaptured 610 marked chicks in 2005. We captured all chicks within each breeding colony by hand every other week at A1 and A8 (South Bay, Alviso salt ponds) and weekly at A16 (South Bay, Alviso salt pond) and Pond 2 (North Bay, salt pond). For each chick, we estimated age using a multiple regression developed from a subset of our data that included chicks with known hatching dates. We then calculated mass, wing, culmen, and tarsus growth rates. For Hg analysis, we collected down feathers from the rump when chicks were first captured (to represent Hg levels in the egg) and collected pin or fully grown feathers from the breast of recaptured chicks (to represent Hg accumulated after hatching). We also collected a subset of these chicks just before they fledged at 24.2±4.2 days old. We immediately processed chicks and analyzed Hg levels in blood, feathers, muscle, liver, kidney, and brain. Here, we present only Hg data from muscle as the other Hg analyses are in progress. We found significant differences in chick muscle Hg levels among tern colonies, but no overall difference in growth rates among colonies. However, at the individual level, wing, but not mass or culmen, growth rates of chicks declined with increasing concentrations of muscle Hg. These results underscore the importance of examining effects of Hg at the individual level. In the future, we will use our mark-recapture dataset to relate individual growth rates to Hg concentrations in feathers. This larger dataset will help elucidate the relationship between tern chick growth and Hg levels, and ultimately the ecotoxicological risk of Hg to avian reproduction. Our results indicate that Hg levels in Forster's tern chicks reared in South Bay salt ponds are near adult toxic threshold levels, highlighting the need to monitor this avian life stage during salt pond restoration activities that could alter Hg dynamics.

Bird Monitoring in the Salt Ponds of the South Bay Salt Pond Restoration Project

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In 2003, the U.S. Fish and Wildlife Service and the California Department of Fish and Game acquired over 10,700 ha of commercial salt ponds in San Francisco Bay for the purpose of restoring tidal wetlands. However, San Francisco Bay estuary has been recognized as a site of hemispheric importance for migratory birds, and salt ponds support large numbers of migratory and wintering shorebirds and waterfowl. One goal of the South Bay Salt Pond Restoration Project (SBSPRP) is to maintain existing ecological value for waterbirds, but information is needed to ensure that habitat requirements of large numbers of waterbirds can be met with reduced salt pond acreage. USGS has conducted monthly bird monitoring at salt ponds in the Alviso, Eden Landing, and Ravenswood systems since 2002. Additionally, we have collected environmental data including water depth, salinity, DO, pH, and temperature. In addition to documenting baseline conditions, this monitoring has provided a dataset for relating environmental variables to bird use and determining which

characteristics of salt ponds are most valuable to different avian foraging guilds. This long-term salt pond monitoring data, in conjunction with avian mudflat surveys, is important for SBSPRP planning processes as well as adaptive management of the ponds.

Factors Controlling Tidal Flat Morphology in South San Francisco Bay

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Since the 1850's, the San Francisco Bay has been subjected to a wide array of human-induced change. Since the first bathymetric measurements made in 1858, the saltmarshes and mudflats of South San Francisco Bay (SSFB) have decreased in area by 80% and 40%, respectively (Foxgrover et al., 2004). Much of the loss of saltmarsh was due to reclamation for the purposes of salt harvesting, while mudflat loss can be related to lack of sediment input (Krone, 1977), and sea level rise. Currently, there is a proposal to abandon some of the salt ponds, restoring them to salt marsh. While research has been done regarding the expected regeneration of marsh following a levee breach (e.g. Williams & Orr, 2002), the effect this would have upon the adjacent mudflats is unclear, and will require both local and regional examination of their function and behavior. Often overlooked, intertidal mudflats play an important ecological role as habitat for benthic invertebrates and feeding grounds for migratory birds.

The data used in Foxgrover et al. (2004) to determine trends of erosion, deposition, and bathymetric change in SSFB from 1850 to the present offer physical scientists a great opportunity to examine more closely the varying behavior and evolution of the mudflats in response to temporal factors – river discharge and subsidence, for example - and spatial factors – exposure to wind and waves, proximity to major sediment sources, and whether the mudflat borders a marsh or a salt pond levee.

Using ARC GIS software, the tidal flats of SSFB will be broken into geographically similar segments and multiple cross-sections will be drawn from highest high water to lowest low water (the extent of the mudflats) at close intervals, allowing for a mean tidal flat bathymetric profile to be determined for each segment and for each time period - 1898, 1931, 1956, 1983, 2005 (Note: There is information from an 1858 bathymetric survey that is currently incomplete; it will be included in the analysis upon its completion). Using eigenfunction analysis, which allows for the spatial and temporal changes in profile shape to be separated into the dominant components of the variability, we hope to classify the behavioral response of tidal flats to the spatial and temporal forcings listed above. Initial analyses will be presented at the June symposium.

The above components of bathymetric variability derived from objective statistical analysis will also be compared to theoretical models for tidal flat profiles as a function of waves, tides and sediment supply (e.g., Friedrich and Aubrey, 1996). Theoretical models predict that wave-dominated or sediment starved flats tend to have concave-upwards bathymetric profiles, whereas tide-dominated or accretionary flats tend to have convex-upwards bathymetric profiles.

Up to this point, most research on related topics has focused on the response of saltmarsh to reclamation or restoration; very little attention has been paid to the accompanying change in mudflat shape and sediment character. This research should allow us to make conclusions of the interactions of the saltmarsh pioneer zone and the mudflats from the intertidal zone's point of view. This data will be useful to the South Bay Salt Pond Restoration for determining which mudflats would respond most favorably to levee breaching and saltmarsh restoration.

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Invasive *Spartina* in the Cooley Landing Salt Pond, Menlo Park, CA

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The Cooley Landing Salt Pond is located within the Ravenswood Open Space Preserve in Menlo Park, CA. In the 1950s, a perimeter levee was constructed around tidal wetlands adjacent to the San Francisco Bay to form a 115-acre salt production pond. Salt production was discontinued in the 1980s and in 2000 wetland restoration activities were conducted to meet agency requirements for the offset of the loss of 3.3 acres of seasonal, nontidal wetlands, which were filled at a nearby soil remediation site. Tidal circulation was re-introduced to the Cooley Landing restoration site on December 20, 2000.

Based on monitoring conducted to date, the restoration project has successfully created the appropriate hydrologic and geomorphic conditions to support marsh function and development. The breach inlet channels have evolved rapidly and are approaching equilibrium dimensions and the re-occupation of the remnant historic channel system in the site interior has extended to the most upstream reaches of the channel system. Tidal circulation and sediment delivery to the marshplain have improved in response to tidal channel evolution and tidal exchange is now comparable to natural marshes in the South Bay. Due to sedimentation, elevations in portions of the site are appropriate for establishment of marsh vegetation.

The project, however, is not meeting the interim goals for native vegetative coverage and is at risk of not meeting the performance criteria requiring less than five percent non-native vegetation cover at the end of the ten year monitoring period. Accretion rates on the marsh surface were lower than predicted for the first three years of monitoring resulting in little expansion of existing pickleweed at higher elevations and persistence of substantial subtidals areas. Areas that have accreted above Mean Sea Level have been colonized by both the native California cord grass (*Spartina foliosa*) and the non-native smooth cordgrass (*Spartina alterniflora*) and its hybrids. *S. alterniflora* existed on the outboard portion of the levee surrounding the restoration area prior to the project and control of this cordgrass was a condition of project permits. Because S. alterniflora is able to colonize at lower elevations than native *Spartina*, the newly restored tidal wetland, due to its lower substrate elevations, is highly susceptible to invasion by *S. alterniflora* and its hybrids.

In 2001, genetic testing of suspected S. alterniflora hybrids in the restoration area found several seedlings and hybrid adult stands indicating that *S. alterniflora* was colonizing the restoration area. A non-native vegetation control plan, which included application of herbicide to all known stands of *S. alterniflor*a was implemented. Due to a court decision in 2001, the herbicide applications were no longer covered under the statewide general NPDES permit. Manual control of *S. alterniflora* stands

within the project area was conducted until an NPDES permit could be obtained. In 2003, genetic sampling was again conducted and indicated an increased presence of non-native *Spartina* in the restoration area. In 2004 coverage under an NPDES permit obtained by the Invasive *Spartina* Project (ISP), administered by the California Coastal Conservancy, was obtained. With guidance from the ISP, herbicide applications were re-initiated in August 2004, repeated in September 2005, and are scheduled to be repeated in 2006. Efficacy of efforts to date has been low with one of five pre-existing stands on the outboard levee of the restoration area eliminated and continued colonization of the restoration area by hybrids. The recently approved and more effective herbicide Imazapyr and improved application techniques are expected to result in better control, however, this eradication will not ensure that non-native performance criteria for the project will be met as ongoing colonization from the regional infestation of non-native cordgrass is likely to be a problem beyond the control of project managers. As the marsh surface in the pond accretes, the site will be prime habitat for *S. alterniflora*. Currently Cooley Landing has only 16% coverage of salt marsh vegetation leaving over 87 acres for potential establishment of *Spartina*. Control of hybrid clones on adjacent properties and beyond will be necessary before the non-native performance criteria can be met. The amount of *S. alterniflora* and its hybrids in the restoration area has increased every year since 2001 and project maintenance costs, originally estimated between $2,000 and $4,000 per year, have increased to more than $20,000 annually to deal with the invasion of *S. alterniflora* and its hybrids.

