

BAY-DELTA SCIENCE
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Oral Abstracts

Sorted by Date and Session

CONCEPTUAL MODEL OF MERCURY IN TOMALES BAY

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This second presentation on mercury in Tomales Bay focuses on hydrodynamics, mercury in sediment, and provides a conceptual model to support a Total Maximum Daily Load (TMDL) for mercury in Tomales Bay. (Kat Ridolfi's first presentation focuses on methylmercury bioaccumulation in wildlife prey.) Tomales Bay is a potential case study for how mine remediation may benefit the Bay-Delta. Mercury, methylation, and bioaccumulation are issues common to both Bay-Delta and Tomales Bay. They share sources in common (mercury mining and atmospheric deposition), although there are no industrial or wastewater discharges to Tomales Bay. In contrast to the Bay-Delta, mercury mining in Tomales Bay occurred recently (in the 1960s) and the single mine site was remediated in 2000. Hydrodynamic forces in Tomales Bay confine mine pollution to a localized area (Walker Creek delta) where it is buried by cleaner sediments. Our preliminary conceptual model describes that mercury in sediments is methylated and bioaccumulated through the food web to levels that sometimes exceed safe thresholds for humans and wildlife. Mean mercury in preferred shell- & sportfish is 0.2 mg/kg (the proposed target), but in less frequently consumed sportfish (sharks & rays) is 0.8 mg/kg. There are bay-wide fish consumption advisories for sport fish (but not commercial shellfish). Total mercury concentrations in sediment decrease with distance from the Walker Creek delta, as do methylmercury concentrations in benthic biota (limited data). Initially, we plan to leverage existing mercury control programs. We estimate that mine site remediation reduced loads by 90 percent (see related poster). Previously eroded mine wastes still caught in the downstream channel will be addressed by other, existing TMDLs. Marin County already has programs in place to reduce mercury from stormwater runoff. We plan to monitor mercury concentration trends in biota over time to ensure they decline to safe levels.

Monday, September 27, 2010: Room 306 Mercury (I) - Order: 1

ASSESSING IMPAIRMENT OF TOMALES BAY DUE TO MERCURY

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Mercury (Hg) contamination is a key challenge impacting ecosystems in the Bay-Delta region of California. Though Tomales Bay's relatively localized, recent Hg source and distribution contrasts with the Bay-Delta's wide range of Hg sources (dominated by legacy mining) and larger spatial distribution, management of the two systems have faced similar challenges and used some of the same methodologies to develop regulatory guidelines. This study offers insights into better understanding and managing the Bay-Delta ecosystem through the example of studying mercury contamination in Tomales Bay. Mercury mining occurred in the 1960s on Walker Creek, a major tributary to Tomales Bay. Since then, storm events transported mercury-laden sediment into Tomales Bay, resulting in a bay-wide fish consumption advisory for sport fish. We focused on risk to birds and wildlife from mercury to supplement existing information on risk to humans. To assess risk to wildlife, we calculated numeric targets based on prey fish following the same methodology used in the Guadalupe River and Delta TMDLs, and collected common species of small prey fish to determine if mercury concentrations in fish exceed these targets. Target prey fish (5-15cm in length) had a mean Hg concentration of 0.05 $\mu\text{g/g}$ ww, meeting the numeric target for protection of piscivorous wildlife. Additionally, we collected sediment and water samples to answer key questions regarding the spatial distribution of total and methylmercury. Since elevated sediment mercury concentrations were confined to the Walker Creek delta (where mining-contaminated sediments accumulate), we conducted a second round of biota sampling in that area on a wider range of bird prey to better assess risk to birds from mercury. The results will be used by the San Francisco Bay Regional Water Quality Control Board to develop a TMDL for mercury in Tomales Bay, and as a baseline for a long term monitoring program.

Monday, September 27, 2010: Room 306 Mercury (I) - Order: 2

METHYLMERCURY EXPORT FROM A RESTORED TIDAL MARSH: CRISSY FIELD, GOLDEN GATE NATIONAL RECREATION AREA, SAN FRANCISCO, CA

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Due to its small size, a single inlet and outlet, and a tidally-dominated water budget, the restored salt marsh at Crissy Field, Golden Gate National Recreation Area provides a good opportunity to construct a total mercury (THg) and methylmercury (MeHg) mass balance for a tidal wetland. We sought to determine a) the extent to which Crissy Marsh was a source or a sink of MeHg to San Francisco Bay, b) where and when MeHg is produced within the marsh, and c) the MeHg concentrations in sediment and water during and outside of periodic extended flooding brought on by inlet closure events. Surface water at a well-mixed station within Crissy Marsh showed surprisingly high aqueous MeHg concentrations ($>1 \text{ ng L}^{-1}$) given its low sediment THg concentrations. A 24-hour sampling event over a full asymmetrical tidal cycle was conducted during August 2008. Particulate and filter-passing (0.45m) THg and MeHg concentrations were assessed, along with key water quality parameters including concentrations of chlorophyll a and total suspended solids. Concentrations of THg and MeHg were coupled to flow calculations from a USGS-tailored hydrodynamic model developed for tidal prism relationships at this site. The resulting load calculations demonstrated that for this 24-hour period, the marsh was a net source of dissolved MeHg to the bay and a net sink of particulate THg from the bay. Overall total Hg flux was not significant with compounded errors. Spatial and temporal patterns of sediment %MeHg suggest that microbial production of MeHg was most active in the low intertidal (cordgrass-dominated) zone. We conclude that mercury present in Crissy Marsh, whether originating from historic contamination or current atmospheric deposition, is subject to methylation and a portion is exported as MeHg. With isotopic evidence pointing to the importance of local sources of MeHg to San Francisco Bay foodwebs, we suggest that these conservative flux estimates from a small well-constrained wetland system is consistent with the idea that salt marsh MeHg flux may be a significant source of MeHg to San Francisco Bay.

Monday, September 27, 2010: Room 306 Mercury (I) - Order: 3

MONITORING METHYLMERCURY AT THE BASE OF AQUATIC FOOD WEBS: A BOTTOM UP, INTEGRATED APPROACH FOR ASSESSING CHANGE IN MERCURY BIOAVAILABILITY IN NATURE

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Mercury (Hg) is a naturally occurring trace element in the San Francisco Bay and Delta that has been mobilized by human activities in sufficient quantities such that it poses a threat to fish, wildlife, and humans that consume fish. A significant challenge in addressing the problem in San Francisco Bay has been identifying the relationship among Hg load, biogeochemical transformation to methylmercury (MeHg) and uptake into the base of the food web. Zooplankton have been shown to be particularly sensitive to short term changes in dissolved MeHg concentrations in water and suspended particulate matter within freshwater and more recently marine and estuarine environments. As part of a larger study evaluating Hg dynamics in Sinclair Inlet from August 2008-August 2009, WA, we examined monthly and spatial variability of MeHg concentrations in whole community and species-specific zooplankton samples as well as the MeHg content of their food. Factors thought to influence the bioavailability and uptake of MeHg into the base of the food web were also measured (e.g. chlorophyll a concentrations, TSS, DOC, particulate carbon, particulate nitrogen, and their stable isotopes). A strong seasonal cycle in MeHg in zooplankton was found that corresponded to changes in food quantity and quality. Mean zooplankton MeHg concentrations in the summer and autumn of 2008 from Sinclair Inlet were elevated compared to values in winter. Seasonal variability of chlorophyll a concentrations ranged from >60 µg/L in summer to <2 µg/L in winter. Further, seasonal variation in zooplankton MeHg corresponded with changes in MeHg in sediments and porewater (reported elsewhere). Monitoring MeHg accumulation in base consumers provides a direct measure of changes in MeHg sources that control accumulation in top predators and thus, could provide a sensitive tool to manage future potential risks associated with climate change, restoration projects, and water management practices in San Francisco Estuary.

Monday, September 27, 2010: Room 306 Mercury (I) - Order: 4

A PRELIMINARY FRAMEWORK FOR MONITORING MERCURY IN WETLAND PROJECTS: TIDAL MARSH MERCURY BIOSENTINELS AS ADAPTIVE MANAGEMENT TOOLS

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The potential to increase net methylmercury production and bioaccumulation is a concern for wetland restoration efforts. Wetland projects incorporate different habitat types with distinct food webs and potentially different mercury cycling regimes. Biosentinels can be effective tools for monitoring wetland food webs for mercury exposure and distinguishing differences in methylmercury bioaccumulation in particular geographic areas and food webs, which can in turn, inform managers and restoration designers in their decision-making about wetland projects. A case study will be presented from the South Bay Salt Pond Restoration Project. South Bay is already impacted by contaminants, and has the largest historic mercury mine in North America, the New Almaden Mine, in its watershed. The South Baylands Mercury Project was a multifaceted effort to evaluate restoration and management options for a complex of ponds at the foot of the New Almaden watershed. Water, sediment, and biota were sampled in a three-year effort to assess changes in mercury bioaccumulation that could occur when the ponds are restored to tidal action and, eventually, to tidal marsh wetlands. This study included the development of biosentinel species that indicated mercury exposure at appropriate spatial and temporal scales, as well as with appropriate habitat specificity to answer the management and restoration-design questions. Probabilistic ambient surveys and site-specific comparisons of biosentinel tissues were completed for key habitats in managed pond and tidal marsh. All scientific results were analyzed within a decision-tree framework to increase the utility of the project for the restoration project managers.

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GUADALUPE RIVER WATERSHED MODEL: SUPPORT TOOL FOR REGIONAL HG AND PCB MANAGEMENT

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San Francisco Bay is listed as impaired for mercury (Hg) and PCBs, and the associated TMDLs call for improved regional loads estimates and large load reductions from urbanized small tributaries, including a >90% load reduction from the Guadalupe River watershed. In order to address this call, managers need improved information on which BMPs may be effective and what magnitude of application will be needed to see measurable loads reductions at the watershed and regional scales. To inform the management questions, the Regional Monitoring Program for Water Quality in San Francisco Estuary funded a pilot study to develop a dynamic watershed model of the Guadalupe River Watershed. This watershed offers a unique opportunity to study legacy Hg from the largest-producing former Hg mine in North America as well as legacy PCBs from the manufacturing industries of the 1950s and 1960s. The availability of abundant local data combined with management issues make Guadalupe River Watershed an ideal location to explore the use of models for better understanding transport of contaminants in the urban landscape. The objective of the Guadalupe Watershed Model project is to understand the source, release, and transport of sediment and contaminants from a large mixed land-use, highly urbanized watershed. The first phase of the project was to develop the underlying hydrological model in the EPA's watershed modeling software suite BASINS/HSPF. A reasonably accurate model (within 20% of annual flow volumes) was developed despite challenges due to the high degree of watershed hydromodification including numerous reservoirs and percolation ponds. The second phase, currently underway, is to add sediment, Hg and PCBs into the model. The final model will serve to improve the accuracy of Hg and PCB load calculations, to investigate inter-annual load variability due to climate, and to allow scenario testing for optimizing management practices.

