Factors Controlling Spatial and Temporal Trends in Tidal Flat Shape in South San Francisco Bay

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South San Francisco Bay (SSFB) tidal flat morphologic change is examined, using 5 sets of bathymetric data collected by the USCGS, NOAA, and Sea Surveyors between the 1890's and 2005. The tidal flats are broken into geographically similar regions and multiple cross-sections are drawn across the extent of the tidal flats at close - ~50m - intervals, allowing for a determination of mean mudflat bathymetric profile in each region. Eigenfunction analysis is used to separate profile shapes into the dominant components of morphologic variability, which are compared to theoretical models for profiles as a function of waves, tides and sediment supply. Theory predicts that wave-dominated or sediment-starved flats tend to have concave-upwards bathymetric profiles; tide-dominated or accretionary flats tend to have convex-upwards bathymetric profiles. Eigenfunction scores that quantify the spatial pattern of convexity are correlated to spatial variability in fetch length, sediment grain size, recent erosion/deposition, and tidal height. Trends for morphologic change between 1890 and 2005 in twelve geographically diverse regions within SSFB are compared to temporal trends in sediment discharge, mean sea level, diurnal tidal range, and Pacific Decadal Oscillation Index (as a proxy for storminess). Overall, convex profiles were favored in the inner (south of Dumbarton) and concave profiles favored in the outer (north of Dumbarton) estuary throughout the entire historical period. Furthermore, tidal flat morphology of the outer estuary displayed a steady increase in concavity with time. The trend of increasing concavity in the outer-estuary flats was consistent with temporal changes in hindcasted sediment discharge from the Central Valley.

Key Words - *mudflat; tidal flat; shape; sediment; restoration; change*

Theme: Climate Change

Poster Board Number: 2. Submission Number: 202

Peat accretion and carbon sequestration rates in tidal marshes of the Sacramento-San Joaquin Delta, California

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Tidal freshwater marshes accrete peat and, in so doing, sequester carbon. These two functions are of increasing importance as new strategies are required to combat carbon pollution, and the sustainability of marsh habitats are threatened by sea-level rise. The goal of the CALFED-funded REPEAT project was to study peat formation processes over the millennia in marshes of the Sacramento-San Joaquin Delta of California. Peat cores were collected in two high-energy sites, a main channel and the confluence of two rivers, highly influenced by watershed processes, and two sheltered sites, along low-energy tributaries of rivers, largely removed from watershed processes. Bulk density (BD), % organic matter (OM), and % organic carbon measurements and radiocarbon dating were conducted on samples throughout all four cores. Spline fit age-depth models were constructed with the radiocarbon results. The data showed that despite considerable temporal variability in the high energy sites, they had greater BD and lower OM than the sheltered, low energy sites. Mean vertical accretion rates in each of the marshes over the past 6000 years ranged between 0.12 - 0.18 cm yr^{-1}. Mean carbon sequestration rates over the millennia ranged between 80 - 180 g m^{-2} yr^{-1}. For both vertical accretion and carbon sequestration, higher rates were found in the high-energy sites than the low-energy sites. The main determinant of the total amount of carbon stored was the accretion rate, however, this might not necessarily be so in other tidal marsh regions. Scientists and managers interested in increasing carbon sequestration through wetland restoration need to consider vertical accretion rates, carbon sequestration rates, and long-term marsh sustainability in order to choose sites with the highest potential for success.

Key Words - *carbon sequestration; marsh; peat; sea level rise; vertical accretion*

Theme: Climate Change

Poster Board Number: 5. Submission Number: 55

Modeling the Effects of Sea-Level Rise on the Flow and Waves in South Bay, San Francisco, California.

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Global warming is expected to result in a sea-level rise in San Francisco bay of 55 inches (1.4 m) by the end of the century putting an estimated 270,000 people and an estimated $62 billion in economic value at risk of flooding (BCDC, 2009). Knowles (2008) presents a comprehensive analysis of future inundation due to sea-level rise in the bay area. The research presented on this poster focuses on the effects of sea-level rise on tidal propagation, waves, and currents in the South Bay. The Delft3D model system is used. Validation of the model shows that the main characteristics of the tidal motion are reproduced. Model results for various scenarios of sea-level rise illustrate a near-linear response in South Bay in the water levels for sea-level rise scenarios between 0.5 and 5 m. For a 1.40 m sea-level rise scenario (BCDC, 2009) large flow velocity increases occur south of Dumbarton Bridge where the effects of inundation were most pronounced. Near the Golden Gate, along the San Francisco waterfront, and towards Oakland harbor flow velocity magnitudes locally increase up to 10%. Sensitivity simulations assessing the effects of sea-level rise on wave generation, using a range of wind speeds (5-25 m/s) and directions (0 - 260º), illustrate up to 0.50 m increases in wave heights at key locations. Largest increases are observed on tidal flats areas. Besides the well-known problem of inundation, this study points to the possible important effects of increased flow velocities and augmented wave heights, that might pose a hazard for recreational and commercial shipping, and could induce (increased) erosion of the tidal flats.