Space Use of Foraging Forster's terns (*Sterna forsteri*) in South San Francisco Bay, California

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Forster's tern (*Sterna forsteri*) is a medium-sized tern found breeding colonially in saltwater and freshwater habitats in North America. In California, Forster's tern is a Species of Special Concern and, in the San Francisco Bay, nests primarily on island or levee habitats provided by artificial salt evaporation ponds. In 2005, we captured and radio-marked 31 pre-breeding Forster's terns on 4 colony sites within the Alviso salt pond complex of Don Edwards San Francisco Bay National Wildlife Refuge (DESFBNWR) in the South San Francisco Bay, California. Foraging Forster's terns were tracked aerially and using truck-mounted telemetry systems throughout the San Francisco Bay region. For terns with 20 or greater foraging locations, we estimated home-range and core-area sizes, defined as the areas encompassing 95% and 50% of the probability distribution, respectively. Foraging terns average (±se) home-range size was 5,843 (±1,016) ha, with a core-area size of 864 (±206) ha. All core-areas encompassed artificial salt evaporation ponds within DESFBNWR, indicating the importance of salt pond habitat for foraging terns. Forster's terns are potentially faced with vast habitat alterations as restoration efforts in the South San Francisco Bay aim to convert artificial salt pond habitat to tidal marsh. Effective management of Forster's terns in the South San Francisco Bay will need to not only conserve or create colony sites but also take into account the foraging movements of terns within the bay and salt pond systems.

The Significance of Stakeholder Participation in the South San Francisco Bay Salt Pond Restoration Project

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Issues of adaptive management and governance in large-scale, long-term ecological restoration projects include adaptive design and problem-solving that bridge disciplines, institutions, interests, and cultures. Public support is vital because it is ultimately linked to the long-term sustainability of the restoration project in terms of stakeholder cooperation, a sense of community "ownership," and also to ensuring adequate project funding.

However, many projects minimize or lack the social and policy research necessary to understand the social context that will affect the ultimate success of the restoration. Some recent studies have found that although several large-scale ecosystem restoration programs cite the importance of incorporating all scientific disciplines into restoration efforts, they do not actually involve social scientists as part of their institutional framework. Nor do they include processes for collaborative or social learning, which is critical in building knowledge among the various project stakeholders.

The South Bay Salt Pond Restoration Project (the Project), a 15,100-acre restoration site at the south end of San Francisco Bay, is an urban project with many social and political dimensions that is incorporating extensive public involvement and social dimensions research. This research will examine what constitutes successful stakeholder and public involvement in undertaking restoration of large-scale ecosystems in which people have an increasingly greater role and impact.

The results of this research will provide useful insights into how meaningful various stakeholders view their participation to be in the South Bay Salt Pond Restoration Project to date and their expectations for future participation. In-depth interviews with representatives of each of the stakeholder groups, as well as review of project documents and other materials, will indicate the level of buy-in and commitment to the Project, which will be useful in future project planning, adaptive management implementation and related applied studies, and an indicator of what further steps could be taken to enhance community support.

Space Use of American Avocets in South San Francisco Bay

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Wetland conservation of endemic waterbirds may be improved with greater knowledge of their space use patterns. Life-history patterns are often not considered in the analysis of home range, core use areas, and spatial movements. From March through July 2005, we radio-marked 50 American Avocets (*Recurvirostra americana*) in the South San Francisco Bay and monitored 5 individuals from pre-breeding through post-breeding. Our results indicated that American Avocet space use did vary with life-history stage. Pre-breeding habitat use was primarily non-tidal salt ponds and some surrounding tidal areas, while avocets used only non-tidal salt ponds for nesting habitat. Pre-breeding home ranges (960 ha) and core use areas (133 ha) were greater than during the incubation stage (151 and 23 ha, respectively). Post-breeding home ranges (5,389 ha) and core use areas (1014 ha) were, in turn, greater than during pre-breeding and incubation stages. Pre-breeding and incubation stage core use

areas often overlapped, indicating that avocets were prospecting in potential nesting locations prior to egg-laying. As expected, core use areas during the incubation stage centered on nest locations. Stable water levels, consistent food resources, and lack of ground predators may play a role in nest site selection. Large post-breeding home ranges suggested that American Avocets used a wider range of foraging areas when not restricted by reproductive activities. During each stage, American Avocets used a wide variety of habitats, including non-tidal and tidal salt ponds, tidal sloughs, mud flats, and water treatment ponds. This species could benefit from management practices that include large foraging and nesting areas composed of a variety of wetland types.

Mercury Concentrations in Prebreeding and Breeding Forster's Terns

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We examined the relationship between breeding status and mercury (Hg) accumulation in Forster's terns breeding in the San Francisco Bay. We collected male and female Forster's terns from South Bay salt ponds during both the pre-breeding and breeding time periods. We analyzed methyl mercury (MeHg) in liver and total mercury (THg) in blood of pre-breeding and breeding birds. Blood THg and liver MeHg concentrations were highly correlated (R^2=0.94 P=<0.001, N=94). We found that Hg in both tissues varied among breeding status (ANOVA, P=0.002). Liver [MeHg] increased from pre-breeding to breeding by 71% (8.7-14.9 ppm dw) in Forster's terns, whereas blood [THg] increased during the same time period 293% (0.89-3.5 ppm ww). Although there were no differences in Hg levels between sexes during the pre-breeding time period (ANOVA, P=0.94), males had concentrations nearly double those of females during the breeding time period, with males increasing in concentrations by 169% (7.5-20.2 ppm dw) compared to females, which increased just 17% (9.8-11.5 ppm dw). Our results indicate that bioaccumulation of Hg in terns occurs rapidly in the estuary to levels well above established toxic thresholds, and also that Hg deposition into eggs likely serves as an important mechanism for reducing overall body burdens in females during the breeding season. This suggests that piscivorous birds may be sensitive indicators of changes in Hg cycling resulting from restoration activities.

Mercury Concentrations Differ Among Five Species of Waterbirds in San Francisco Bay

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Legacy mercury (Hg) contamination of the San Francisco Bay (Estuary) has resulted in elevated Hg concentrations in several species of invertebrates, fish, and waterbirds. Currently, there is concern that the on-going restoration of the Estuary and associated conversion of salt evaporation ponds to tidal

marsh may alter Hg dynamics in the Estuary and adversely affect wildlife. In waterbirds, Hg bioaccumulation results from dietary exposure and is dependent upon several factors including space use, foraging habitat, and diet. We examined liver methyl mercury (MeHg) and blood total mercury (THg) concentrations in five species of birds that occupy three distinct foraging guilds: diving benthivores (surf scoters), littoral foragers (American avocets and black-necked stilts), and obligate piscivores (Forster's terns and Caspian terns). We also assessed whether MeHg concentrations differed among regions for each species (North Bay, Central Bay, South Bay, and Suisun Bay). Across all locations, MeHg concentrations were highest in Caspian terns, followed by Forster's terns, black-necked stilts, surf scoters, and American avocets (2.11-9.38 ppm dw). Both Caspian terns and Forster's terns had liver MeHg concentrations that were more than three times those of American avocets and surf scoters, and approximately double those of stilts. In addition, 50% of Caspian terns, 45% of Forester's terns, 29.4% of stilts, 1.4% of scoters, and 8.3% of avocets contained liver MeHg concentrations above the 6.0 (ppm dw) LOAEL established for mallards. Spatial analysis showed that MeHg concentrations in Forster's terns and surf scoters differed among regions, with terns from the South Bay and scoters from Suisun Bay having liver concentrations nearly twice those of Central Bay birds, while neither stilts nor avocets showed any regional differences. Our results highlight the importance of avian foraging strategies and locations in assessing the risk of Hg to wildlife and suggest that restoration goals should include an understanding of potential Hg accumulation and reproductive effects based on foraging guilds.