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A NEW WAY OF LOOKING AT CONTAMINANTS IN THE DELTA-- USING THE RMA PARTICLE TRACKING MODEL TO ASSESS THE FATE AND TRANSPORT OF METHYL MERCURY IN THE DELTA

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Currently about one half of the Delta has top level predator species that are above the EPA human health guidelines for mercury. There are goals by the California Bay Delta Authority to create and restore thousands of acres of wetlands and to drastically alter the structure and functioning of the Delta with additional storage and conveyance (peripheral canals) structures. The effect of these changes on mercury concentrations in water, sediment and fish are unknown. Government managers would like to know what areas of the Delta would increase or decrease in mercury for each of the proposed changes to the Delta. In previous reports a methyl mercury mass balance model was developed but only allowed predictions between the riverine input sites and the export sites of the Delta by lumping all the import sites together and export sites together. In this study the RMA particle tracking model was used to predict the transport routes and fate of methylmercury in sub regions of the Delta. The findings indicate there are major processes including photodemethylation and sedimentation that occur in the central Delta as opposed to the Sacramento River Channel. The particle transport model could be used to predict how different water conveyance projects and methylmercury control programs would influence fish mercury concentrations. For example, flow or methyl mercury concentrations could be reduced in the model from one of the tributaries and predictions could be made on how the fish would change in mercury concentrations at several downstream areas in the Delta.

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ASSESSMENT OF THE POTENTIAL FOR USING IRON AMENDMENTS TO DECREASE NET METHYLMERCURY EXPORTS FROM TIDAL WETLANDS IN SAN FRANCISCO BAY

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Many wetland restoration projects are planned or underway within the Bay-Delta System, including a commitment to restore around 40,000 acres in the Delta by 2030. Because tidal wetlands can be important sources of methylmercury (MeHg) there is concern that wetland restoration will increase MeHg loading to sensitive aquatic ecosystems. In recognition of this potential problem, the Delta Basin Plan and mercury TMDL establish a goal of no significant increases of MeHg due to restoration activities. While these are laudable goals, the absence of landscape-scale approaches for controlling MeHg production in wetlands puts restoration in conflict with mercury control activities. Amendment of wetland sediments with iron offers a potential means of limiting the concentration of dissolved, bioavailable mercury-sulfur complexes in the sediment porewater to the methylating bacteria. We previously demonstrated the efficacy of this approach in laboratory experiments with sediment slurries. To better understand the effect of iron amendments on in situ tidal marsh biogeochemistry, microcosm and field studies have been conducted at a tidal salt marsh along the Petaluma River. Before and after amending the sediments with iron, porewater from pickleweed-dominated sediments on the high marsh plain were analyzed for iron, sulfur, and methylmercury. Seasonal variations in MeHg production and the effect of iron addition on sulfur and iron cycling and MeHg production were evaluated by following concentration changes over time. Understanding these cycles and the length of time for which iron amendments are effective is an important step in evaluating the potential for using this approach to help reduce MeHg production from the restoration of tidal wetlands.

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BEST MANAGEMENT PRACTICES TO REDUCE METHYLMERCURY CONCENTRATIONS AND EXPORTS FROM SEASONAL WETLANDS IN THE YOLO WILDLIFE AREA, CALIFORNIA

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There is widespread mercury contamination in the Sacramento-San Joaquin Delta. The mercury species of greatest concern to human and wildlife health is monomethylmercury (MeHg). There is concern that increasing total acreage of wetlands in the Delta will have the unintended consequence of increasing MeHg contamination. The goal of this study was to develop best management practices (BMPs) to limit MeHg loads discharged off wetlands in the Yolo Wildlife Area (YWA). Two experiments were conducted: 1) measured MeHg concentrations in seven ponds during seasonal flooding, and 2) measured MeHg as seasonal wetlands were drained into permanent ponds. Results show concentrations of MeHg in most of the seasonal ponds studied have an initial peak occurring in fall followed by a decrease and a leveling off after January. Concentrations are high (6-15 ng/L) relative to supply water indicating seasonal wetlands produce MeHg. Permanent ponds had lower MeHg concentrations than supply water from seasonal wetlands. Reduction in MeHg concentration occurs once tail water from a seasonal wetland enters a permanent pond. Permanent pond S5 received water from a seasonal pond high in MeHg (average 11.3 ng/L) and concentration was reduced by an order of magnitude (average 1.18 ng/L). Permanent ponds acted as treatment ponds and removed an average of 81% of the MeHg that entered the ponds. Further development of a BMP using permanent ponds to treat seasonal pond tail water is warranted from data presented in this study. Several factors in permanent ponds may be important in removal of MeHg and should be investigated to develop the BMP to implementation stage. These factors include pond design, biological communities, photodemethylation, hydraulic residence time, and particle settling. Development of BMPs to reduce MeHg loads from seasonal wetlands is relevant to wetland restorations as they limit an increase in mercury contamination to surrounding waterways.

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SALINITY CONDITIONS IN THE BAY AND DELTA: NATURAL VARIABILITY AND ANTHROPOGENIC INFLUENCE

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Salinity in the San Francisco Bay and Delta, where saline ocean waters meet fresh riverine waters, is affected by both natural events and human activities. Paleoclimatic evidence, obtained from proxy information such as tree rings and sediment deposits, provides a history of hydrology and salinity conditions starting well before human influence, but continuing through the 20th Century. Examination of paleoclimatic studies, together with modern direct instrumental observations, reveals natural variability and the effect of human interference. Historical salinity information is recorded in situ in the sediments and determined by quantification and taxonomic identification of diatoms, plant seeds and roots, and plant pollen, as well as measurement of peat carbon isotope ratios. Sediment cores at multiple locations in the Bay and Delta reveal site-specific variability, yet many reconstructions indicate that salinity increased abruptly about 100 years ago, reaching or exceeding salinity levels at any other time in the 2,500 years of reconstructed records. Furthermore, although multi-century dry periods are evident in Bay sediments, these long dry periods are not seen in Delta sediments, indicating that salinity did not intrude as far into the Delta during past droughts as it has during the last 100 years. This suggests a change in spatial salinity gradient characteristics, and is possibly due to the effect on salinity intrusion of the vast tidal marshes that existed in the Bay and Delta until the late 19th and early 20th centuries. This change in salinity distribution is further examined using the earliest salinity measurements taken within the Bay and Delta (starting in 1908) to provide a finer temporal resolution and additional insight into the effect of anthropogenic modifications. Comparing time periods with similar hydrology, during the early 1900's, fresh water was present farther downstream and persisted for a longer period during the spring and early summer.

Monday, September 27, 2010: Room 307 The Natural Delta: Pattern and Process before Modern Management - Order: 1

MODELING THE HISTORICAL DELTA

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Increasing attention has been focused on the Sacramento-San Joaquin Delta as the ecosystem continues to decline and the water supply reliability suffers. Most agree about the complexity of the Delta (Moyle et al. 2010), but discussions on the solutions continue to be varied. Estimating human demands for water, both in quantity and quality, is fairly straightforward with well-established methods. Estimating flows for improving habitat conditions, particularly to support fishes with different and often conflicting life history strategies, is much more complex and is hampered by numerous uncertainties. Methods have been proposed that include scientific evidence to support suggested environmental flows (Fleenor et al. 2010). Anthropogenic modifications to the Delta began in 1849 and the physical changes to the Delta were mostly completed over a 60-year period ending in 1910. Upstream consumptive use of Delta water began during the physical development of the Delta and was mostly developed by 1920 (Thompson 1958, Hundley 2001). Additional hydraulic infrastructure was built during the 1940-1965 period to control flows and export water south. Manipulation of Delta flows continues today to control water quality and export levels. More recently, environmental flow requirements have increased stress between environmental and water supply interests. However, current efforts all utilize recently collected data to determine what is best for desired biota in the current Delta configuration. To provide a more historical perspective of the water use changes on Delta habitat, a modeling effort has been undertaken to reverse engineer the Delta hydraulic regime. The approach was to examine the changes in the reverse order in which they occurred, effectively turning the clock backwards. Early results will be presented showing the effects, against a base case, of the Sacramento Deep Water Ship Channel, the creation of the Stockton Deep Water Ship Channel, and the early 20th century modifications of channel changes within the Delta. It is hoped that the approach taken will bring additional information of the habitat changes to the Delta.

Monday, September 27, 2010: Room 307 The Natural Delta: Pattern and Process before Modern Management - Order: 2

HYDRODYNAMICS AND TRANSPORT PROCESSES ON THE HISTORICAL LANDSCAPE: GEOMORPHIC CONTROL OF FUNCTIONAL COMPLEXITY AND IMPLICATIONS FOR RESTORATION

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Native fishes and food webs in the Bay-Delta evolved largely in response to the morphology of the historical landscape. Processes like sedimentation, tidal dynamics, and water temperature regulation are mediated by the particular morphology of bays, channels, sloughs, and marsh plains. In turn, morphology is influenced by tidal action, vegetation, and soil dynamics. Ecosystem functions and services that support nekton depend on both the productive capacity of, and access to, morphological attributes that support food, refuge, and ontogeny options. This talk will examine the historical and modern Delta planform and propose that historical landscape scales, as perceived by nekton, are in some ways much larger, and in other ways much smaller, than the modern Delta. The straightened and widened, and cut-across channels of the modern delta tend to preserve tidal energy and produce efficient mixing of scalar gradients and residence time, while at the same time reducing the distance between any two points. The functional outcome of the channelized modern Delta is that the distance to different environmental conditions is generally much larger than in the historical Delta. A combination of data, modeling, and graphical evidence will be presented to show that modern Delta channel connectivity is high, yet access to ecotonal gradients and associated habitat options is severely limited. Given this hyper-degraded state, Delta ecosystem restoration designs must consider the wetland-to-channel “connectivity rate” to optimize both the capacity to produce ecosystem services, and access to those services by both marsh and channel preferring organisms.

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HISTORICAL HABITAT VARIABILITY AND COMPLEXITY IN THE UPPER SAN FRANCISCO ESTUARY

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High variability in environmental conditions in both space and time once made the upper San Francisco Estuary highly productive for native biota. The original Delta was a vast freshwater marsh interlaced with tidal channels that collected flow from marsh areas through shallow dendritic drainage systems. There was considerable north-south spatial variability created by differences in flow patterns and sediment deposition from the Sacramento and San Joaquin Rivers, as well as east-west variability created by proximity to the inflowing rivers and the more open and salty lower estuary. Seasonal and annual variation in outflows was created by the natural variability and strong seasonal patterns of precipitation. The rich aquatic system created by this variability contributed to the huge populations of Chinook salmon, Sacramento perch and other fish, large diverse overwintering flocks of waterfowl, and abundant elk and other mammals, as well as dense populations of Native Americans. This physical system has been radically changed by water projects, diking and draining, and other human actions, changes which are irreversible. However, recognizing the conditions under which the native fauna evolved can guide efforts to create habitat favorable for native fish and fowl.

Monday, September 27, 2010: Room 307 The Natural Delta: Pattern and Process before Modern Management - Order: 4

HISTORICAL DELTA HABITAT MOSAICS: CONCEPTUAL MODELS FOR BUILDING A DIVERSE AND RESILIENT FUTURE DELTA

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The historical Delta supported large and diverse communities of native plants and animals, including a majority of the State's migratory birds and anadromous fishes. But there has been relatively little research into how this support was distributed within the Delta. Since the advent of Euro-American settlement, much of the historical understanding of the spatial and temporal distribution of Delta habitats has been forgotten. But, this understanding can be recovered. By synthesizing the available historical record through conceptual models and GIS, we are beginning to learn how the Delta looked and functioned prior to significant modification. Useful data are provided by sources such as federal General Land Office surveys, engineering and property maps, Mexican land-grant cases, early aerial photography, and 19th century textual accounts. We find that the historical Delta was spatially very complex, with a variety of subsystems distinguished by unique habitat mosaics, the composition of which varied along identifiable physical gradients, especially topography, tidal range, and freshwater input. These mosaics include dense channel networks occupying low tidal elevations as well as high marsh ecotones merging into seasonal wetlands and oak savanna. Alkali meadows, small ponds, and tule patches characterized the South Delta, while perennial floodplain marshes, large ponds, and riparian gallery forests were more prominent in the North Delta. Ecological function can be inferred from these reconstructed mosaics through expert interpretation across many scientific disciplines. As expected, the complexity of each mosaic and their diversity supported an unusually rich endemic flora as well as large and diverse communities of resident and migratory wildlife. Furthermore, the historical reconstructions are beginning to reveal how physical processes that controlled the mosaics were distributed within the Delta, and where the processes might be nurtured or restored. This information will be important for designing realistic ecosystem targets for contemporary and projected future Delta conditions.