Key Words - *sea-level rise; numerical modeling; South Bay*

Theme: Climate Change

Poster Board Number: 4. Submission Number: 221

Bathymetry and acoustic backscatter of the mud flats between the Dumbarton Bridge and the Hetch-Hetchy Aquaduct, South San Francisco Bay, California

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On 8 December 2008, 9 February 2009 and 8 April 2009 the USGS conducted hydrographic surveys of the western mud flats between the Dumbarton Bridge and the Hetch-Hetchy aqueduct. The surveys are part of a multi-year program designed to establish baseline bathymetry for the study area and to monitor seasonal geomorphic change and the effects of salt pond restoration. The surveys were conducted using the state-of-the-art research vessel R/V Parke Snavely outfitted with an interferometric sidescan sonar for swath mapping in extremely shallow water. Favorable survey conditions prevailed throughout the first three surveys and the system was able to map in 1.5 m water depth; collecting 10 m to 15 m swaths of bathymetry and acoustic backscatter with as little as 30 cm of water under the transducers. The data from each survey were binned on a 1-m grid and had 95% vertical uncertainties on the mud flat and main channel of 0.20 m; 0.18 m and 0.16 m for the December, February and April surveys. respectively. No statistically significant differences in bathymetry were detected between the average mudflat depth suggesting that mean geomorphic change in the mud flat between December 2008 and April 2009 was below the detection threshold of the mapping system. When the three surveys were stacked together (to average out system noise), the uncertainty in the seafloor bathymetry drops to 0.12 m at 95% confidence---close to the theoretical limit of this sonar mapping system. Unlike the bathymetry, the acoustic backscatter showed a variation between the first two surveys. In the December 2008 survey, the lower third of the mud flat had anomalously bright acoustic returns with no expression in the bathymetry. In spite of its large size, the feature disappeared from the backscatter in subsequent surveys. At this point, the nature of the feature and its geomorphic significance is unknown.

Key Words - *mudflat; tidal flat; mapping; sediment; restoration; change*

Theme: Climate Change

Poster Board Number: 1. Submission Number: 194

What have we done to the Bay? Anthropogenic impacts on net sediment volume change in Central San Francisco Bay, 1855 – 1979

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Understanding the patterns and quantities of sediment deposition and erosion in Central San Francisco Bay is not possible without accounting for the many anthropogenic alterations made to the system. Dredging, dredge disposal, the use of bay sediment for construction, and sand mining are detectable in the series of five bathymetric surveys from 1855 to 1979. During this time period approximately 50 million cubic meters of sediment were removed from the system.

The first federally recognized dredging project for navigational purposes, Oakland Harbor, was authorized in 1874. Since that time there have been approximately 17 locations within Central San Francisco Bay that have been maintained by dredging. Of the documented 56 million cubic meters dredged, approximately 37 million cubic meters of sediment can be quantified by our study.

Dredge disposal went unregulated up to 1972, but depressions southwest of Alcatraz Island and southwest of Yerba Buena Island were used often. During the period from 1985 to 1920, we calculate that these two areas gained approximately 16 million cubic meters of sediment.

The removal of sediment and the creation of borrow pits strictly for use in development is first noted in 1935 with the construction of Treasure Island for the Golden Gate International Exposition 1939—1940. This undertaking required 22.5 million cubic meters of sediment taken from within Central San Francisco Bay.

Sand mining in San Francisco Bay started in the late 1800s and continues to date and always results in a loss of sediment from the system. In the sand mining lease areas, there was a net loss of 6 million cubic meters of sediment from 1947 to 1979.

It is possible to estimate the volume of sediment affected by dredging and other activities using bathymetric change grids. Although it may be difficult to separate the sediment volume change associated with anthropogenic activities from those associated with natural changes in deposition and erosion, it is important to do so. From 1947 to 1979, of the 50 million cubic meters of sediment lost from Central Bay, we estimate approximately 60 % was removed by anthropogenic activities.