Permanent Scatterers Interferometry: A tool for identifying the local dynamics of ground motion

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Synthetic Aperture Radar Interferometry (InSAR) from Earth-orbiting spacecraft has revolutionized the field of crustal deformation research since its first geophysical application, about a decade ago. During the last 10 years, InSAR has been used to study a wide range of surface displacements related to active faults, volcanoes, landslides, aquifers, oil fields and glaciers, to name just a few, at a spatial resolution of less than 100 m and cm-level precision. The temporal resolution is limited by the monthly repeat time of satellite flyovers. Due to the viewing geometry of the radar satellite, InSAR is particularly sensitive to vertical deformation, but cannot detect displacements parallel to the orbit track. Severe limitations to the InSAR method remain, especially decorrelation of surface scatterers due to vegetation or other surface change processes, incoherence caused by large satellite orbit separations between the two image acquisitions used to make an interferogram, and noise from signal delays in the Earth's atmosphere. A new approach, the Permanent Scatterer (PS) method improves our ability to determine mm-scale displacements of individual features on the ground using all data collected over the target area by a SAR satellite (such as the European Space Agency's ERS-1&2 spacecrafts or the Canadian sensor RADARSAT). As long as a significant number and density of independent radar-bright and radar-phase stable points (i.e. PS) exist within a radar scene and enough radar acquisitions have been collected, displacement time series and range-change rates can be calculated. Using the PS method, surface motion can be measured in the range of ~0.5 mm/yr whether for large areas or more local structures such as bridges or dams, not previously recognized in traditional SAR interferometry. PS usually correspond to features on buildings, metallic objects, outcrops, exposed rocks, etc. exhibiting a "radar signature" that is constant with time. Once these "radar benchmarks" have been identified from a time series of radar data, very accurate displacement

histories can be obtained for the period 1992 to the present – the time frame over which SAR imagery has been archived. In this poster, we show the results obtained from processing more than 100 radar acquisitions acquired over the Bay area, by ESA-ERS and RADARSAT sensors. Apart from surface deformation phenomena related to seismic faults many other signals are clearly visible (e.g. subsidence patterns, compaction phenomena and motion of individual structures). More than 100,000 measurement points have been identified in the Southern part of the Bay, including the area of the salt ponds. Data seem to demonstrate that many situations impacted by surface deformation can benefit from radar space measurement of this phenomenon. In the near future, data from SAR sensors and GPS networks will be jointly exploited to extract information not only for the scientific community but also for other users such as engineering companies, Civil Protection authorities and Public Administration bodies in charge of land management.

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A tool for assessing mercury loadings from restored tidal systems

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Accurately quantifying net loads in tidal systems is difficult owing to the high variability in constituent concentrations over the vastly different time scales present in these systems. Perhaps most difficult is the measurement of fluxes over the tidal time scale. On this scale, the net export of the constituent is orders of magnitude less than the bulk exchange in either direction because of the vast quantities of water that are exchanged. Therefore, numerous measurements are required in a brief amount of time to accurately quantify constituent fluxes between a tidal wetland and its surrounding waters. These complications with sampling are exacerbated for mercury species because of the difficulties related to clean sampling and trace-level analysis. One approach to overcome these difficulties is to develop surrogates that may be measured *in situ* and which may be used for interpolating and extrapolating from discrete measurements over a number of tidal cycles and a range of conditions.

The South Bay Salt Pond Restoration Project intends to restore many acres of impounded ponds to tidal exchange. There is evidence that tidal wetlands produce methyl mercury, the bioavailable form of mercury. This is a concern because sediment in the project area has relatively high concentrations of mercury and pond restoration is known to increase tidal prism and to scour sediment from adjacent sloughs. Although restoration is slated to begin, it is unknown (1) how much methyl mercury the restored ponds will export, (2) how much sediment and associated mercury will be scoured in adjacent sloughs, and (3) which management actions will best minimize the transport of these contaminants. The development of an instrumentation package that can be used to monitor *in situ* measurement of the transport of these contaminants would offer a valuable tool for the adaptive management of South Bay restoration efforts.

We have collected data to determine the fluxes of total mercury (Hg) and methyl-Hg (MeHg) in dissolved and particulate phases at Browns Island, a tidally influenced brackish marsh in the San Francisco Bay-Delta. Our field deployment package consists of an upward-looking current profiler to quantify water flux and instruments to measure dissolved oxygen, pH, salinity, temperature, water depth, optical backscatter, and absorption across the ultra violet and visible ranges, as well as the fluorescence of the dissolved constituents and visible spectral attenuation of the particles. Measurements are collected at 15- to 30-minute intervals in the main slough of Brown's Island to capture variations in water chemistry over different time scales. We infer Hg and MeHg concentrations by using multivariate analysis of spectral absorbance and fluorescence properties of the continuous measurements and comparing them to the results of discrete samples taken hourly during each deployment.

Results indicate that *in situ* measurements can be used to predict MeHg and THg concentrations in a tidal wetland slough in the filtered and unfiltered fractions. Despite seasonal differences in constituent concentrations and the optical signatures, these correlations remain robust throughout the spring and fall. These correlations are used to generate high-resolution time series for each Hg species, which then are used to calculate net tidal fluxes.

Sharing Habitat: Can Harbor Seals and Recreational Boaters Coexist in an Urban Wildlife Refuge?

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Public access represents one of the major challenges today's wildlife managers face with respect to protecting species and habitat; that of maintaining the appropriate balance between allowing the public to experience, enjoy and thus productively "consume" these valuable resources while also preventing the negative impacts of disturbance and destruction, which often accompany human activity in natural settings. Resident harbor seals (*Phoca vitulina*) at the Bair Island Wildlife Refuge who share their natural habitat with recreational boaters along the meandering Corkscrew Slough are a case in point. Seals regularly haul-out to rest and rejuvenate on the banks of the slough while human piloted kayaks, motorboats, and other watercraft ply the waters within close range of the animals.

An observational study will be performed to determine the impact of such watercraft encounters on the behavior of seals at two locations within the Bair Island Refuge. Seal behavior will be compared between these two sites in an attempt to determine whether or not the animals are able to habituate to the presence of watercraft in their environment to any degree. Ground based surveys will be conducted to observe and record numbers, age and behavior of harbor seals hauled out or swimming in a particular area of Corkscrew Slough where the animals are exposed to some level of recreational boating throughout the year. Numbers, age and behavior of harbor seals at a more remote location on Outer Bair Island, which incurs almost no boating traffic, (to our knowledge) will also be documented. Baseline levels of group vigilance will be measured through periodic counts of seal visual scanning activity during each observation session. Watercraft traversing these locations will be counted and classified and the reaction of the seals to such watercraft will be observed and recorded. Behavioral response states of "relaxed", "vigilant", "disturbed", and "harassed", will be defined and systematically recorded as the animals react to environmental stimuli including, but not limited to watercraft, humans, aircraft, or the presence of other animals. The responses of seals at the different sites will be compared to determine whether or not seals that have relatively frequent contact with humans and watercraft respond differently to their presence than seals that have very little such contact. Results will be analyzed using t-Tests, ANOVA, and correlations.

The results of this study will contribute to the South Bay Salt Pond Restoration project by assisting wildlife management in the development of recreational boating policy within the refuge. Public stakeholders strongly support the use of waterways for recreational boating in areas to be restored by the project, but they also remain sensitive to the goals of habitat and wildlife protection. Increased knowledge regarding the ability of humans and harbor seals to co-exist within Bair Island waterways will hopefully assist in supporting the needs of each.

What Can Historic Bathymetric Surveys Tell us about How to Move Forward with Restoration Plans?

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Since the California Gold Rush of 1849, trends in sediment deposition, erosion and the geomorphology of South San Francisco Bay (South Bay) have been altered by both natural processes and human activities. Successful restoration of the South Bay salt ponds (with minimal impact upon existing habitats) will be dependent largely upon the amount of sediment available within the system and our understanding of its exchange between tidal wetlands and the rest of the bay.

To assess long-term spatial and temporal variations in sedimentation processes we analyzed a series of six hydrographic surveys collected from 1858 to 2005 in South Bay (Foxgrover et al., 2004). We modeled the surface of the bay floor to quantify net sedimentation volumes, rates of sediment deposition and erosion, changes in tidal flat extent, and alterations in morphology.

Tidal flats in South Bay changed in both total area and distribution from 1858 to 2005. Net sedimentation over the past 150 years oscillated between periods of net deposition followed by periods of net erosion. In addition, trends in net sedimentation varied spatially within the bay; the region south of the Dumbarton Bridge is the only area that experienced net deposition throughout all of the time periods. The most recent period, 1983 to 2005, was marked by a net deposition of sediment south of the Dumbarton Bridge, while north of the bridge, there was infilling of the main channel and slight erosion of the shallows. Such variations suggest a dynamic system in disequilibrium with sediment supply, which should be kept in mind when evaluating the potential success and sustainability of restoration strategies.

Reference

Foxgrover, A.C., Higgins, S.A., Ingraca, M.K., Jaffe, B.E., and Smith, R.E., 2004, Deposition, erosion, and bathymetric change in South San Francisco Bay: 1858-1983: U.S. Geological Survey Open-File Report 2004-1192, 25 p. [URL: http://pubs.usgs.gov/of/2004/1192]

Mapping South San Francisco Bay's Seabed Diversity for use in Restoration Planning

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In an effort to understand the role of sediment in the restoration of South San Francisco Bay (South Bay) salt ponds, an acoustic seabed classification was performed along with the collection of over two hundred sediment samples. The success of the large-scale tidal wetland restoration of up to 15,000

acres of South Bay partly depends on the ability of the converted ponds to acquire and retain enough sediment to support marsh growth. Determining the distribution of South Bay's seabed sediment types and understanding their potential erosive properties helps answer critical planning questions about sediment budgets and sediment transportation.