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SUISUN MARSH IN REVIEW: TRENDS IN ENVIRONMENTAL CONDITIONS, THE FOOD WEB, AND FISH ABUNDANCE

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Suisun Marsh is important habitat for native and alien fishes of the San Francisco Estuary. While few species complete their life cycle in the marsh, it supports large populations of many species by providing both refuge and food. The Suisun Marsh Fish Survey (University of California) has systematically monitored the marsh's fish populations with otter trawls and beach seines since 1980. The purpose of the study has been to determine environmental factors affecting fish abundance and distribution, especially in relation to water management activities. While general trends in fishes show a slow decline, like much of the estuary, abundance in some key regions of the marsh remain high. These regions contain long, shallow sloughs mostly without functional levees, complex geomorphology and circulating hydrodynamics, which contribute to high residence time. When such areas are allowed to maintain high water quality (free from excessive nitrogen inputs and eutrophication) and are free of destabilizing invasive invertebrates (such as jellyfish and clams), they remain considerably more productive of native fishes than other regions of the estuary. Identifying the factors supportive of fish habitat in the marsh can guide restoration throughout the estuary, and help to anticipate future changes in climate, sea level and water operations.

Monday, September 27, 2010: Room 307 Suisun Marsh: Present and Future - Order: 1

SEX, CLONES, AND SUISUN MARSH: GENETIC DIVERSITY AND REPRODUCTIVE MODE IN TWO SPECIES OF INVASIVE HYDROMEDUSAE IN THE UPPER SAN FRANCISCO ESTUARY

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Three species of non-native hydromedusae have become established in the brackish water habitats of the San Francisco Estuary (*Maeotias marginata*, *Blackfordia virginica*, *Moerisia* sp.). Their impact on the aquatic community maybe great, as they are novel predators in this system with high density seasonal blooms. Despite their likely ecological importance, relatively little is understood about the ecologies of these non-natives, their impacts, and what makes them so successful outside their native range. Included in this paucity of understanding is knowledge of the overall genetic diversity of the population and the relative contribution of asexual and sexual reproduction to its growth. In this study, we examine these unknowns in *M. marginata* and the *Moerisia* species. We developed microsatellite genetic markers to investigate the clonal diversity of these species collected from Suisun Marsh in the upper San Francisco Estuary. We quantified overall genetic diversity and examined clonal diversity. Our results show relatively high genetic diversity, as would be expected with sexual reproduction, but also a strong presence of asexual reproduction. Our findings demonstrate the importance of these modes of reproduction to the invasion and provide insights into characteristics that may make them successful invaders in the Bay-Delta system.

Monday, September 27, 2010: Room 307 Suisun Marsh: Present and Future - Order: 2

LIFE HISTORY AND POPULATION DYNAMICS OF MOERISIA SP., A NON-NATIVE HYDROZOAN IN THE UPPER SAN FRANCISCO ESTUARY

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The goal of this study was to investigate the life history and population dynamics of the small, non-native *Moerisia* sp. in Suisun Marsh, within the upper San Francisco Estuary. Medusae and polyps were collected from 8 and 2 sites, respectively, during 2007 and 2008. Polyps emerged from a resting stage during June, at a minimum temperature of approximately 14°C. Asexual reproduction of medusae buds was positively correlated with increasing temperature and salinity in summer, while the production of polyp buds was positively related to dissolved oxygen and water transparency levels. Sexual reproduction, defined by the presence of eggs, was related to the size of medusae. Cessation of reproduction of both polyps and medusae occurred in October, when temperatures dropped below 17°C. This life history is similar to other hydrozoans and allows *Moerisia* sp. to reach large numbers seasonally in the San Francisco Estuary, possibly contributing to the recent declines noted of pelagic fish and zooplankton.

Monday, September 27, 2010: Room 307 Suisun Marsh: Present and Future - Order: 3

DISTRIBUTION AND IMPLICATIONS OF ALIEN CLAMS IN SUISUN MARSH, CA

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Clams can have a large effect on plankton in estuaries. This has been demonstrated in the San Francisco Estuary by the invasion of *Corbula amurensis*, which through its efficient filtering capabilities and high densities has contributed to the decline in phytoplankton in the upper estuary. This study investigates the distribution of *C. amurensis* and its freshwater counterpart *Corbicula fluminea* in Suisun Marsh with the goal of elucidating factors that may be constraining their abundance in this highly productive marsh. The effect of clam grazing on the phytoplankton biomass in Suisun Marsh is also investigated. This study utilizes data from a 2-year (2003-2005) CALFED funded investigation on the Suisun Marsh invertebrate community and a 30 year time trend (1980-2009) on the Suisun Marsh clam distribution using the UCD/IEP Suisun Marsh monitoring study.

Monday, September 27, 2010: Room 307 Suisun Marsh: Present and Future - Order: 4

LANDSCAPE-SCALE CONSIDERATIONS IN RESTORING ECOSYSTEM FUNCTIONS IN SUISUN MARSH AND BAY

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Significant depressions in dissolved oxygen (DO) concentrations and elevated levels of methylmercury (MeHg) have been observed at certain times of the year in several sloughs in northwestern Suisun Marsh that coincide with discharges from managed wetlands along these sloughs. Shifts in aquatic community structure in impacted sloughs to dominance by low-DO tolerant species, and in some cases even fish kills, have co-occurred with these events. The purpose of the project was to understand the contribution of managed wetland discharges to low DO and elevated MeHg events in Suisun Marsh and to develop best management practices for reducing such events. The study involved two years of data collection at two managed wetlands in northwest Suisun Marsh and their adjacent sloughs. Within the wetlands we collected data on water quality, water level, soil properties, topography, and vegetation. Within the sloughs we collected data on water quality, water level, flow, and aquatic biology. Baseline data were also collected in three managed wetlands in central Suisun Marsh for comparison. The results indicate that, following fall flood-up, the water within the managed wetlands routinely has low DO and elevated levels of dissolved organic carbon and MeHg. This water, when discharged to surrounding sloughs during fall drain events, causes an immediate drop in slough DO levels. Fall flood-up also causes net upstream flow in these sloughs, thereby reducing mixing with larger sloughs. Water quality within the wetlands and sloughs generally improves by winter, but spring drain events from the wetlands still result in DO sags within the sloughs, though not as severe as in the fall. We recommend several wetland management changes that may help to reduce the impacts upon greater Suisun Marsh. These changes are focused on water, vegetation, and soil management within wetlands and improved communication and coordination between wetland managers and regulatory/resource agencies.

Monday, September 27, 2010: Room 307 Suisun Marsh: Present and Future - Order: 5

CHANGES IN THE QUALITY AND QUANTITY OF NUTRIENTS OVER TIME AND THE RELATIONSHIPS WITH CHANGES IN PHYTOPLANKTON COMPOSITION

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Changes in nutrient loads and imbalances in nutrient ratios can have major effects on food webs. The extent to which such changes may have impacted food webs in the San Francisco Estuary over time are of considerable interest due to the relationships between production at the base of the food web and that of higher trophic levels. The following question was addressed using the long-term, 30-year, data from numerous sites in the Bay Delta: how have changes in nutrient loads and forms related to changes in phytoplankton community composition? Changes in the phytoplankton community have occurred over time in terms of species composition and in terms of seasonality of blooms. These changes have also differed over time in the different subembayments of the bay delta system. Different algal functional groups were related with either total load of a particular nutrient form, or to different nutrient ratios. The ratio of inorganic nitrogen:inorganic phosphorus (DIN:DIP) was significantly correlated with the availability of cryptophytes and flagellates; these groups were not abundant when the ratio was above Redfield proportions. Cyanobacteria, on the other hand, were not well correlated with the ratio of inorganic nitrogen:inorganic phosphorus, and occurred across the spectrum of observed ratios. They were the dominant functional group at high DIN:DIP ratios. The ratio of nitrate:ammonium was related to diatom abundance. These relationships are consistent with nutrient physiological strategies that differ among these algal groups. These findings have management implications because they can help inform the process of nutrient criteria development and can help to identify which forms, as well as loads, are most important to target for nutrient reduction.

Monday, September 27, 2010: Room 311-313 Bay-Delta Phytoplankton Trends and Drivers - Order: 1

CAUSES OF SEASONAL AND SPATIAL VARIATION IN WATER CHEMISTRY IN THE SACRAMENTO RIVER, DELTA, AND EASTERN SAN FRANCISCO BAY AND THEIR EFFECTS ON CHLOROPHYLL LEVELS

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High concentrations of NH_4 have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline (POD) in the San Francisco Estuary (Dugdale et al. 2007). To obtain more data on the critical region downstream of the Sacramento wastewater treatment plant (SRWTP), water samples were collected along ~30 transects of the Sacramento River (SR) from July 2008 to April 2010. Depending on transect, water samples were collected from 6-25 sites extending from >10 miles upstream of SRWTP downstream to Rio Vista and usually further downstream. Data were also obtained from an additional 8 sites between Rio Vista and Angel Island from monthly excursions by the USGS RV Polaris. All samples were analyzed for EC, nutrients, chlorophyll, and many were also analyzed for DOC, DON, and N and C uptake rates. A comprehensive suite of isotope analyses has been made for 3 transects and analyses of samples from other transects are in progress. Efforts thus far have focused on evaluating (1) how NH_4 , NO_3 , and organic matter concentrations vary under different hydrologic conditions, and (2) how nitrification rates (the main biogeochemical process responsible for lowering NH_4 levels) vary seasonally and in different reaches of the SR and upper estuary. Examination of these transects has revealed that NH_4 and NO_3 concentrations at any particular site and date downstream of SRWTP are the product of a large number of time-varying factors, including flow, interruptions in effluent discharge, apparent variations in effluent composition, water chemistry upstream of SRWTP, nitrification rates, and changing inputs from tributaries, the San Joaquin River, and point-sources to the Bay. This kind of detailed examination of processes along transects complements the statistical approaches (Glibert 2010) and lumped approaches (Foe et al. 2010) currently being utilized to evaluate the linkage between NH_4 , algae, and POD.