Key Words - *Anthropogenic, Sedimentation*
Theme: Climate Change
Poster Board Number: 3. Submission Number: 169

Youth Understanding Water Resource Systems in the Face of Climate Change

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Problem: Lack of understanding and considerable misconceptions among youth on how water flows through and is used by their communities, how that usage affects the health of downstream ecosystems, and how climate change may affect local water systems. Approach: UC Davis John Muir Institute of the Environment's public education programs seek to disseminate knowledge, correct misconceptions, and change behaviors and attitudes of school-aged youth about water in the face of climate change. A variety of in- and out-of-school water education programs in Yolo and Solano Counties establish the connection between upstream watershed actions and downstream San Francisco estuarine consequences. To close the gap between generalized knowledge and lived experiences, our programs trace the path of water through our sub-watersheds in interactive activities using familiar places, everyday actions, and contextualized examples. Understanding "how water works" in turn allows youth to accurately predict the consequences of their actions on the local watershed and the San Francisco Estuary as the repository of the entire watershed's runoff. Finally, our programs support personal and community action projects in pursuit of protecting the natural resource most endangered by climate change, water. Findings: Feedback from educators and surveys with youth indicate that youth demonstrate marked improvement in understanding water systems and the implications of their actions after participating in our programs. For example, comparison of pre- and post-responses revealed that youth misconceptions about the sources and destinations of their water decreased and, conversely, their content knowledge about their watershed and an awareness of the need for water conservation increased. Implications: Public education programs can provide youth with a comprehensive understanding of water and the experience of being problem-solving resource protectors. This builds confidence, knowledge, and self-efficacy that youth can make a difference in the health of aquatic systems in the uncertain era of global climate change.

Key Words - *youth; education; watershed; climate change*

Theme: Climate Change

Poster Board Number: 11. Submission Number: 254

The effects of local climate variation on heron and egret nesting activity: implications of climate change

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Changes in the structure and composition of wetland systems as a consequence of rising global temperatures have been predicted, yet little is known about how these changes might alter the activities or roles of top wetland predators. Herons and egrets are important wetland predators that breed and winter throughout the San Francisco Bay area. Winter rainfall enhances the extent of seasonal wetland feeding areas for herons and egrets, but heavy winter weather may also reduce prey availability and foraging efficiency. Therefore, climate variation might enhance or reduce the availability of food needed for nesting and the survival of juveniles during their first winter. In addition, intra-seasonal thresholds in prey availability have been associated with the timing of nest initiations, and herons and egrets are known to delay nesting in response to extended (late) winter rainfall. We investigated variation in heron and egret nesting performance and abundance in relation to climate variation, over 19 years at all known nesting colonies in the northern San Francisco Bay area. We measured local climate variation using annual and monthly rainfall and temperature estimates generated by the PRISM Climate Group, Oregon State University. Response variables included the timing of nest initiations, net local and regional nesting recruitment, nest survivorship, and the productivity of successful nests. Our results revealed rainfall effects on annual variation in regional nesting abundance and suggested that local climate variation may be related to annual shifts in nesting distribution and abundance. We used these results to consider the implications of long-term climate change on the regional nesting activities of herons and egrets and changes in the structure of regional wetland systems.

Key Words - *climate change; wetlands; Great Blue Heron; Great Egret;*

Theme: Climate Change

Poster Board Number: 7. Submission Number: 170

Long-term trends in nutrient and chlorophyll-a concentrations in the Central San Francisco Estuary, CA

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Estuarine environments exhibit large seasonal and interannual changes in nutrient and chlorophyll–a concentrations as a result of variable flow conditions and phytoplankton activity. In the San Francisco Estuary (SFE), freshwater flow is a critical driver of this variation and is likely a determinant of the timing and magnitude of spring blooms. High concentrations of nutrients occur in the estuary, at non-limiting eutrophic levels; with elevated ammonium levels probably from anthropogenic sources. This eutrophication (e.g. high dissolved inorganic nitrogen) does not result in the negative side effects common in other estuaries (anoxia and harmful algal blooms) but may instead influence the food chain for sensitive upper trophic level organisms that rely on phytoplankton. Long-term records of key chemical and biological parameters paired with river discharge provide insight into potential biogeochemical impact from perturbations in freshwater flow due to changing climate and water diversions. Here we describe variation in nutrients and extracted chlorophyll-a during the spring period using a 6-yr time series from the most seaward embayment of the SFE, Central San Francisco Bay. With close proximity to the ocean, nutrients and chlorophyll-a in Central Bay appear to be modulated by variations in freshwater flow, particularly in spring during anomalously wet and dry years. High flow conditions lead to water column stratification, mobilize non-point nutrient sources, and potentially dilute point source nutrients. Insights gained from this analysis may help elucidate the links between climate and increased water demand on biogeochemical functioning of major estuarine systems.

Key Words - *climate change, phytoplankton, nutrients, chlorophyll*

Theme: Climate Change

Poster Board Number: 10. Submission Number: 148

Assessing the effects of climate change and globalization on the pathways of species invasion in the San Francisco Bay/Sacramento-San Joaquin River Delta Ecosystem

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Globalization and new technologies of the past half-century have increased by orders of magnitude the speed, frequency and types of pathways by which non-native invasive species (NIS) introductions occur. The San Francisco Bay, known as the "most invaded ecosystem", has a new NIS introduced every 14 weeks (Cohen and Carlton 1998) with many of these introductions arriving in ballast water. Introduced by ballast water to the Great Lakes in the mid 1980's, quagga and zebra mussels rapidly spread throughout many major rivers, via trailered boats, including the Colorado River, and reaching Southern California in 2006. Both examples illustrate how our global and mobile society has aided in the transport of NIS.