Acoustic seabed classification is the organization of the seafloor into discrete units based on the characteristics of the acoustic response generated by an echosounder. Acoustic diversity is considered a proxy for geoacoustical parameters including acoustic impedance contrast, scatter and volume reverberation which all vary with sediment type. In addition, biological and anthropogenic features can influence the acoustic response.

Data for an acoustic seabed classification were collected as part of a California Coastal Conservancy funded bathymetric survey of South Bay in early 2005. A QTC VIEW seabed classification system recorded echoes from a single beam 50 kHz echosounder. Approximately 450,000 seabed classification records were generated from an area of about 30 sq. miles. Ten distinct acoustic classes were identified through an unsupervised classification system using principle component and cluster analyses. One hundred and sixty-one grab samples and forty-five benthic community composition data samples collected in the study area shortly before and after the seabed classification survey, further refined the ten classes into groups based on grain size. A preliminary map of surficial grain size of South Bay was developed from the combination of the seabed classification and the grab and benthic samples. The initial seabed classification map, the grain size map, and locations of sediment samples will be displayed along with the methods of acoustic seabed classification.

Tidal Wetland Restoration at Cooley Landing: Design, Implementation & Observations on a San Francisco Bay Salt Pond Restoration

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The 115-acre Cooley Landing Salt Pond Restoration was restored to tidal action in December 2000. Post-breach monitoring of site bathymetry, sedimentation rates, and tide elevations one month, eight months, and three years after breaching indicates that sedimentation is occurring on the restored marshplain and the remnant historic tidal channel system is rapidly re-establishing. The Cooley Landing salt pond – like many others in the Bay – had intact, but silted-in, natural tidal channels and large artificial perimeter "borrow ditches" (created during excavation to create the perimeter levees). In other previous salt pond restorations, the large internal borrow ditches became the major tidal channels, limiting the re-establishment of a more natural channel system. A typical marsh channel system, with sinuous branching channels, is expected to provide improved fish and wildlife habitat compared with the oversized, straighter borrow ditches. The Cooley Landing restoration design included two levee breaches to restore tidal action and borrow ditch "blocks" to promote scour and re-occupation of the natural channel system. The ditch block design features were intended to preferentially direct tidal flows into the remnant natural tidal channels and block flow through the artificial borrow ditches. Monitoring results show that the remnant channels have reoccupied through tidal scour, with channel enlargement and nick point migration progressing upstream from the breaches. Sediment is accumulating both on the restored marshplain and the artificial borrow ditches.

Monitoring also provides insight into two other key issues in San Francisco Bay tidal wetland restoration: breach sizing design criteria and rates of offshore mudflat channel erosion. The breaches, sized to the expected long-term equilibrium channel depth and width have provided adequate tidal drainage within eight months of breaching. The inlet channels eroded quickly through the wide Bay mudflats outboard of the site, deepening by one to two feet in the first month and a total of three feet over eight months.

Baseline Data for Salt Pond Restoration Planning: The New Integrated LIDAR and Bathymetric Surveys of the South San Francisco Bay Region

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The pre-restoration elevations of marshes and depths of ponds and the bay are primary controls on physical processes that will determine the restoration trajectory for South San Francisco Bay salt ponds. Without this fundamental information, the chances for successful restoration are greatly reduced. From 2003 to 2005, three detailed surveys were conducted to collect these critical data to support salt pond restoration in South San Francisco Bay. In 2003 and 2004, the bathymetry of 35 salt ponds were surveyed. From May 5 to 21, 2004 an airborne topographic LIDAR survey was made of the dry ponds, intertidal mudflats (flown at tides below mean lower low water- MLLW), marshes, and the 100-year floodplain. This survey covered more than 325 km^2, extending north from the Alviso ponds to Oakland airport on the east shore and to San Francisco airport on the west shore. Approximately 250 million data points of alternating first and last return data were collected resulting in a data density greater than one point per square meter. Georeferenced digital video was also collected during the lidar survey for use in ground-truthing and characterization of habitat types. From January 10 to April 5, 2005 a comprehensive bathymetric survey was made of the South Bay, Coyote Creek, and selected tidal sloughs. The survey area covered 250 km^2, extending from tidal sloughs and Coyote Creek in the south to approximately San Leandro Marina on the east shore and to Coyote Point on the west shore. Sounding data was collected every 0.3 m along track lines. Track line spacing was 100 m in the Bay and less in Coyote Creek and the sloughs. NOAA played a key role in the bathymetric survey by selecting tide gauge type, loaning accurate acoustic tide gauges, determining optimum locations for tide gauges, aiding in installation of tide gauges, and developing tidal zoning to correct soundings to the 1983-2001 tidal epoch MLLW tidal datum. Referencing soundings to MLLW for the 1983-2001 tidal epoch allows comparison to earlier surveys to determine geomorphic change and whether the bay and mudflats are sinks or sources of sediment—a key question in restoration. NOAA also developed the conversion from MLLW datum to NAVD88, the LIDAR datum. This conversion makes it possible to merge the bathymetry and LIDAR survey to create continuous coverage of elevation and depth. Scientists and managers will use the integrated topographic and bathymetric data as baseline conditions, to document historical change of the bay-mudflat-slough-marsh-pond system, and, in conjunction with future monitoring, to evaluate the system's response to different restoration strategies.

Effects of California Gulls on Nesting Forster's Tern Behavior

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Nest defense is a vital aspect of parental care that involves physical risks and disruption of nesting activities. I examined patterns of nest defense in Forster's tern (*Sterna forsteri*) colonies with respect to California gull (*Larus californicus*) intrusions at three different salt pond sites with Forster's tern colonies. In addition, I performed a spatial analysis of the dispersion of California gull colonies, Forster's tern colonies, and landfills in the South San Francisco Bay area to investigate possible sources of variation in the disturbance rates.

Forster's terns and the co-nesting shorebirds 61% of the times ignored overflying gulls. They responded more aggressively to attacking California gulls that attempted landing on the island compared to gulls that exhibited less aggressive hunting behavior. The disturbance rate associated with the gull activity, especially during California gull attacks, was significantly different between the three salt pond sites. The disturbance rate at the tern colony in A1 salt pond, which was the closest to a California gull colony, was significantly lower (0.030 defense seconds/nest per hour) than at A16 (3.234 defense seconds/nest per hour) and B1 (5.217 defense seconds/nest per hour) salt pond sites. The frequency of gull intrusions accounts for the most of the differences in the disturbance rates at the three sites. The spatial analysis revealed that the distribution of aerial paths used by California gulls, potentially to travel to landfills for foraging, may explain the differences in the California gull activity and disturbance rates between the three salt pond sites.

Habitat Restoration in an Urban Setting: Uncovering Opportunities, Creating Partnerships and Mobilizing Volunteers To Restore the South Bay Salt Ponds

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This poster from Save The Bay provides information about working with volunteers in community-based methods of invasive non-native plant control, site-specific native plant propagation, and outplantings at multiple wetland revegetation sites in the South Bay. Information included descriptions of methods and techniques, native and non-native species lists, monitoring data, and pictures of sites and volunteers. Restoration sites include Bair Island in Redwood City, San Francisquito Creek in Palo Alto, and Eden Landing Ecological Reserve in Hayward.

Major Aspects of Poster

- *Invasive Plant Control* – See examples of projects that successfully reduce invasive plant cover at restoration sites with a variety of manual techniques, including hand digging, sawing, lopping, weed whipping, mulching, and follow-up maintenance.
- *Site-specific Native Plant Restoration*- Focus on importance of native plants from the mid-marsh zones up to the upland transition along leveed sites. See diagram of seasonal process from seed collection to propagation to outplanting, all done by volunteers. Learn about diverse plant palettes, seed collection timing, and best nursery practices.
- *Monitoring* – Do these projects make a difference? By monitoring habitat restoration sites, one can see if a project is affecting the surrounding environment in a positive or negative way. Examples include photomonitoring, vegetation transect surveys in restored plots, and ongoing seedling monitoring in the nurseries.
- *Partnerships* – Diverse partnerships are extremely important in restoration projects. By working to involve local, county, state and federal agencies, private businesses, community foundations, and

other non-profits, more people will become educated about why this work is so important and support future salt pond restoration.

- *Community involvement* – When a community cares about something, they will take a stand to protect it. By involving community members in area projects, they learn how stewardship can be the difference. Involving youth and schools in the restoration process results in classrooms becoming conduits for raising environmental awareness throughout the South Bay community.