Monday, September 27, 2010: Room 311-313 Bay-Delta Phytoplankton Trends and Drivers -
Order: 2

DIFFERENT RESPONSE TYPES OF PHYTOPLANKTON TO CHANGING NUTRIENT REGIMES IN SUISUN BAY: BOTTOM-UP EFFECTS OF AMMONIUM AND NITRATE

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Worldwide, estuaries receive large fluxes of nutrients including reduced forms of nitrogen (e.g. ammonium) as the result of human activities. One major source is effluent from municipal waste water treatment plants. A high relative contribution of ammonium versus nitrate to the dissolved inorganic nitrogen (DIN) pool may have detrimental consequences on primary production and phytoplankton accumulation. Elevated ammonium precludes phytoplankton use of nitrate (the largest pool of DIN in the SFE) limiting the magnitude of phytoplankton biomass accumulation. In the northern San Francisco Estuary/Delta these bottom-up effects impact the food web and may contribute to the Pelagic Organism Decline. To assess how SFE phytoplankton in the northern estuary and Delta respond to elevated ammonium concentrations supplied by the Sacramento River, enclosure experiments were conducted with water from Suisun Bay and Rio Vista. Nutrient drawdown and uptake, primary production, and chlorophyll accumulation were tracked and compared to measurements made in enclosures with Central Bay water. Three types of response were identified; Type I in Central Bay was characteristic of healthy phytoplankton in low ammonium, that were able to drawdown all available DIN (all ammonium and nitrate) and accumulate chlorophyll within 72 hours. Type II response in Suisun Bay was delayed in time, usually with ammonium drawdown by 96 hours, little nitrate uptake and chlorophyll accumulation peak by 144 hours. Type III in Rio Vista, where ammonium was the highest concentration, there was a very poor response by the phytoplankton with little DIN drawdown or chlorophyll accumulation, even after 144 hours. This approach allows a way to classify the productivity potential or quality of the water and may suggest a management tool for increasing production. Evaluating the role of ammonium, that is likely a WWTP product, on the SFE food web is essential for long term ecosystem sustainability.

Monday, September 27, 2010: Room 311-313 Bay-Delta Phytoplankton Trends and Drivers -
Order: 3

HOW WELL DO WE UNDERSTAND THE FEEDING ECOLOGY OF ESTUARINE MESOZOOPLANKTON? A SURVEY OF THE DIRECT EVIDENCE

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Over the last three decades, a shift in phytoplankton composition has been observed in the upper San Francisco Estuary (the brackish and freshwater Delta) characterized by a decline in the relative abundance of diatoms, especially centric diatoms belonging to the order Thalassiosirales, and an increase in other taxa including flagellates, green algae, and cyanobacteria. A central assumption underlying recent food-web-based hypotheses for the recent decline in several pelagic fish species (the Pelagic Organism Decline, or POD) is that these changes in phytoplankton composition signal a deterioration in the quality of food for estuarine mesozooplankton, and calanoid copepods in particular, that may have repercussions for organisms at higher trophic levels. Direct evidence of feeding preferences of mesozooplankton from the San Francisco Estuary is provided by a few studies of gut contents and feeding trials which indicate that the trophic status of copepods in the estuary is complex and that motile food sources (including heterotrophic ciliates) and non-diatom phytoplankton are potentially well-utilized by ecologically important zooplankton taxa. In this study, the status of our knowledge regarding the feeding behavior of copepods and other key zooplankton taxa is evaluated using an extensive survey of published literature and pertinent unpublished studies from the San Francisco Estuary and other systems. Evidence from feeding trials and gut analyses of field caught zooplankton are compared, and data gaps identified. The availability of information regarding the nutritional value of heterotrophic and autotrophic food resources for pertinent zooplankton taxa is described.

Monday, September 27, 2010: Room 311-313 Bay-Delta Phytoplankton Trends and Drivers - Order: 4

USING CLIMATOLOGICAL ANOMALIES TO UNDERSTAND THE OCCURRENCE OF SPRING BLOOMS IN SUISUN BAY

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Spring phytoplankton blooms rarely occur in Suisun Bay in spite of high inorganic nutrient concentrations delivered to the Bay by the Sacramento River. Recent research suggests that access to nitrate, the largest pool of dissolved inorganic nitrogen, is a necessary condition for rapid intense blooms to occur in the northern San Francisco Estuary. However, in Suisun Bay ammonium concentrations are typically too high (at inhibitory levels) to allow access to nitrate by the phytoplankton. Blooms may be initiated when ammonium concentrations fall below 4 M partially relieving this inhibition of nitrate uptake. A further decrease of ammonium concentration to 1 M fully relieves ammonium inhibition resulting in high rates of nitrate uptake and intense chlorophyll accumulation. In the last decade, two large phytoplankton blooms were observed in Suisun Bay (in spring 2000 and spring 2010) with shared features of low ammonium concentrations and low salinity. The reason(s) for the low ammonium concentrations are not clear, although it is known that the source of the ammonium arises from the discharge of sewage effluent upstream in the Sacramento River that may be variable. Within the river some of the introduced ammonium is oxidized to nitrate (nitrification) but little ammonium is used by phytoplankton. To reveal changes related to bloom formation, climatological anomalies of variables from long term data sets for Suisun Bay will be analyzed.

Monday, September 27, 2010: Room 311-313 Bay-Delta Phytoplankton Trends and Drivers -
Order: 5

FACTORS THAT HAVE INFLUENCED THE INCREASE OF MICROCYSTIS BLOOMS IN THE SAN FRANCISCO ESTUARY SINCE 2003

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Blooms of the toxic cyanobacterium *Microcystis* were first observed in the San Francisco Estuary in 1999. Field studies were conducted between 2003 and 2008 to determine the magnitude, duration and rate of bloom increase over time and the factors affecting bloom development and toxin concentration. Data suggest there has been a 20 to 40 fold increase in *Microcystis* cell density, chlorophyll a concentration and microcystin toxin concentration in the surface layer of the estuary during the summer between 2003 and 2008. The increase in bloom density was associated with decreased water flow and increased water temperature, water transparency, specific conductance, and nitrogen concentration. The initiation and duration of the bloom was influenced by the presence of water temperature above 20°C, water flow below 36 m³/s, nitrogen to phosphorus molar ratios below 16, total dissolved solids below 500 mg/L and total suspended solids below 10 mg/L. The study confirmed the increase in both magnitude and distribution of *Microcystis* blooms in the estuary over time and the potential impact of water quality conditions on this increase. Understanding the impact of environmental conditions on *Microcystis* blooms is an important need for development of management plans under the Bay Delta Conservation Plan (BDCP).

Monday, September 27, 2010: Room 311-313 *Microcystis* in the SF Estuary - Order: 1

WHAT CONTROLS MICROCYSTIS BLOOM AND TOXICITY IN THE SAN FRANCISCO BAY-DELTA?

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The potential adverse impact of the bloom-forming cyanobacterium *Microcystis* on the estuary is large. Water from the northern region is used directly for drinking water and irrigation and the region is an important recreational area for sport fishing and water contact sports. The estuary is habitat for many anadromous, commercial and recreational fish including and is a feeding ground for marine mammals. The estuary also contains many threatened or endangered aquatic organisms and many of these species are declining (e.g. Delta Smelt).

Monday, September 27, 2010: Room 311-313 *Microcystis* in the SF Estuary - Order: 2

USE OF STABLE ISOTOPES FOR EVALUATING ENVIRONMENTAL CONDITIONS ASSOCIATED WITH MICROCYSTIS BLOOMS IN THE DELTA

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The toxic cyanobacteria *Microcystis aeruginosa* first appeared in the San Francisco San Joaquin Delta in 1999, and now poses a serious water quality concern. As part of a larger study aimed at determining the impact of *Microcystis* on ecosystem structure and function, human and wildlife health, and environmental conditions in the Sacramento-San Joaquin River Delta, isotope samples were collected from 12 sites that were experiencing annual *Microcystis* blooms. These sites represented a range of typical fresh and brackish water habitats. All sites were sampled every two weeks in summer 2007 and in January 2008, and 5 were also sampled every two weeks in summer 2008. All samples were analyzed for $\delta^{15}\text{N}$, $\delta^{13}\text{C}$, and C:N of seston, and $\delta^{18}\text{O}$ and $\delta^2\text{H}$ of water. A subset was analyzed for $\delta^{13}\text{C}$ of dissolved organic matter (DOM), and samples were archived for future nitrate and DOM isotope analyses. The goal of the study was to evaluate the usefulness of isotopes for answering questions such as: what is the source of the *Microcystis* biomass (internal islands or external rivers), what is the source of N utilized by *Microcystis*, and does *Microcystis* affect the quality of the DOM available for the microbial food web. As seen in earlier CALFED-funded studies of organic matter in the Delta, we find that seston and DOM show seasonal and spatial variations in isotopic composition related to source of the organic matter (terrestrial/macrophyte vs algae), the source of the N used by the algae, and biogeochemical processes affecting dissolved nitrogen and carbon species. Two sites, Antioch and Collinsville, showed strong inverse correlations of seston $\delta^{15}\text{N}$ and C:N, and positive correlations of $\delta^{15}\text{N}$ and $[\text{NH}_4]$ and/or $[\text{NO}_3]$. Other sites showed more complex correlations among seston $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, chlorophyll concentrations, and nutrient levels.

Monday, September 27, 2010: Room 311-313 *Microcystis* in the SF Estuary - Order: 3

MICROCYSTIS IN THE SAN FRANCISCO ESTUARY: ABUNDANCE OF TOXIC AND NONTOXIC STRAINS, INITIAL ESTABLISHMENT OF LABORATORY CULTURES, AND LOCALIZATION IN FISH EXPOSED TO BLOOMS AND SPIKED DIETS

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Microcystin (MC) levels in the San Francisco Estuary (SFE) – Delta, produced mainly by recurring *Microcystis aeruginosa*, are theoretically governed by two key mechanisms in the ecosystem: regulating the abundance of toxic strains, and regulating microcystin (MC) production from toxin-producing strains. Two studies were initiated to address these assumptions. First, the abundance of MC-producing (toxic) and MC-lacking (nontoxic) *Microcystis* were determined during the bloom season in the SFE in 2007. The proportion of toxic and nontoxic *Microcystis* across sites and stages of bloom development in the estuary was assessed by qPCR that we developed based on local *Microcystis* strains. Second, pilot studies are in progress to generate mass cultures of local *Microcystis* species. Establishing laboratory cultures is central to evaluating the role of key environmental factors on the growth, survival, and MC production of local *Microcystis* strains. Initial results on abundance of toxic and nontoxic strains of *Microcystis* cultures from the estuary will be described. Lastly, retrospective analyses of key species in the Delta such as delta smelt and striped bass previously exposed to blooms in 2005 were initiated to determine the fate of *Microcystis* among these fish. In parallel, biological effects of *Microcystis* on threadfin shad and Sacramento splittail were examined by feeding *Microcystis*-spiked diets in the laboratory. Using DNA probes specific to local *Microcystis* and specific antibodies to MC-LR, localization of *Microcystis* and MCs were analyzed by in situ hybridization and immunohistochemistry, respectively among fish exposed in the field and in the laboratory. Monitoring blooms using qPCR can reveal trends in the sources and magnitude of toxic and nontoxic *Microcystis* in the estuary. As such, rapid risk assessment and strategies can be designed to manage the adverse effects of cyanobacterial blooms to the ecosystem and its fishery resources. Forthcoming evaluation of manipulated physicochemical stressors using *Microcystis* cultures will provide the knowledge to predict conditions that will enhance or decrease MC synthesis. Fish exposed to blooms and *Microcystis*-spiked diets demonstrated the bioaccumulation of MCs in high trophic levels and that *Microcystis* uptake can be mediated through their zooplankton prey. These results will lay the groundwork for future studies designed to address how zooplankton and other primary food resources of larval pelagic fish will respond to expanding *Microcystis* blooms.