Climate change is likely to exacerbate the already complex NIS problem. Increases in atmospheric carbon dioxide and global temperatures lead to changing precipitation patterns and a whole realm of other environmental factors that will cause stress in ecosystems which may allow NIS to expand their distribution range. Natural resource managers need tools to help prevent, control and manage NIS. As a starting point for assessment, Hellmann et al (2008) identified five potential consequences of climate change for NIS: (1) altered pathways, (2) altered environmental constraints, (3) altered distribution, (4) altered impact, and (5) altered management effectiveness.

The most practical approach to prevention and control is eliminating the pathways, or means and routes by which NIS are introduced and developing methods to reduce the risk of spreading all species that have "access" to these pathways. Assessing the invasive pathway as a starting point for gauging the potential consequence of climate change and globalization for NIS may help land and water managers in the Bay-Delta develop strategic plans to combat the growing threat of NIS

Key Words - *invasive species; climate change; pathways*

Theme: Climate Change

Poster Board Number: 8. Submission Number: 183

Modeling the Impacts of Climate Change and Reduced Freshwater Flows on San Francisco Bay-Delta Wetlands and Their Associated Plant and Animal Communities

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Climate change and population growth will both impact future water inputs to the San Francisco Bay-Delta. Climate change will shift the timing and amount of seasonal freshwater inputs and will increase water levels and push saline water farther into the estuary via sea-level rise. Population growth will cause greater freshwater diversions, exacerbating impacts of climate change. As a result of these changes and increased summer temperatures, Bay-Delta wetlands will experience increased summer salinities and increased inundation rates. These wetlands perform important ecosystem services, including providing habitat for endangered species and recreationally important fishes, sequestering carbon, and improving water quality. We have initiated a multi-year study evaluating the effects of climate change on marsh dynamics, concentrating on the effect of salinity and inundation regimes and modeling how changes in these factors associated with climate change will impact Bay-Delta wetland ecosystems. We are investigating plant distributions, decomposition and productivity, sediment accretion, and food web dynamics across the estuary. Freshwater inputs clearly structure plant communities as freshwater marshes have higher rates of both diversity and productivity (>60 species, 2440 g m-2 y-1) than brackish (24-50 species, 900-1400 g m-2 y-1) or salt marshes (10-17 species, 270-700 g m-2 y-1). Measurements of sediment accretion and plant decomposition rates indicate greater importance of mineral versus organic matter contributions to marsh accretion as freshwater inputs decrease. Preliminary δ15N and δ13C stable isotope data suggest a dependence of resident fishes on the productivity of specific assemblages within marshes, suggesting that pelagic consumers will be impacted by changes in marsh plant communities in response to changes in freshwater flows, salinity, and inundation. Although climate change impacts on Bay-Delta wetlands will be unavoidable, careful management that maintains freshwater flows into the estuary will be critical to preserving these ecosystems and the diversity of services they provide.

Key Words - *Climate Change; Plant Communities; Food Webs; Accretion*
Theme: Climate Change
Poster Board Number: 6. Submission Number: 203

Managed Shoreline Realignment in San Francisco Bay

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The low-lying San Francisco Bay shoreline is exposed to the risk of flooding and erosion with the magnitude and frequency of these events likely to increase due to accelerated sea level rise (Pacific Institute, 2009; PWA, 2009). Protecting the shoreline using traditional methods, such as "hard" shoreline armoring, is expected to incur adverse effects on the natural shoreline and ecosystems, constraining the natural evolution of beaches, mudflats, and salt marsh (Caldwell, 2007). These traditional methods are a short-term solution to protecting property and infrastructure on a dynamic Bayshore, where erosion and deposition produce continually changing geomorphic features. A more sustainable alternative is to work with the dynamic Bayshore and move development and infrastructure away from erosion and flood hazards and allowing evolution over time, a process of "managed retreat" or "managed realignment." Managed realignment presents a long-term solution which allows the shoreline to evolve over time, yet continues to protect property. While managed retreat does not preclude the use of hard armoring, the realignment of levees and removal of artificial bay fill has several benefits: natural Bayshore processes are allowed to continue, levee size is reduced for the same level of protection, and future risk of damage is reduced. Discrete shoreline setbacks will play a major role in land-use planning to provide a buffer in zones of erosion and flood hazards. Examples of the application of managed shoreline realignment in the San Francisco Bay area will be presented.

Key Words - *managed shoreline retreat; managed shoreline realignment; setback; sea level rise*

Theme: Climate Change

Poster Board Number: 9. Submission Number: 213