Save The Bay is one of many partners supporting the South bay Salt Pond Restoration Project, assisting in many ways from advocacy to planning to providing some of the first opportunities for the public to be involved at the Eden Landing Ecological Reserve in partnership with the CA Department of Fish and Game. This poster is relevant to the Project because it provides:

- A model for responsible public access/ restoration stewardship
- Low-cost techniques for how to move forward beyond the breach- eradicating invasives and establishing natives
- Site monitoring appropriate for volunteers- small low-cost pilot experiments that may be applied to larger breaches

Salt Pond Restoration in the San Francisco Estuary: Management Options for Reducing Mercury Methylation

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To assist the San Francisco Bay Regional Water Quality Control Board with its mercury TMDL implementation plan, tidal wetlands in the San Francisco Estuary are being evaluated to identify options for reducing methylmercury production. Although salt ponds are void of emergent vegetation, they represent one of three major tidal habitat categories in the Estuary being considered in this project (the other categories are tidal and managed marshes). Collaboration of the project team (LFR and UCSC) with the South Bay Salt Pond Restoration Project began three years ago when our proposal was submitted with a letter of support from the Coastal Conservancy. We have met with Restoration Project staff and developed initial plans for conducting studies in the salt ponds. Our evaluation will consider long-term salt pond management as well as the three phases in salt pond restoration: 1) levee breaching and initial environmental alterations, 2) intermediate-term evolution of breached ponds, and 3) "climax" condition of resulting habitats. For each phase we will estimate the potential for methylmercury production, identify potential control strategies for managing and/or restoring the ponds, and determine whether or not such strategies are expected to reduce methylmercury production. This poster will describe how evaluation of salt pond restoration is being incorporated into the conceptual framework for all tidal wetland categories and will report also on the status of our investigations to date. This three-year project, initiated in late 2005, is being funded by the Coastal Nonpoint Source (Northern) bond funds established under California's Proposition 13 (Costa-Machado Water Act of 2000) via a grant titled "Wetland Design and Management Options for Control of Mercury in San Francisco Bay."

A box model of a series of salt ponds in the Alviso Salt Pond Complex, South San Francisco Bay, California

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A box model was developed and applied to simulate water level, salinity, and temperature of the Alviso salt ponds in South San Francisco Bay. These ponds were recently purchased for restoration and are currently managed by the US Fish and Wildlife Service to maintain existing habitat and prevent a build up of salt while a long-term restoration plan is being developed. The model was developed for the purpose of aiding pond managers during the current interim management period, and incorporates management actions specified in the Interim Stewardship Plan (ISP), such as winter inflow controls, in order to achieve these goals.

A previously developed box model of a salt pond, SPOOM, which calculates daily pond volume and salinity, was reconfigured to simulate multiple connected ponds and a temperature subroutine was added. The model simulates rainfall, evaporation, water flowing between the ponds, and water exchange with the adjacent tidal slough network. Theoretical and measured relations between culvert discharge and corresponding water-level differences were used to simulate most flows between ponds as well as between ponds and sloughs. The principle of conservation of mass is used to calculate daily pond volume and salinity. The temperature subroutine calculates hourly net heat transfer to or from a pond and records daily average, minimum, and maximum pond temperatures. The temperature subroutine was validated by comparing temperature output with hourly and monthly measured temperature data from a pond in the Napa-Sonoma salt ponds. Results showed good comparison between the measured and simulated pond temperatures on the daily and monthly time scales. The Alviso SPOOM model is a useful tool for predicting how pond salinities, water volumes, and temperatures will be affected under various pond management scenarios in order to maintain existing habitat and prevent a build up of salt in the ponds in a cost-effective manner during the ISP period.

Monitoring Restored Marshes as Guidance for Future Restoration

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Since the early 1970s, over 45 tidal marsh restoration projects have been constructed around San Francisco Bay, restoring tidal action to more than 2800 acres. Over the next 20 years, with current initiatives being implemented it is likely that tens of thousands more acres will be restored including large areas in the South Bay. Unfortunately, monitoring of the long-term evolution and performance of first generation restoration sites was rarely carried out. This meant that our collective learning experience to answer key practical design questions has been impeded.

In 1986, with the support of local foundations and citizens groups, the first long term monitoring studies were initiated at Muzzi Marsh and Coyote Creek Lagoon. In later years long-term monitoring was started in other restored sites. There are, as of the year 2006, 34 years of restoration history and up to 20 years of systematic monitoring data from tidal wetland restoration projects in San Francisco Bay. There is now sufficient information from these monitoring efforts, and from ‘snapshot’ observations of other restored sites in San Francisco Bay, to provide guidance for the next generation of restoration design. This will allow us to construct future restoration projects more successfully and economically.

Funding from the State Coastal Conservancy to The Bay Institute has allowed the documentation of this experience to produce a design guidelines report. Its target audience includes agency staff and environmental professionals involved in tidal wetland restoration in San Francisco Bay. The full report can be downloaded from http://www.wrmp.org/design/.

This design guidelines report is intended to be a 'Version 1.0' that will help restoration practioners by providing an assessment of how well we can answer key design issues based on what we know now. We anticipate that new insights will be provided in future years by continued monitoring data from restored sites. At some point, we hope there will be a 'Version 2.0'.

Sediment Mercury in Eden Landing and Alviso Salt Ponds, 2003 – 2006.

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We collected sediment cores for analyses of total (THg) and methyl (meHg) mercury twice annually from fall 2003 – winter 2006 at the Alviso and Eden Landing Salt Ponds as part of monitoring efforts for the South Bay Restoration Project. We had 2 main objectives: 1) establish a set of baseline concentrations of total and meHg in south bay salt ponds, and 2) conduct subsequent sampling in ponds with (a) the highest baseline meHg concentrations, (b) scheduled for changing water and salinity regimes, or (c) characterized by important physical features. We sampled 3 sites at each pond. GPS coordinates and discrete water quality measurements (e.g. pH, temperature, salinity, Redox potential, dissolved oxygen) were recorded. For ponds sampled in multiple seasons or years, we collected sediment samples at the same sites to control for geographical variation whenever possible. Sites within ponds were generally 1) near an area of water exchange, 2) a distance of about halfway across the pond and 3) a distance at the far end of the pond away from water exchange. At the Alviso Ponds, THg ranged from 0.27 to 4.2 µg/g (parts per million), and meHg ranged from 1.8 to 9.0 ng/g (parts per billion). Ponds A12, A13, A15, A17, A9, A7, and A3N had meHg that exceeded 2.0 ng/g. Mercury levels in sediments were lower at the Eden Landing than Alviso Ponds, where THg ranged from 0.5 to 0.16 µg/g, and meHg ranged from 0.2 to 3.1 ng/g.

Temporal and Spatial Distribution of Macroinvertebrates in Select Alviso Salt Ponds, 2002 – 2005

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Prior to recent water regime changes in 2005 – 2006 executed as part of the South Bay Restoration Project, we determined the structure of the macroinvertebrate communities from 2002 – 2005 in select Alviso Salt Ponds that represented a range of salinities from about 20 to 140 ml/l (parts per thousand).

The U.S. Fish and Wildlife Service acquired ownership of many of the decommissioned salt ponds and in doing so were responsible for cooperating with State water quality regulations that included salinity reduction. Macroinvertebrate diversity was estimated 3 times per year in winter, summer, and fall in Ponds A9, 10, 11, 12, 14, and 16. In general, species richness decreased with salinity, but biomass in these ponds was balanced by high numbers of species (characteristic of the bay) in low salinity ponds and highly abundant invertebrate resources (corixids, brine shrimp, brine flies) at higher salinities. We document that varying hyperhaline wetlands have unique invertebrate attributes that in turn supported a high diversity of migratory birds.

Critical Parameters of Southern San Francisco Bay: Monitoring Ecosystem State Change from Salt Ponds to Tidal Marsh Habitat in the Alviso Island Ponds Using Geospatial Technology

L. Jean Palmer-Moloney, Ph.D., NASA Ames/SJSU Co-Op; East Carolina University Dept of Geography & Coastal Resources Management Program

Estuarine restoration requires the inventory, assessment, and monitoring of the numerous conditions to evaluate its effectiveness across a broad regional area, incorporating numerous labor intensive, direct measurements. However, inevitable data gaps caused by selective point sampling inhibit statistically valid assessments, for they exclude conditions that exist in unmonitored areas. Analysis utilizing geospatial technology--remote sensing and GIS-- coupled with existing models and sampling schemes can help fill in the gaps and strengthen adaptive management approaches to resource management in this complex environmental system.

The goal of my current research is to develop a predictive geo-spatial model of estuarine wetland ecosystem change that strengthens ecosystem restoration and adaptive management. The central research hypothesis is the allogenic processes that cause state change in the Alviso island ponds of the South Bay Salt Pond Restoration can be determined using Level I ecosystem assessment**,** validated with Level II rapid assessment in the field, and Level III assessment, using remote sensing spectral analysis/mapping combined with extensive sampling and lab analysis. The research methods chosen to guide this study supports the following **research objectives**:

1. Determine extent to which changes in allogenic processes can be detected by or derived from remote sensing in the Alviso island ponds.
2. Determine effectiveness of remote sensing as an extension to field deployments for monitoring change in the Alviso island ponds.
3. Determine the effectiveness of remote sensing for monitoring of parameters established in the SBSP adaptive management project objectives.

Level I assessment will incorporate a suite of existing data (including previously acquired Landsat, ASTER, MODIS, and AVIRIS images), as well as newly acquired imaging (i.e., IKONOS, DOQQs) at various spatial resolutions. ***Level II*** assessment and ground-truthing includes the use of traditional assessment methods (Indices of Biotic Integrity (IBI) and hydrogeomorphic (HGM)), as well as the gathering of field spectra to increase the library of spectral reflectance data for the land cover in the study area. Imaging from satellite and aircraft-based spectrometers will be incorporated and spectral analysis will be conducted in the ***Level III*** assessment of the complex estuarine wetland environment.