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EFFECTS OF MICROCYSTIS AERUGINOSA ON THREADFIN SHAD, DOROSOMA PETENENSE

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In the San Francisco Estuary (SFE), the presence of the toxic algal bloom *Microcystis aeruginosa* has been suggested as a link to the Pelagic Organism Decline (POD) by the Interagency Ecology Program (IEP) (2005). The bloom is predominantly of the microcystin LR strain (MC-LR), a hepatotoxic protein that may impact the survival of fish. The purpose of this study was to determine whether toxins from *M. aeruginosa* collected from the SFE were toxic to POD species, such as threadfin shad, *Dorosoma petenense* (TFS) and to use the biomarkers of exposure to link toxicity to exposure in field samples from the SFE. Juvenile TFS, were exposed to diets containing 5 (D5) and 10 (D10) $\mu\text{g/g}$ MC-LR for 57 days. The treatments were compared to the control diet, 0 $\mu\text{g/g}$ MC-LR (D0). Preliminary results revealed that condition factor (CF) and liver and gonadal lesions were sensitive to exposure. There was a significant inverse relationship with CF and MC-LR, with exposed fish exhibiting severe cachexia. Liver lesions of sinusoidal congestion, and glycogen depletion significantly increased with increasing MC-LR concentrations, indicating hemorrhaging in the liver and poor nutritional status, respectively. In females, there was a significant increase in severe ovarian atresia with increasing MC-LR concentration, indicating loss of reproductive potential. The results indicate that chronic exposure to MC-LR from *M. aeruginosa* significantly impairs the health and reproductive potential of threadfin shad. The biomarkers characterized from the dietary study will be compared with field samples of TFS from the SFE collected during *M. aeruginosa* blooms to determine whether the TFS were exposed to MC-LR. The results from this study may help establish the link suggested by the IEP between the bloom and POD therefore aiding in determining management protocols for controlling the *M. aeruginosa* blooms in the SFE.

Monday, September 27, 2010: Room 311-313 Microcystis in the SF Estuary - Order: 5

MULTI-SCALE, INTEGRATED REPORTING SYSTEM FOR BAY-DELTA REGIONS

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California and the Bay-Delta system in particular needs a reporting system that describes scientific understanding of ecological and socio-economic status and trends in ways that the public and decision-makers can understand. Reporting conditions and how these conditions change and are influenced encourages participation in knowledge and policy networks that have formed around big social and ecological issues in the state (e.g., water management through the Delta). In 2008, three state-funded regional programs began developing a science and stakeholder-input based reporting system that included environmental, social, and economic indicators of whole system status and trends. The North Bay program (led by Napa County) focused on the Napa River and its watershed as an appropriate model unit for the Bay-Delta; the Central Valley program (led by the Sacramento River Watershed Program) focused on the Feather River system, arguably the most important managed water system in the state; the Southern California program (led by the Los Angeles & San Gabriel Rivers Watershed Council) focused on the Los Angeles River and the Arroyo Seco in particular. All three programs selected goals and objectives for ecological, social, and economic conditions from extensive stakeholder input. Indicator sets were selected for each measurable objective and filtered through selection criteria to develop feasible, yet scientifically meaningful sets of system-indicators. The programs collected all available data and measured system-indicator conditions relative to reference standards for poor and good conditions to normalize indicator “scores” to a 0-100 scale. These normalizations included non-linear transformations where appropriate (e.g., fish sensitivity to water temperature). Trends analyses were performed using the Mann-Kendall series of tests (including the Seasonal and Regional Kendall tests). The outcome was the development of a consistent and scalable approach for California for measuring and reporting whole system condition relative to stakeholder expectations for condition, using contemporary scientific literature and statistical tools.

Monday, September 27, 2010: Room 314 Management and Decision Support - Order: 1

ACHIEVING THE CALIFORNIA WATER SUPPLY AND DELTA ECOLOGICAL IMPROVEMENT SIMULTANEOUSLY

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It is clear that the current CVP system needs to be fixed. The decision on how it is to be fixed is critical to spending billions of dollars wisely. This decision must be made now before Delta levees crumble or before the Delta water supply is exceeded. There is only one alternative that can achieve the stated dual objectives of securing an ample water supply and improving ecological conditions in the Delta. The Sacramento River must be used as the sole water source for water supply and all of the San Joaquin River water must be used to resist salt intrusion during incoming tides. The peripheral canal is needed because sufficient amounts of Sacramento River water are unattainable under the present CVP configuration. There are two mandatory operational conditions that must be kept at all times to avoid continuing adverse ecological effects: 1) No San Joaquin River water can be used for water export because export of that water is the chief factor of Delta ecological degradation, and 2) The present level of outflow to San Francisco Bay shall be maintained because it is already at half its historical levels, would be easy to use as an operational term condition, and is a necessary control to operate Delta water export in a sustainable manner.

Monday, September 27, 2010: Room 314 Management and Decision Support - Order: 2

INTEGRATED WATER OPERATIONS AND ECOSYSTEM DECISION SUPPORT MODELLING: THE ECOLOGICAL FLOWS TOOL (EFT)

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It's challenging to integrate multi-species and multi-habitat needs when evaluating water operation scenarios. The Ecological Flows Tool (EFT) is a decision support tool emphasizing clear communication of trade-offs for key ecosystem targets associated with alternative conveyance, water operations, and climate change. We take a bottom-up, process-based view of how flow and related aquatic habitat variables (e.g., salinity, temperature, turbidity) are tied to a variety of ecosystem functions for representative sets of focal species and habitats (Chinook salmon, steelhead, green sturgeon, Delta smelt, splittail, tidal wetlands, invasive species deterrence, bank swallows, Fremont cottonwoods). By leveraging many of the same planning models used in existing socioeconomic evaluations (e.g., Calsim, DSM2) EFT provides an "eco plug-in" to the water management studies based on use of these tools. EFT is being used in the BDCP analysis. We present example results from applying EFT to the mainstem Sacramento River, exploring the ecological effects of various water and channel management options on five of the above-listed focal species (results: www.dfg.ca.gov/ERP/signature_sacriverecoflows.asp). Currently, we are extending EFT to the Delta, expanding existing modules for Chinook and steelhead, and adding components for Delta smelt, splittail, tidal wetlands and invasive species deterrence. In the above applications we've found that it's difficult to simultaneously meet all focal species' objectives in a single year, but this is not necessarily a problem for some species (e.g. Fremont cottonwood). We have developed a number of approaches to communicate trade-offs across regions and species to both managers and scientists, and catalyze definition of state-dependent management practices that promote the development of needed flexibility in the water management system.

Monday, September 27, 2010: Room 314 Management and Decision Support - Order: 3

ASSESSING THE POTENTIAL RESTORATION IMPACTS TO LOCAL WATER USERS IN THE CACHE SLOUGH COMPLEX: A MODELING APPROACH

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The Cache Slough Complex is located in the northwest tidal fringe of the Sacramento – San Joaquin Delta. The Complex is one of the last areas of the Delta where both tidal marsh areas exist and Pelagic Organism species such as delta smelt can be found. There is substantial interest by federal, state, and local agencies to further restore tidal marsh habitat in this area. One possible negative product of tidal marsh creation is the production of dissolved organic carbon (DOC), which can be problematic for municipal water users. In the Cache Slough Complex, the main municipal project is the North Bay Aqueduct (NBA) which serves over 400,000 people in Napa and Solano counties. With the likely creation of substantial wetlands in the Complex, local water agencies are concerned with increases in DOC, which could impact public health, lead to increased regulatory action, and increased water treatment costs. To begin to address these questions cbec, inc., eco engineering was hired to develop a 2-dimensional hydrodynamic model of the entire Cache Slough Complex. A series of restoration scenarios were then determined based upon old reports, current policy discussion with the Bay Delta Conservation Plan, and local interest. A total of six scenarios were developed, which included scenarios representing the restoration of Prospect Island, Lower and Upper Egbert Tract, two scenarios at Hastings Tract, and restoration along Peter's Pocket and Moore Tract. Computational tracers were applied at each levee breach to represent sources of DOC and to study the fate and transport of the tracer through the Complex. Each scenario was modeled for 10-days and a comprehensive scenario was modeled for 30-days. The model results show that proximity to the NBA is the single biggest factor. Additionally, local diversions such as the NBA and agricultural diversions substantially influence the hydrodynamics. The model results also show that likely restoration scenarios a substantial distance from the NBA, such as Prospect Island, will not likely impact water quality at the NBA.

Monday, September 27, 2010: Room 314 Management and Decision Support - Order: 4

UNDERSTANDING THE STRATEGIES AND DECISION MAKING OF CALIFORNIA'S URBAN WATER AGENCIES

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California's growing population has long been a driver of water management decisions, and a competing user for scarce water resources. Today, efforts to adapt water use patterns in cities have become a cornerstone of water policies, such as Governor Schwarzenegger's '20x2020' proposal. However, little work has been done to systematically characterize and analyze the decisions urban water agencies make about water production and distribution. A new database using the California Department of Water Resource's Public Water System Survey is used, for the first time, to further our understanding in these critical areas of water management. This presentation includes the following analytical results: (1) a description of urban water use and distribution patterns throughout the state, (2) how these patterns result in different types of strategies for water agencies, and (3) what we can learn from these patterns about the effectiveness of various water production strategies in urban water agencies. These results have significant implications as they use new data to improve our understanding of strategy and decision making in urban water agencies, and suggest ways that policy reforms and planning efforts may be more effective in the future.

Monday, September 27, 2010: Room 314 Management and Decision Support - Order: 5

DELTA FLOW CRITERIA: REGULATORY AGENCY SYNTHESIS OF THE SCIENCE

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Senate Bill 1, enacted on November 12, 2009, added the Sacramento-San Joaquin Delta Reform Act of 2009 to the California Water Code. The Act requires the State Water Board to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. In August 2010 the State Water Board considered adopting a staff report that contains recommended delta flow criteria, and considers the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. The staff report reviews existing water quality objectives and uses the best available scientific information in determining the flow criteria. The staff report also reviews the utility of adaptive management and considers short versus long-term flow needs.

Monday, September 27, 2010: Room 314 Technical Approaches to Suggest Delta Flow Standards - Order: 1

DEVELOPING FLOW CRITERIA TO PROTECT PUBLIC TRUST RESOURCES IN THE SACRAMENTO-SAN JOAQUIN DELTA

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Flow is the key physical and ecological driver in riverine and estuarine ecosystems. In California's Sacramento-San Joaquin watershed and its Delta, flows are highly altered and intensively managed for water storage and diversion. The intensity of water management activities has increased steadily during the past fifty years and there is now substantial scientific evidence that these flow alterations have contributed to both long-term and recent population declines of native fish species by degrading habitat conditions and providing favorable conditions for invasive species. In response to the SWRCB's request for information regarding flows necessary to protect ecosystem and fishery resources, we developed quantitative recommendations for four flow parameters: Delta outflow, inflows from the Sacramento and San Joaquin basins, and in-Delta hydrodynamic conditions. Our recommendations were designed to promote adequate levels of four population viability criteria: abundance, productivity, diversity and spatial structure. We used statistical, mechanistic and retrospective historical analyses of the relationships between flow and the viability criteria to identify flow levels needed to support viable populations of public trust species. Numerous other stressors may contribute to recent declines of fish populations that use the Delta but the effects of altered flow regimes exacerbates each of them. We assumed that, where necessary, additional actions were taken to address other known stressors; thus, our recommendations are for flows necessary to protect the public trust if these other stressors are completely mitigated. Based on these analyses, we recommended increases in winter-spring Delta outflows and Sacramento and San Joaquin River inflows during appropriate months and seasons. We also recommended improved Delta hydrodynamic conditions (positive Old and Middle River flows). These recommendations were tied to specific population viability objectives for key species.

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ENVIRONMENTAL FLOWS FOR NATIVE FISHES

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Recent state legislation has required the development of flow prescriptions for supporting habitat conditions for desirable fishes in the Delta. In the larger professional literature, much is written on environmental flows for rivers and other water bodies, with little consensus on method (Richter et al. 1997; King and Louw 1998; others). This stems, in part, from the complexity involved (Moyle et al. 2010). Estimating human demands for water, both in quantity and quality, is fairly straightforward with well-established methods. Estimating flows for improving habitat conditions, particularly to support fishes with different and often conflicting life history strategies, is much more complex and is hampered by numerous uncertainties. For the Delta, these difficulties are compounded by major geological, biological, and engineering changes and transitions, particularly the return of subsided diked lands to aquatic habitat (subtidal, intertidal and floodplains), changes in water management within and upstream of the Delta, invasive species, and water contamination from upstream and in-Delta uses. These massive ongoing and potential changes cast doubt on the long-term value of empirical relationships often used to establish required Delta flows. As pointed out elsewhere (Lund et al. 2008), we are unlikely to ever resolve all these uncertainties and issues in the Delta before proactive actions are required – since courts are already requiring action. Initial flow prescriptions with a habitat and biological basis need to be developed to move the planning and policy process forward, even knowing that these prescriptions are based on incomplete data and understanding, and will undoubtedly be modified in the future. As support to the State Water Resources Control Board, we present a method for estimating fresh water flows needed to sustain viable populations of native fishes in the Delta. Three separate approaches to this problem are explored and illustrative quantities of water are estimated. While it is hoped these estimated flows might have some value in furthering discussions in light of the justifications and references provided, the greater value, for the time being, lies in the approach developed and applied here. This approach is developed largely to facilitate more transparent and scientific discussion of desirable freshwater flows and to suggest potential methods for their estimation.

Monday, September 27, 2010: Room 314 Technical Approaches to Suggest Delta Flow Standards - Order: 3

APPLICATION OF DYNAMIC REGIME THEORY TO ASSESS THE EXTENT OF ESTUARINE ECOSYSTEM CHANGE: OH, YOU DON'T KNOW, THE SHAPE I'M IN

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The concept of regime change originated separately in oceanography and in ecological theory. Ideological and logistical differences led to a focus in oceanography on identifying associations and breakpoints among time series, i.e. correlations; whereas, a more process-based perspective developed in ecology due to opportunities for manipulative studies, e.g. in lakes, and developments in population and system modeling. To aid in unifying these two conceptual lineages, and better assess the human role in estuarine change, we evaluated the extent to which dynamic regime changes have occurred in the San Francisco Estuary and Delta. We focus our evaluation at various regional and whole-system scales, using a variety of long-term data sets extending back to the 1970s. First we examine relative changes in various ecosystem constituents in phase space to explore patterns in dynamic behavior consistent with a regime shift, and then apply two techniques designed to detect “leading indicators” of a pending regime shift; i.e. evidence for the slowing down of system dynamics. Our results provide robust support for a regime shift occurring in the Delta region in about 2000-2001. Although less evidence was observed for similar shifts in other regions or across the entire estuary, the likelihood of future regime shifts was bolstered by evidence for leading indicators of change in near-by regions such as Suisun Marsh. Overall, this study underscores the fundamental nature of ecosystems as continuously changing, which in highly human altered systems is almost always irreversible. Thus, Delta policies relying on historical abundances as baselines, or targets for restoration of desired species have little relevance in this new regime. Ongoing efforts to restore or rehabilitate native species are likely to fail without carefully targeted and prolonged investments to reestablish habitat conditions that reflect the life history characteristics of native and desirable fishes.

Monday, September 27, 2010: Room 314 Technical Approaches to Suggest Delta Flow Standards - Order: 4

HISTORICAL CONTEXT FOR DELTA FLOW AND SALINITY STANDARDS

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The watershed of the Sacramento–San Joaquin Delta provides drinking water for more than 23 million Californians as well as irrigation water for millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. Successful revival and sustainability of the Delta ecosystem requires an understanding of the conditions under which native species evolved. Our detailed review of monitoring data, scientific reports, and modeling analyses establishes an historical record of flow and salinity conditions in the Western Delta and Suisun Bay before European settlement through to the present day. While it is not feasible to remove all human interference from the system, this review of natural variability provides context for discussion of further modifications to Delta flows.

Monday, September 27, 2010: Room 314 Technical Approaches to Suggest Delta Flow Standards - Order: 5

SACRAMENTO RIVER SEDIMENT SOURCES, TRANSPORT, AND SUPPLY TO THE DELTA

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The Sacramento River is the primary source of sediment to the Delta. Recent studies indicate that suspended sediment is an important indicator of habitat quality for endangered native fish. Also, previous work documented decreases in sediment supply from the Sacramento over the past half century in response to anthropogenic impacts. Predictions of future sediment supply in response to climate and water management scenarios require an understanding of sediment sources and transport in the watershed. To this end, this study reviews sediment data collected during 1979 and 1980 when an intensive monitoring program existed in the Sacramento Valley. These data serve to illustrate sources and transport processing during below normal (1979) and above normal (1980) hydrologic conditions. For both years, the primary source of sediment was the upper reaches between Keswick Dam and Hamilton City. In 1979, spills to Sutter and Yolo bypasses were minimal such that the sediment generated in the upper reaches was transported downstream in the main channel to the Delta. Though the Feather River was a significant source of water, its sediment supply was relatively small compared to the supply from the upper reaches (for 1979 and 1980). During 1980, substantial spills occurred to the bypasses and this substantially affected sediment (and water) routing in the system. Sediment loads decreased substantially in the middle reaches as water and sediment were spilled to Sutter bypass. Above Verona, Sutter bypass and the Feather join the Sacramento and can spill into Yolo bypass. In 1980, this resulted in a large increase in downstream Sacramento flows but only a modest increase in sediment loads because of the low sediment load of the Feather as well as deposition in Sutter bypass. Limited data exist for sediment loads in the Yolo bypass and lower Sacramento, and this remains an area for further study.

Tuesday, September 28, 2010: Room 306 Sediment Transport Modeling and Observation in the Sacramento-San Joaquin Delta (I) - Order: 1

AN OBSERVED STEP CHANGE IN DELTA TURBIDITY FOLLOWING 1982-1983 EL NINO FLOODS

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Sediment transport influences the geomorphology, biogeochemical cycling, pollutant load, and ecology of river deltas and estuaries. In the Sacramento-San Joaquin Delta, turbidity is largely considered a surrogate of suspended sediment concentration, and has been declining over the past 30 years. This has contributed to dramatic changes in the ecology of the Delta and to the decline of the endemic and endangered delta smelt. The declining turbidity trend in the Delta has been attributed to reduced sediment inputs and expansion of invasive submerged aquatic vegetation. In this study, we analyzed historic monthly turbidity records collected by the California Department of Water Resources Environmental Monitoring Program from 1975-2008. We investigated structural changes in the turbidity trend, and identified a significant step decrease in turbidity after the beginning of the 1984 water year at nine different sites within the Delta. This significant decrease in Delta turbidity appears to have been caused by the combination of large El-Nino driven winter floods from both the San Joaquin and Sacramento Rivers in 1982-1983 and the high inflows throughout the summer. We suggest that these extended high flow events flushed the erodible sediment pool from the Delta into the San Francisco Bay. This event has left the Delta in its current, low-turbidity state. Another study found that a step decrease in suspended sediment concentration in San Francisco Bay in 1999 may have been caused by depletion of erodible sediment. This indicates that depletion of erodible sediment may have progressed downstream and, if the erodible sediment pools were created by hydraulic mining in the late 1800s, sedimentation in the estuary has largely recovered from hydraulic mining.

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COMPREHENSIVE GEOMORPHIC AND SEDIMENTATION ANALYSES OF LOWER SACRAMENTO RIVER SHOWS PROMISE FOR SEDIMENT BUDGET MODELING OF THE DELTA

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The sediment budget of the Sacramento and San Joaquin Delta system is required for assessing future adjustments in the morphology of this complex landscape of channels, floodplains, and islands. To better understand implications of the sediment budget on morphology, comparisons of the sediment budget with observed morphological adjustments such as bankline adjustment, channel bed change, and the feedback to channel hydraulics is required to develop reliable forecasting tools for predicting future changes to the sediment budget. Northwest Hydraulic Consultants (NHC) completed a sediment budget analysis of the Delta as part of a comprehensive analysis for subsidence management alternatives on Delta islands (Shvidchenko et al., 2004). This analysis included estimates of both bed material and suspended wash load, and identified pathways of sediment inflow, storage, and outflow. More recently, NHC undertook a systematic analysis of the sediment transport and channel morphology of the Sacramento River system for the Army Corps of Engineers. This study collected and reviewed available historic and present-day data related to geomorphology and sediment transport of the Sacramento River system and assessed implications of channel evolution trends and sediment transport regime on the river as well as sediment delivery to the Delta. A 1-dimensional numerical model of the lower Sacramento River was developed that includes sediment routings through the river channel as well as inflows and diversions to the river from the flood bypass systems. The verified model provides very good agreement to measured sediment discharge loads, bed material gradations, stage-discharge rating shifts, and measured bathymetric changes. The computed sediment yield at the Freeport gaging station shows an excellent correspondence between computed and measured sediment discharge for the 1997-2008 time period. Combining NHC's Delta sediment budget with this new tool provides a means for linking implications of future river management activities on Delta sedimentation dynamics.

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MODEL BASED INTERPRETATION OF SEDIMENT CONCENTRATION AND VERTICAL FLUX MEASUREMENTS IN THE SHOALS OF SOUTH SAN FRANCISCO BAY

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Our study focused on the driving factors of sediment resuspension and settling dynamics in the shoals of South San Francisco Bay. We deployed an array of stations in spring and fall 2009 at a shallow field site (2.19-2.59 MLLW) to measure horizontal and vertical gradients of turbidity together with fluid flow, turbulence, and pressure across the shoal-channel transition. Flow velocities, Reynolds stress, wave properties, sediment concentration and turbulent sediment fluxes were measured using ADVs. We developed a simple 1-D dispersion-settling model to interpret the observed sediment concentrations and fluxes. We assumed the existence of two sediment fractions with differing settling behavior. Sediment resuspension into the water column was described as a linear function of the observed sediment flux. Our model study showed that the observed concentrations were best described by a fast settling fraction with a constant settling velocity w_s of 0.003 ms⁻¹ attributed to coarse particles and a slowly settling fraction with a concentration dependent settling velocity $w_s = k * C_{Sed}$ with $k = 8 * 10^{-6} \text{ m}^4 \text{ s}^{-1} \text{ g}^{-1}$ attributed to fine particles, suggesting a coagulation mechanism for the settling of the latter fraction. Modeled sediment concentration profiles showed that the fine sediment fraction can contribute over 70% of the sediment mass. Still, steeper gradients in the profiles of the coarse particles show that these particles are the main contributors to the measured sediment flux. Understanding the sediment transport in the South San Francisco Bay is of crucial importance for the prediction of contaminant and nutrient dynamics as well as predicting the formation and erosion of wetlands and intertidal mudflats. Our study highlights the importance of differing particle fractions in the sediment dynamics of the Bay, especially since these fractions differ in residence time in the water column. The presented results also provide a good starting point for a fully coupled sediment bed-water column model.