This research links remotely sensed and in situ data from different spatial, spectral, and temporal resolutions—from the relatively coarse landscape and regional resolutions of remote sensing to the smaller scale of in situ sampling—to determine the extent to which remotely sensed imaging from operational sensors can be used to characterize the estuarine ecosystem, to assess estuarine ecosystem health, and to predict changes in estuarine habitats in the SBSP Restoration Project.

Western Snowy Plover and Waterbird Use of Managed Salt Ponds at Eden Landing Ecological Reserve, Hayward, CA

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The South Bay Salt Pond Restoration Project is currently planning the restoration of over 15,000 acres of South Bay salt evaporation ponds to tidal salt marsh and managed ponds. One of the goals of the project is to recreate tidal marsh habitat while maintaining the current bird population that uses the salt pond habitat. This study will test whether managing ponds for western snowy plover (*Charadrius alexandrinus nivosus)* nesting and foraging can maintain and sustain snowy plover numbers. This study will compare the federally-threatened western snowy plover use of 5 managed ponds and numerous unmanaged ponds at Eden Landing Ecological Preserve in Hayward. Observations will be made of snowy plover nesting abundance, nest success, chicks fledged as well as preferences to micro-habitat within the salt ponds. During the months when the ponds are flooded, data will be taken on waterbird abundance. Data will be collected during the 2006 and 2007 snowy plover nesting seasons and over the 2006-2007 fall and winter. This study is important to the restoration project so land managers can better control the habitat of this threatened species.

Detecting Annual Changes in Vegetation in a Restoring Salt Marsh using Automated Remote Sensing Techniques

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Tidal wetland restoration projects in the San Francisco Bay-Delta region have increased in number and magnitude over the past 30 years, yet few projects have examined the patterns by which natural vegetation colonization occurs within these sites. Remote sensing techniques using fine-scale imagery, such as aerial photography, can provide large-scale observation of land cover in a cost-effective, time-efficient, and non-invasive manner, while allowing for broad-scale estimation of many parameters valuable to ecologists and managers, including land cover, vegetation structure, biophysical characteristics, and habitat areas. Carl's Marsh, a site located on the Petaluma River that was restored to tidal flow in 1994, served as an exemplary case for testing an automated method of measuring vegetation colonization location, rates, and patterns using common geospatial software. Nine years of high spatial resolution color infrared aerial imagery spanning from 1995 through 2004 were analyzed in order to classify vegetation change since tidal restoration occurred. All images were reprojected and georeferenced to a common projection system using ground control points. Normalized Difference Vegetation Index (NDVI) was calculated for each image and threshold values establishing vegetated versus non-vegetated pixels were determined. Vegetation change detection was calculated by subtracting one year's data from the next and maps showing areas of vegetation gain and loss were generated. Changes in vegetation colonization were successfully captured using this automated technique, including new recruitment near levee and channel edges as well as radial clonal growth around existing patches. By 2004, 90% of the site had been colonized by native vegetation. In addition to quantifying gain/loss, we also explored overall vegetation pattern over the years to elucidate the primary drivers of change, such as growth type and channel proximity. This exploration into vegetation colonization patterns in tidal salt marshes will aid future restoration projects such as the South Bay and Napa/Sonoma salt pond restorations by providing an automated approach using common geospatial software to measure colonization location and rates using readily available and affordable aerial photography.

Degradation of water quality by bird feces in and around managed wetlands

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The South San Francisco Bay salt pond restoration is a multi-faceted project with a major goal of habitat restoration – particularly habitats that support resident and migratory birds. Another goal of restoration is to provide public access and recreation in the project area. Parts of the Alviso ponds, a publicly accessible section of the Don Edwards National Wildlife Refuge within the project area, are currently home to year-around bird residents and large numbers of seasonally migrating or wintering waterfowl.

Bird feces carry fecal indicator bacteria [FIB; specifically total coliforms (TC), *Escherichia coli* (EC), and *Enterococcus* (ENT)] identical to the FIB in human waste. Although FIB are not pathogens, they indicate the potential presence of pathogens, and epidemiological studies show that exposure to FIB during recreation in water correlates with increased risk of acquiring various diseases, including gastrointestinal and respiratory illnesses. Although these studies were conducted in sewage- and urban runoff-polluted waters, not specifically in bird feces-polluted waters, bird feces-polluted waters may pose a threat to human health. There are a number of diseases that potentially can be transmitted from birds to humans, including salmonellosis and campylobacterosis (etiologic agents *Salmonella* spp. and *Campylobacter* spp., respectively). Both *Salmonella* and *Campylobacter* have been isolated from bird feces that were deposited along wetlands in southern California.

Because of the large, seasonal bird populations in the Alviso pond system and the fact that some of the Alviso ponds now discharge to sloughs, there is potential for the discharged water to be of a reduced quality, as indicated by the presence of FIB. In addition, recreation in or around the ponds creates a potential route of human exposure to FIB and pathogens by way of incidental ingestion or inhalation of slough or pond water.

The relationship between winter and summer use of Alviso ponds A9 and A10 by the birds and FIB concentrations in these ponds and adjacent sloughs currently is being examined. Preliminary results from the winter sampling period show that 89 to 100 percent of the slough samples and 0 to 28 percent of the pond samples exceeded the California recreational marine contact water-quality standards for TC, EC, or ENT. Average TC concentrations always were higher in pond A9 than in pond A10 (as was the bird use), while average EC and ENT concentrations typically were similar in the two ponds. FIB concentrations showed a relatively strong negative correlation with salinity. The human pathogen *Salmonella* was isolated from 2 of 3 slough samples and from 1 of 12 pond samples. Analysis of FIB concentrations and bird use of the ponds will be performed after summer sampling is completed.

Processes Affecting Temporal Patterns of Sediment Accretion in a Rapidly Accreting Northern San Francisco Bay Restored Tidal Marsh

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Through physical and biological processes, restored tidal marshes evolve toward conditions more closely resembling natural tidal marshes in their vicinity. In the San Francisco Estuary, and especially in South San Francisco Bay, many lands suitable for tidal marsh restoration are diked former tidelands that have not been developed and their intervening land uses and effects of neighboring land uses have lead to land subsidence. To restore tidal marsh functions, projects must reverse this subsidence through

natural or mechanical accretion. The inextricable linkages between tidal marsh geomorphology, tidal amplitude, and ecology are widely understood – the inundation regime drives all intertidal ecology. This research used high-precision topographic and water column measurements to study patterns and processes of accretion over a 2.5-year period in a tidal marsh restoration in the northern San Francisco Estuary. Mean accretion rates ranged from 0.0 to 0.2 m yr^{-1} during the study period and up to 0.5 m yr^{-1} prior to detailed sampling. These sedimentation rates are "rapid" in that external sediment raised study site elevations from about mean lower low water to nearly mean high water before significant vegetation colonization occurred. Elevations stabilized initially just below mean high water. Key findings from this research include: (1) flood tide suspended sediment concentrations were greatest during biweekly spring tide events, driven by off-site conditions; (2) most of the net sediment influx occurred on one of the two monthly spring tide series, and (3) even with considerable ongoing net sediment influx, site elevations remained nearly constant, just below mean high water prior to major vegetation colonization, suggesting that one or more elevation-lowering processes exerted strong control at this stage of marsh restoration evolution. The results inform our understanding of how the various processes affecting net accretion act at different evolutionary stages, knowledge that can be applied to projecting restoration outcomes especially for South San Francisco Bay.

Integrated Regional Wetland Monitoring Pilot Project – Project Overview

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Regional tidal marsh restoration efforts aim to support and recover populations of plant, fish and wildlife species. These ecological support functions follow successful establishment of a variety of ecological processes in restoration projects. In order to understand the effectiveness of tidal marsh restoration efforts regionally, we must determine which processes are in fact important to establish and the means by which we can measure and quantify these processes.

The California Bay-Delta Authority Science Program's Integrated Regional Wetland Monitoring Pilot Project (IRWM) utilizes a five-element strategy. (1) IRWM is multi-disciplinary, intensive monitoring program covering physical processes, landscape ecology, vegetation, birds, fish, invertebrates, primary production, and nutrients. (2) IRWM established a series of core and component conceptual models that describe the current state of knowledge and define a suite of hypotheses. (3) IRWM developed sampling and data QA/QC and management programs to test these hypotheses, to develop data sets to address the ecological process question, and to evaluate different approaches to restoration monitoring. (4) IRWM selected a suite of six sites (four restoration and two natural) spanning the western Delta to San Pablo Bay based on set of criteria tied to the conceptual models. (5) IRWM will integrate results across disciplines and thereby begin to address the fundamental ecological process question.

IRWM initiated field sampling in fall 2003 and completed sampling in fall 2005. IRWM methods and results, including data, aerial imagery, GIS and mapping products, are accessible to the public at www.irwm.org as data are finalized.