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UNCERTAINTY ANALYSIS FOR GEOMORPHIC MODELING

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The prediction of changes in long-term sedimentation (decadal time scale) are necessary if the impacts of projects that affect sedimentation in San Francisco Bay and Delta are to be adequately estimated. However, the prediction of sedimentation over these time scales is subject to a large amount of uncertainty. Causes of the uncertainty include unknown inputs, model approximations, errors in model parameters and method adopted for geomorphic analysis and the natural variability in sedimentation. This presentation presents a method for quantifying the uncertainty. The method is then applied to a proposed project in South San Francisco Bay as an example. An important component of estimating the uncertainty in the prediction of future long term sedimentation is to estimate the variance in the random error associated with the future prediction, which is assumed to be equal to the variance of the actual prediction of sedimentation. This value is estimated by dividing the simulation area in contiguous zones with similar habitat type, environmental conditions, and project impacts. The variance in the error is then estimated from point and average estimates of error within each zone based on hindcast simulations. The variance associated with project impacts can then be estimated based on the variance in the error in estimating future sedimentation and the expected correlation between no action and project conditions. An example application of the method is applied to a proposed project in the South Bay. The results include a map of the Bay showing the expected changes in sedimentation, the forecast uncertainty and the coefficient of variation of the forecast error.

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THREE-DIMENSIONAL MODELING OF SEDIMENT DYNAMICS IN SAN FRANCISCO BAY USING THE SUNTANS MODEL

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We employ the unstructured-grid SUNTANS model to simulate hydrodynamics and sediment transport in San Francisco Bay. The domain extends offshore of the Golden Gate by 25 km where sea-surface tidal constituents at Point Reyes are imposed, and the Delta is modeled as a “false Delta” with two rectangular boxes at the confluence of the Sacramento and San Joaquin Rivers. With an average horizontal resolution of 200 m and a minimum vertical resolution of 25 cm, the model is calibrated to produce accurate predictions of sea-surface height, salinity, and depth-averaged currents throughout the Bay. Cohesive suspended sediment transport is modeled with the transport equation with a settling term that accounts for flocculation using results from observations, and this suspended sediment interacts with a multilayer bed model with five layers ranging in thickness from 25 mm to 1 m. A phase-averaged wave model is employed to incorporate the effects of wind-wave induced sediment resuspension. We demonstrate the behavior of the combined hydrodynamics-sediment-wave model and focus on comparisons to observations in South Bay, and we demonstrate the sensitivity of the results to the relative effects of tides and wind-waves.

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SEDIMENT TRANSPORT AND VEGETATION GROWTH SIMULATION ON THE SAN JOAQUIN RIVER

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Sedimentation and River Hydraulics – One Dimension (SRH-1D) is a one dimensional hydraulic and sediment model used to simulate water surface profiles, sediment transport rates, and erosion and deposition within rivers and canals. There is also a vegetation module that has been built into SRH-1D and this version is called SRH-1DV. The vegetation module tracks the establishment, growth, and survival of various riparian species. The model parameterizes the establishment, growth, and mortality using available information for each species. In addition, a companion paper in this conference describes laboratory measurements of cottonwood establishment used to parameterize the model. SRH-1DV has been applied to the San Joaquin River and the flood bypasses from Friant Dam to the confluence with the Merced River to predict future erosion and deposition with and without the San Joaquin River Restoration Program (SJRRP). The model requires several inputs. Cross section information was taken from existing HEC-RAS models of the system. Bed material data was collected from field samples collected throughout the river and bypass system. The daily flows used in the simulations were generated by CALSIM II and a daily time step model. We used the simulated daily flows under with and without SJRRP and we also simulated the erosion and deposition using historical stream gage data. Some of the main concerns of the project include improving and maintaining anadromous fish habitat below Friant Dam and maintaining flood capacity in the project reaches. To this end, we analyzed the mobilization of gravel, analyzed simulated changes to the bed elevations, and also to the riparian vegetation. The reach downstream of Friant is primarily gravel and cobble and we analyzed whether project flows will be able to mobilize this gravel to maintain salmon spawning beds. This reach is already heavily vegetated and does not have significant levee systems. Further downstream, the San Joaquin transitions to a sand bed river and several reaches are without surface water the majority of the year. There is currently little vegetation and the levee system is already stressed. The resupply of base flow to these dry reaches will potentially cause erosion or deposition and increase riparian vegetation density. We use SRH-1DV to assess the erosion or deposition in these reaches and also additional vegetation growth under the San Joaquin River Restoration Project.

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TECHNICAL DETAILS OF THE DEVELOPMENT OF A SEDIMENT- TRANSPORT MODULE FOR DSM2

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This presentation describes the development of a one-dimensional Sediment and Transport Module (STM) for the Delta Simulation Model 2. STM is a general transport model for conservative and non-conservative constituents with special focus on sediment transport. The module includes cohesive and non-cohesive sediment transport in tidal channel networks. Both suspended sediment and bed load are simulated in the module. STM uses a second order accurate, finite volume numerical solution. To verify that components of the model are coded properly, a companion testing code has been developed.

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EXPERIENCE MODELING TURBIDITY IN THE SACRAMENTO-SAN JOAQUIN DELTA FOR THE 2009-2010 WINTER SEASON

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With funding from the Metropolitan Water District of Southern California (MWD) and in collaboration with DWR Operations and Maintenance (O&M) staff, Resource Management Associates (RMA) has developed a 2-D turbidity modeling protocol for short-term forecasting. Starting in December 2009, many new real-time turbidity monitoring stations became available in the Delta, providing a rich data set for developing model boundary conditions and evaluating the performance of turbidity predictions. Using O&M's DSM2 flow and salinity forecast boundary conditions as a starting point, flow boundary conditions for the Sacramento and San Joaquin Rivers and for the Yolo boundary were refined using forecast conditions from the California-Nevada River Forecasting Center (CNRFC). A simple methodology was developed for forecasting 50% and 90% exceedance values for turbidity boundary conditions at the Sacramento and San Joaquin boundaries. The initial application of a simple turbidity model based on exponential decay gives reasonable results throughout much of the Delta, however, comparison of model results to the extensive observed data set reveals several factors that should be included in a more comprehensive model including: wind-driven resuspension in open water areas; turbidity loading from local rain; ungaged inflows particularly in the Eastern Delta; and settling and resuspension in channels with low net velocity. Overall, the results indicate that measured turbidity will be better approximated by a full suspended sediment model with meteorological inputs for local precipitation and wind, particularly if flow can be measured more accurately during and shortly after storm events.

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SEDIMENT MODELING FOR THE DELTA ISLANDS AND LEVEES FEASIBILITY STUDY

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The Sacramento – San Joaquin River Delta consists of a 700-mile network of controlled channels, 1,100 miles of levees, and 70-plus islands, most of which are well below sea level. The current system is a patchwork of projects implemented over the last 150 years primarily for land reclamation, flood control, navigation, and water delivery. Delta water supports \$400 billion of the state economy, supplies two-thirds of the households, and provides habitat for many species. The Delta as a vital economic and ecologic resource for the residents of California and the nation is at risk. Continued development, changes in conveyance, subsidence, invasive species, seismic risk and weather/climate risks are likely going to challenge the system even further. While many models have been used in the system the 3-dimensional Environmental Fluid Dynamics Code (EFDC) has been chosen for this work. The 3-D hydrodynamic EFDC model will provide the necessary detailed predictions of water level and velocity for flooding analyses and all constituent transport processes from salinity to sediment to dissolved oxygen for existing conditions and predicted future scenarios, including plan alternatives. The numerical model has been designed to represent the major hydrodynamic processes, transport pathways and fate of nutrients, sediments, carbon and contaminants in surface waters and is capable of capturing subtle circulation patterns such as residual flows and density currents that are essential to representative transport of dissolved constituents and suspended materials. The purpose of the work described is to support the Delta Islands and Levees Feasibility Study (DILFS) and CALFED, specifically through the modeling of sediment transport, deposition and erosion. It is generally understood that sediment in the Delta can be beneficial, as when it nourishes wetlands and provides habitat for aquatic species that prefer turbid water or a specific substrate. It can have adverse effects when it produces a hostile habitat for aquatic species or clogs channels and outlet works that cause significant expense in the dredging of navigation channels, ports, and terminals. The EFDC suite of models will be used to support the development of water resource management plans for the Sacramento-San Joaquin Delta and provide managers with quantitative evaluations and comparisons of the relative effectiveness of alternative plans to achieve the objectives in relation to known Delta issues related to water supply, water quality, flooding, navigation, recreation, sedimentation, ecosystem health, economics, and aesthetics.

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A RE-ASSESSMENT OF THE HISTORIC CHANGES IN SEDIMENT FLOWS INTO SAN FRANCISCO BAY

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There is good deal of interest in understanding how sediment flows into San Francisco Bay have changed relative to historic and natural conditions. These changes can affect dredging needs, erosion rates, the re-suspension of buried contaminants, tidal marsh restoration efforts and the capacity of the Bay to support oyster and eelgrass beds. They also provide a benchmark for assessing projected impacts from climate change. The Bay sediment literature uniformly quotes estimates from Grove Karl Gilbert's 1917 monograph on hydraulic mining debris as the baseline for natural (pre-1850) and peak historic (roughly the last half of the 19th century) sediment flows into the Bay. However, a review of Gilbert's sediment budget model reveals that his estimates have been misquoted since he does not actually provide a value for historic sediment inflow to the Bay, nor can a specific value be calculated from his data (though rough upper and lower bounds can be determined). More critically, however, incorrect values for bulk sediment density have been used to convert Gilbert's sediment volume estimates to mass units for comparison with modern sediment flow measurements, thereby substantially understating Gilbert's sediment flow estimates, possibly by a factor of 3-5. Overall, the baseline estimates of natural and peak historic sediment inflows are much higher and more uncertain than recent literature has indicated, which greatly alters our perception of both where we are today and where we are headed relative to baseline conditions. This in turn affects our understanding of how shifts in sediment inflows due to dams, diversions, channel alterations, land use, climate change or other anthropogenic factors may affect shoreline erosion, the ecosystem's exposure to legacy contaminants, and the potential to achieve certain types of environmental restoration or enhancement.