IRWM will contribute an essential strategic element to tidal marsh restoration monitoring in the Bay and Delta in support of ongoing public investment in land acquisition and restoration. Methodologies, findings and analyses resulting from this multi-disciplinary effort may serve to inform planning and monitoring of the South Bay salt pond restoration.

California Clapper Rails in San Francisco Bay: Modeling habitat relationships at multiple scales to guide habitat restoration and eradication of non-native *Spartina*

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Restoring tidal marsh habitat that supports the endangered California clapper rail (*Rallus longirostris obsoletus*) and other special status species is a major goal for the Coastal Conservancy's San Francisco Estuary Invasive *Spartina* Project, the South Bay Salt Pond Restoration Project, and other regional restoration and management programs. However, planning is premised on assumptions about clapper rail habitat use that have not been quantified. In particular, the impacts on rail populations of both tidal marsh restoration and non-native *Spartina* spread and control, considered individually or together, have not been previously studied. Updated quantitative information about general clapper rail habitat requirements, responses to restoration, and responses to invasive *Spartina* will facilitate the improvement of invasive *Spartina* control strategies as well as tidal marsh restoration design strategies.

To contribute to these data gaps, we are testing hypotheses about clapper rail habitat use in Central and South San Francisco Bay, including the following: 1) that large contiguous areas of marsh with many high order (small) channels are preferred; 2) that both unvegetated or sparsely vegetated low marsh (such as that found in channels and young restoration sites), and high marsh with dense vegetation are important; 3) that clapper rail population densities tend to be significantly higher in small, low elevation invasive *Spartina*-invaded patches than they would be if *Spartina* were not present, particularly if the small marshes are clustered near large marshes with established rail populations; and 4) that eradication of invasive *Spartina* may result in localized decreases in rail abundance, particularly in marshes where invasive *Spartina* comprises close to 100% of the vegetation. To test these hypotheses, we are modeling clapper rail habitat relationships using a combination of clapper rail survey data collected at 48 sites in Central and South San Francisco Bay in 2005 and 2006, and field and GIS-generated habitat data at multiple scales, including 2005 invasive *Spartina* inventory spatial data, vegetation cover and structural data, and marsh spatial patch data. Preliminary analyses using marsh patch-level rail relative abundance (rails/ha) and habitat data indicate that variability in clapper rail relative abundance among patches is not associated with the amount of marsh habitat in the surrounding area (at a range of scales), but appears to be related to the relative cover of invasive *Spartina* (a positive relationship) and the average width of the closest channel to the vegetation sampling point (with higher abundance associated with narrower channels); however, these variables only explain 19% of the variability in rail abundance among patches. Approximately 70% of the variability in clapper rail abundance at the patch level is associated with channel width and the differences among clusters of patches (where a cluster is defined as an area of contiguous tidal marsh habitat and associated marsh patches separated by less than 200 m of non-habitat). We will conduct additional analyses to explore these relationships more thoroughly, and include 2005 invasive *Spartina* inventory spatial data, channel maps, GIS-generated vegetation coverage, and elevation data (using LiDAR or field collected data).

Forster's Tern, Caspian Tern and California Gull Colonies in San Francisco Bay: Habitat Use, Numbers and Trends, 1982-2003

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We analyzed data on colonies of the Caspian Tern, Forster's Tern, and California Gull in the San Francisco Bay during 1982 to 2003. There were 13, 17, and seven colony sites used by Caspian Terns, Forster's Terns, and California Gulls, respectively, during one or more years from 1982 to 2003. Mean number of birds at a given site (averaged among years when colonies were occupied) was 296 Caspian Terns (SE + 87, N = 13 colonies), 218 Forster's Terns (SE + 37, N = 17), and 1,424 California Gulls (SE + 849, N = 7). Mean size of gull colonies was significantly larger than that of either of the terns (Sidak tests, both $P < 0.05$). Mean colony size differed little between the two tern species (Sidak test, n.s.).

The number of Caspian Terns breeding within the estuary was stable from 1982 to 2003 (linear: $r_{12} = 0.28$, n.s., quadratic: n.s.). The yearly average was 2,070 birds (SE + 116, range = 1,002-2,636 birds). The largest Caspian Tern colony each year differed across the 22 years, involving Alameda, Bair Island, Brooks Island, Mowry, Turk, and Knight. The Brooks Island colony has been the largest since at least 1997. The yearly average of Forster's Terns was 2,710 terns (SE + 143, N = 21 years, range = 1,628-4,312 birds). There was a significant decline in total number of breeding Forster's Terns between 1984 and 2003 ($r_{18} = -0.49$, $P < 0.03$). Colonies with highest numbers of Forster's Terns differed across the 22 years, and included those at Moffett, Bair Island, Baumberg, Mallard Slough, Hayward Shoreline, Turk, and Knight. The largest colony at the beginning of this study (1982) and middle (1992) was at Moffett (655-1,000 birds); however, only three colonies had >300 birds at the end of the study (Baumberg, Belmont, and Turk).

There was a yearly average of 8,739 breeding California Gulls (SE + 1,245, range = 412 - 21,106, N = 22 years), however, the number increased markedly and progressively ($r_{20} = 0.95$, $P < 0.001$) from 412 birds in 1982 to 21,106 in 2003. Between 1982 and 2003, numbers of California Gulls increased significantly at each of the colony sites of this species. The largest and oldest gull colonies were at Alviso, Mowry, and Marina. The Marina, Mountain View, and Brooks Island sites were stable during approximately the first 15 years of the study followed by an increase during the later 90's and early 2000's; at the Mowry colony there was in increase in the early years, followed by stability during the latter part of the study.

All three species nested on five to six different habitat types, however, 59% and 46% of the Forster's Tern and Caspian Tern colonies, respectively, were located on salt pond islands. Four of the seven colonies of California Gulls nested on salt pond islands and salt pond levees. The largest colony (Alviso) was located on a dry salt pond not in commercial use. An overall lack of colony site fidelity in terns and the decline among Forster's Terns is likely due to mammalian predation, human disturbance, and possibly annual variation in food availability.

Flat, unvegetated islands are critical for maintaining nesting larids. Yet, the planned restoration of 65% (9,050 ha) of the salt pond complex of the San Francisco Bay will likely remove some of the salt pond islands and levees where 20%, 80% and 96% of the Caspian Terns, Forster's Terns and California Gulls, respectively, were nesting in 2003. Thus restoration plans must include the creation of sizeable tracts of islands specifically designed to provide nesting habitat for these larids. Severe habitat limitation would lead to competition for nesting space among the three species, likely resulting in exclusion of the terns by the gull, which nests earlier, are larger, more abundant, and more aggressive.

Avian Use of a Managed Pond: A Case Study in South San Francisco Bay and the Implications for Salt Marsh Restoration

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The San Francisco Bay area contains the most important salt pond complexes for waterbirds in the US, supporting significant numbers of migratory waterfowl and shorebirds, and large numbers of nesting shorebirds, terns, and gulls. The current plan to restore tidal action to most of the existing salt ponds in the Bay places an important emphasis on understanding how to manage the remaining ponds for waterbirds. We analyzed a decade of waterbird numbers at a managed pond to look at use by avian species. Shorebirds, gulls and waterfowl used the managed pond for wintering and migratory stopover habitat with year, season, taxonomic grouping, and water level important factors in determining use.

Nineteen species of shorebirds used the waterbird pond overall with four species of shorebirds accounting for the largest proportion (including dowitchers, American Avocets, Western Sandpipers, and Black-necked Stilts; 55.12%) of all birds using the waterbird pond during the survey period. Shorebird numbers peaked seasonally in the summer (July - September) as species were migrating through the region. Shorebirds were consistently the most abundant group of waterbirds on the pond, except for in 2001 when an influx of California Gulls was observed.

Gulls and terns were the second most abundant waterbird group using the pond during the survey period (25.08%). This group was largely absent from the pond during the spring and summer breeding season (April - September), but gathered in larger numbers to use the pond as a winter roost. We counted 12 species in this group, especially California Gulls, Herring Gulls, and Ring-billed Gulls.

The waterfowl group was the third most abundant group (17.88%) of the waterbirds using the pond, with a total of 15 observed species. Waterfowl were most abundant from October - December (autumn), and were nearly absent from the pond from April to September (spring and summer). Northern Shoveler, Gadwall and Mallard were the most abundant species of ducks on the waterbird pond. Waterfowl numbers started out very low in 1992, peaked in the mid-1990s and have since declined somewhat on the pond.

The most important variable effecting numbers of birds on the pond was the classification of bird group ($F=514.01$, $P<0.001$). Numbers of birds were significantly higher in the autumn and winter than in the spring or summer ($F=75.84$, $P<0.001$). Year was also significant ($F=38.56$, $P<0.001$) although fluctuations make it difficult to see a pattern. There were peaks in bird numbers in 1995 - 96, 1998, and 2001 as well as extreme lows in the first three years of the study. Finally water level determined bird use of the pond ($F=13.621$, $P<0.001$), with higher numbers of birds corresponding to lower water levels (<2.9 NGVD).

The pond had numerous management challenges that are directly relevant to the proposed managed wildlife ponds within the salt pond restoration plan. These included sediment deposition, an unreliable water intake system, and the inability to maintain high salinity levels. This pond did not provide habitat for special status species or high-salinity specialists, nor provide for ground nesting birds. Maintenance of this pond will require active management in perpetuity. These results stress the importance of adaptive management and long-term planning in the Bay restoration project.

Snowy Plover Nesting in Salt Ponds around the San Francisco Bay: Locations and Management Issues, 2004-2006

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Since 2003, the San Francisco Bay Bird Observatory (SFBBO) and the Don Edwards San Francisco Bay National Wildlife Refuge (Refuge) have coordinated monitoring efforts for the Pacific coast western snowy plover breeding population in the San Francisco Bay area. We have monitored sites located on the Refuge and the California Dept. of Fish and Game's Eden Landing Ecological Reserve (Eden Landing) as well as areas owned by Hayward Area Recreation and Park District and East Bay Regional Parks District. We estimated plover numbers, nesting success, and assessed predator pressure on plover nests.

Between 2004 and 2006, snowy plovers have nested on ponds A22 in Warm Springs, RSF2 in Ravenswood, A8 in Alviso, and B6A, B6B, B8, B8A, and B12 in Eden Landing. In 2004, the majority of nests were found on B6B (40/57). A22 had the most nests in 2005 (13/20), and currently B8 has the majority of nests with 20 (of 58 total). Within the ponds, plovers mainly nested on large, isolated playas with little or no connection to surrounding levees.

The biggest concerns we have identified that may limit snowy plover numbers in the Bay include water levels and predation pressure.

Low nest numbers in 2005, along with the increased use of A22 was likely due flooding in large areas of Eden Landing and Refuge lands due to heavy rains early in the year. This suggests that the timing of lowering water levels may play an important role in nest site selection. This year, plovers have returned to ponds in Eden Landing in large numbers; despite late rains these ponds are now managed for plover nesting habitat with increased surface area available. Water management during the Initial Stewardship Plan allows managers to provide better nesting habitat, but we are still learning how best to balance water intake with tidal fluctuations and maintaining isolated playas while avoiding nest flooding. In addition, the influx of tidal waters has increased the number of predators (most notably Black-crowned Night Herons) within nesting ponds due to prey brought in by tides.

The most common avian predators included Common Ravens, California Gulls, and Northern Harriers. In 2004, three nests were predated, and in 2005, two nests were predated. As of May 2006, five nests have been predated: four by avian predators and one by a raccoon. There have been direct observations of predation on snowy plover chicks, adults, and nests by ravens and harriers. In 2006, three Northern Harrier nests were located in areas adjacent to ponds used by nesting plovers. Female harriers have been hunting in ponds closest to the harrier nests. Direct evidence of shorebird chick predation by California Gulls (USGS, USFWS unpublished data) and the nearness of large gull colonies implicate gulls in plover chick and/or nest predation as well.

Since all of the snowy plover nesting and foraging habitat is located in project areas of the South Bay Salt Pond Restoration Project, special efforts should be made to retain sufficient habitat for snowy plovers in the future. Our management recommendations include providing drying salt ponds for nesting along with adjacent high salinity foraging ponds for adults with broods. To reduce predation we recommend removing perches and artificial nesting structures such as towers, and an avian predator control in conjunction with the current mammalian management control. Increased law enforcement and public awareness would reduce the impact from human trespassing.

Napa Plant Site Restoration Project

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The California Department of Fish and Game (DFG) is planning a habitat restoration project at the Napa Plant Site, a former salt production facility in the floodplain of the Napa River near the City of American Canyon, California. The 1,460-acre project site was acquired by DFG from Cargill Salt Co. (Cargill) in March 2003, as part of the larger purchase of 16,500 acres of salt ponds in the San Francisco Bay estuary by the State of California, Fish and Wildlife Service and four philanthropic foundations. The project would:

- restore a mosaic of wetland and associated habitats to benefit estuarine biota including fish, resident marsh species, shorebirds, waterfowl, and small mammals;
- re-establish wildlife corridors and connectivity of habitats at the landscape scale;
- provide recreational and educational public access including a launch ramp for canoes and kayaks, trails, and hunting opportunities.

Historically, the area of the proposed project was predominantly tidal marsh in the floodplain of the Napa River until the turn of the century when it was levied for agricultural purposes. Salt was harvested from the site's ponds from the early 1950s through the 1990s. Hence, the restoration project design needed to address tidal circulation and salinity imbalances in the project area.

MIKE 11, MIKE 21 and combined MIKE FLOOD models were utilized to simulate existing and proposed hydrodynamic conditions throughout the site and design the breach geometry, extent of channel excavation, and evaluate effects of the restoration project on adjacent waterways. A sediment mass balance model was developed to predict and quantify the geomorphic (and hence ecological) evolution of the restoration. Due to the high salinities (>350 ppt in some ponds), the Napa Plant Site currently supports limited wildlife use compared to lower salinity ponds in the region. Cargill is implementing a salt reduction plan, focusing on removing residual salt in the ponds. In February 2006 salinities were less than 50 ppt in the ponds that will be restored in 2007. Since the ponds will be dry when they are breached a diffusion model was developed to simulate the salinity that may be released from pond sediments to tidal waters post restoration. They indicated the residual salts will have minimal effect on the salinity of tidal waters circulating through the site.

Given the site's limited existing wildlife use, restoration has focused primarily on tidal habitats, with provision for some managed ponds. Inclusion of managed ponds in the design introduces the need for more intensive management of the site and raises water quality and fish entrainment issues related to pond management. The close proximity of the project to an airport creates an added concern related to a post restoration increase in waterfowl use that is being addressed in the project design. The northern portion of the site will be reconnected with Fagan Marsh Ecological Reserve. The southern part of the site will become the Green Island Unit of the Napa-Sonoma Marshes Wildlife Area and has the potential to connect to the Bay Trail, as well as pedestrian and cycling trail networks in American Canyon and Napa County. The site will afford opportunities for fishing, hand launching of watercraft, hunting and potentially a future ecological interpretive center. The Napa Plant Site Wetland Restoration project is related to the South Bay Salt Pond (SBSP) Restoration in numerous ways. The area was formerly owned by Cargill and transferred to the Department of Fish and Game in the 2003 sale, as did the Eden Landing area of the SBSP project. The need to reduce salinities prior to breaching and avoid impacts to anadromous fish is similar. The existing avian use is less at the Napa Plant Site than in the SBSP project because of the higher salinities in the pickle ponds and crystallizer beds, however the shorter restoration timeline will provide useful information on which to base expectations for restoration outcomes in the South Bay project.

Holocene Sedimentation in South San Francisco Bay – Geologic Framework for Salt Pond Restoration

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Analysis of split cores, core segments, and X-radiographs of cores taken at 50 locations in South San Francisco Bay provide a geologic framework for the Salt Pond Restoration Project. Most of the core segments are more than 1.5 m long. Core sites are located in and near the main channel in water depths from 2 to 18.5 meters between the San Mateo Bridge southward to just north of Moffett Field. Twenty radiocarbon dates obtained from shell material indicate the cores penetrated sediments as old as 5200+ years BP. Based on sediment thicknesses and radiocarbon dates we calculate a net sedimentation rate (core length to oldest C14 date/C14 age at the point) between 0.01 mm/yr and 1 mm/ yr with an average of 0.54 mm/year.

Cores used for this study were collected in 1990 (Anima, et al, 2005), preserved in sealed core liners and refrigerated. Though slightly oxidized, the cores offer an excellent perspective on the sediment type, sequence, sedimentary structures, fossil content and grain-size of late Holocene sediments in the South Bay.

Sediments in the cores consist of clayey silts, silty clays and shell-rich sediments. Sand is rare. Most of the sediments are dense, moist, cohesive, and have been oxidized to a dark brownish gray. Inclined strata are present in fewer than 10% of the cores. Fine-grained sand or silt in sharp-based laminae that fine upward into silty clays comprise the inclined strata. A sequence of inclined strata in a core taken on the tidal mudflat suggests the presence of a meter-deep channel, now buried, at that location.

Organic material and/or burrows are found in the upper parts of nearly all of the cores. Two types have been recognized. The maldanid worm, *Sabaco elegans*, forms decimeter-long, relatively straight burrows that are prominent in many cores. Short, stubby, sinuous burrows made by one or more unknown organisms are less apparent. Plant debris is found in very rare, millimeter-scale laminae or isolated millimeter-scale patches.

Shells of mollusks are common in the south bay sediments. They are most common near the San Mateo Bridge and along the channel near the mouth of Redwood Creek and south to at least Ravenswood Point. North of the San Mateo Bridge, shell material is common enough that it is mined. South of the Dumbarton Bridge, mollusks are less common and gastropods first appear in the sediment.

Comparison of sedimentary features in the cores with modern sediments on the bay floor suggest that very little change over time has occurred both in the kind of sediment deposited or in the distribution of sedimentary environments.

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