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ENVIRONMENTAL IMPACTS AND REGULATORY IMPLICATIONS OF THE APPARENT EXPULSION OF THE HYDRAULIC MINING ERA PULSE OF MERCURY LADEN SEDIMENT FROM SAN FRANCISCO BAY

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Problem Statement: Over several decades, a significant reduction in the sediment load entering San Francisco Bay from the Delta and its major river tributaries has spurred an increase in the resuspension of the Bay's erodible sediment pool allowing suspended sediment concentrations to maintain equilibrium. Recently published data (NOAA 2009) suggest that the erodible sediment pool, consisting primarily of shoaled sediments from Gold Rush era hydraulic mining, may have been essentially depleted. If ambient mercury concentrations in Bay sediments have been reduced with the depletion of mining related sediments, how will policy measures aimed at reducing levels of mercury in San Francisco Bay (i.e. mercury TMDL) be impacted? **Approach:** Recent deepening the Oakland Harbor navigation channels to pre-industrial sediment strata, make this location an ideal for assessing the trend in mercury concentrations in newly shoaled sediments in San Francisco Bay. Sediment samples from the Oakland Harbor were collected prior to maintenance dredging every year since the deepening project was completed and analyzed for mercury. Results were compared to historic levels documented for Oakland Harbor and other regions within the Bay. **Results:** The results of this investigation show that mercury present sediments newly accreted in Oakland Harbor every year since the navigation channel was deepened are consistent with pre-industrial, background concentrations (~0.23 mg/kg). **Conclusions:** Under the Clean Water Act's Section 303d, the San Francisco Bay was deemed impaired for mercury, and a Total Maximum Daily Load (TMDL) for this contaminant was developed and amended to the San Francisco Bay Regional Water Quality Control Board's Water Quality Control Plan. A significant reduction in ambient San Francisco Bay mercury sediment concentrations associated with the apparent dramatic depletion in mining related sediments may imply that a substantial reduction in the total Bay Area mercury load, and warrant a modification to the mercury TMDL implementation plan. This is especially true for Bay Area dredge permit applicants because the TMDL currently prohibits discharge of dredged material to the Bay's authorized aquatic disposal sites unless the material exhibits concentrations lower than the current ambient sediment mercury concentration (0.53 mg/kg).

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NEW ESTIMATES OF SUSPENDED SEDIMENT LOADS TO SAN FRANCISCO BAY

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Information on suspended sediment loads is of paramount importance for managing the Bay-Delta due to associated degradation of water and sediment quality, recreation amenities, native species habitat, and disruption of commercial shipping operations. Yet we still have limited understanding of suspended sediment and contaminant loads in various components of the ecosystem. Research in the 1970s and 80s provided evidence that approximately 80% of the sediment supply to the Bay was from the Central Valley. Since then, sediment loads from the Central Valley have trended downwards, a premise promulgated by Krone (1996) in Hollibaugh (Ed.) *San Francisco Bay: The Ecosystem* and confirmed by Wright and Schoellhamer (2004) *San Francisco Estuary and Watershed Science Journal*. Based on point and cross section measurements of turbidity and suspended sediment concentrations at Mallard Island, we presented evidence that the average annual suspended sediment load passing from the Central Valley through the Delta past Mallard Island is now 1 million metric t (McKee et al. 2006: *Journal of Hydrology*). Recently we completed a new evaluation of suspended sediment loads in small tributaries of the nine county Bay Area using a combination of 177 station years of sediment data covering 29 watersheds, regression analysis, and simple modeling (Lewicki and McKee, 2009: SFEI technical report). Along with updated estimates of Delta loads, this research shows that an estimated 1.3 million metric t is supplied from the tributaries of the nine-county Bay Area, and that the balance is tipped even more than Krone had predicted. Our results imply that the Bay suspended sediment budget is now dominated by supply of fine more highly contaminated sediment from urbanized nine-county Bay Area tributaries. Managers responsible for sediment accumulating in shipping channels and restoring wetlands may need to more carefully account for proximity to urban tributaries and contaminant sources.

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SUSPENDED-SEDIMENT FLUX IN THE SHALLOWS OF SOUTH SAN FRANCISCO BAY

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The shallows of San Francisco Bay retain fine sediments, and are thought to serve as a source of sediments for intertidal mudflats and marshes. Thus sediment transport in the shallows and shoal-channel exchange are important components of the Bay sediment budget. We evaluated near-bed suspended-sediment flux (SSF) at two sites in the eastern shallows of South San Francisco Bay from February 24 to March 16 (spring) and September 9 to October 6, 2009 (fall). The sites were 0.3 km (ShN) and 1.3 km (Be) from the channel edge, at depths of 2.6 m and 2.2 m MLLW. During both deployments and at both sites, the along-channel component of SSF was directed down-estuary during calm periods and up-estuary during windy periods. The up-estuary flux was produced by a correlation of higher suspended-sediment concentration (SSC) with flood tides, due to enhanced wind-wave resuspension at low water and vertical mixing by the ensuing flood-tide currents. SSF during two intense wind events at the end of the fall deployment (wave heights > 0.5 m) was an order of magnitude greater than at any other time during the study. As a result, cumulative flux in fall was directed up-estuary, whereas in spring it was down-estuary and much lower in magnitude. Cumulative cross-shore SSF in the spring was directed toward the channel at ShN, but was toward shore and lower in magnitude at Be. During the fall, cross-channel SSF was directed toward the channel at both sites and was greater at ShN than Be, although the total magnitude of cumulative SSF was much lower at ShN than Be. The spatial variation in cross-channel SSF during both deployments indicates net erosion and transport into the channel, and suggests that the region of the shoals adjacent to the channel does not supply sediment to adjacent marshes.

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MEASUREMENTS OF WATER COLUMN AND SEDIMENT BED INTERACTIONS IN THE SOUTH SAN FRANCISCO BAY ESTUARY

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Sediments in the South San Francisco Bay in the bed and in the water column are composed primarily of fine cohesive sediments which are known to be contaminated with a number of new and legacy contaminants. Changes to the South Bay environment, including sea level rise and habitat restoration, have increased concerns that the South Bay may be erosive, introducing additional contaminants into the South Bay ecosystem. Further understanding of the processes that determine the behavior of fine sediments found in the water column and in the bed are needed to evaluate and model how the South Bay will respond to the changing environment. A three week instrument deployment was undertaken in the South Bay to better understand shoal-channel sediment processes at multiple scales. Instruments deployed at ten stations covering roughly two square kilometers measured water velocities, suspended sediment concentrations, salinity and temperature at hourly or shorter intervals. Measurements of the particle size distribution were also made at one location every 12 minutes for the first five days and sediment cores were collected at the beginning and end of the deployment from two locations. From these measurements turbulence and other parameters have also been calculated. Measurements of suspended sediment concentrations during the deployment usually were in the range of 5-50 mg/L on the shoals, with the lowest concentrations observed during spring tides. Episodic events driven by wind waves created peaks around 100 mg/L. Analysis of sediment cores indicated disturbances to the sediment bed of less than 1 cm. Flood tide resuspension of sediments were affected by several factors including strength, duration and direction of the flood tides. Second resuspension events were observed during ebb flood tides, subject to the same factors. Particle size distributions measured during the second resuspension event were different from those measured during the primary resuspension event.

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CONCENTRATIONS AND LOADS OF TRACE CONTAMINANTS IN THE ZONE 4 LINE A SMALL TRIBUTARY, HAYWARD, CALIFORNIA: WATER YEARS 2007-2010

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Urban runoff has been identified in the total maximum daily loads reports (TMDLs) as a large and potentially controllable source for pollutants of concern (POCs) to San Francisco Bay and these reports encourage further development of loads information from the Bay's tributaries. To investigate the concentrations and loads of mercury (Hg), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), organochlorine (OC) pesticides, various metals and other POCs in urban runoff from a small (4.5 sq km) and highly urbanized watershed, storm and base flow samples were collected from a tributary in Hayward called Zone 4 Line A for Water Years 2007-2010. Loads were calculated using linear interpolation, regression with turbidity, or a stratified flow-weighted mean concentration approach. More than 95% of the loads for all contaminants were carried past the sampling location during storm events, along with over 90% of the total discharge. The organic contaminant class with the greatest concentrations and loadings were PAHs, which appear to be mostly associated with automobile and diesel exhaust and brakelining particles. The relative order of loadings for the other organic contaminant classes was OC Pesticides > PBDEs > PCBs. Total mercury was primarily particle-associated and exhibited higher concentrations (1-147 ng/L) than reported in previous studies for both an urban creek in the Sacramento Area (Arcade Creek (90th percentile was approximately 23 ng/L), in Domagalski, 1998) and Sacramento-San Joaquin River flow from the Delta into the Bay (3 – 75 ng/L, in David et al, 2009). The results support the premise that the control of non-point source pollution in highly urban areas of the Bay-Delta ecosystem may reduce loads of bio-accumulative materials such as Hg and PCBs and improve water and sediment quality to help attain beneficial uses for wildlife and humans.

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COPPER RUNOFF TO SAN FRANCISCO BAY FROM BRAKE PAD WEAR DEBRIS – PHASE 2 WATERSHED MODELING ANALYSES

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The Brake Pad Partnership has conducted a series of interconnected technical studies to determine whether or not copper from brake pads contributes significantly to copper in surface waters in the San Francisco Bay watershed. As part of the Partnership's studies, air deposition modeling, watershed modeling (reported at the 2008 Bay-Delta conference), and bay modeling were conducted. The Partnership's technical studies showed that brake pad wear debris is a significant contributor to copper in runoff to the San Francisco Bay, particularly in highly urbanized sub-watersheds. This paper reports on the Phase 2 of the watershed modeling efforts. The watershed modeling was conducted using the U.S. EPA's Hydrological Simulation Program-FORTRAN (HSPF) model to estimate the copper in runoff to the bay. Based on the Phase 1 modeling, the contribution of copper from brake pads to the total copper load in runoff to the bay is from 10% (for the brakes-low case) to 35% (for the brakes-high case). This follow-on Phase 2 effort was done to better understand the full extent of the contribution of copper from brakes on copper in runoff, and determine the timeframe over which reductions in copper from brakes will result in reductions of copper in surface waters. The buildup/washoff modeling technique used in the Phase 1 watershed modeling effort was modified to capture the copper that is lost from the buildup/washoff algorithm, and transferring that copper to a roadside buffer area, where it is subject to washoff to surface waters. Mean annual loads to the Bay increased from 0.5-3.5% over Phase 1 loads when the buffer area was assumed to be pervious, and 15-30% when impervious. The final portion of the Phase 2 modeling was conducted in order to help understand the length of time it will take for brake pad wear debris copper to wash out of California's urban watersheds. Based on the model results, the answer to the question "How long will it take copper from brake pad wear debris to wash out of California's urban watersheds?" is that it will take from 0 to 5 years for 80% and from 6 to 15 years for 95% of reductions in releases of copper from brake pad wear debris to be realized in urban surface waters in the San Francisco Bay area.

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THE OCCURRENCE OF INDICATOR BACTERIA AND WATERBORNE ZOO NOTIC PATHOGENS IN THE CALIFORNIA DELTA

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A two year intensive study was conducted from June 2006 through December 2008 on a section of the California Delta. This study addressed the use of bacterial indicators, *E. coli* and *Enterococcus*, to identify priority bacterial pathogens potentially shed by livestock populations located throughout the Delta: *Salmonella*, Shiga like toxin producing *E. coli* (SLTEC), and *Campylobacter*. Many of these pathogens can be transmitted to humans, other domestic animals, and wildlife through the waterborne route of transmission. We identified 88 monitoring sites throughout the sloughs and waterways of the eastern and northwestern Delta, and surveilled them monthly for bacterial source identification, pathogen load estimations, and standard water quality metrics. A total of 1740 water samples were taken during three distinct seasons (Rainfall, Nov-Mar; Snowmelt, Apr-Jun; Dry, Jul-Oct) over the course of the study period. The prevalence of indicators appears to be seasonally dependent with a higher percentage of samples exceeding the single sample maximum (SSM) for both *E. coli* (235 CFU/100 ml) and *Enterococcus* (61 CFU/100 ml) in the Rainfall season and the Dry season than the Snowmelt season. The occurrence of pathogens was low to moderate; *Salmonella* (4.7%, n=1740), *Campylobacter* (14.99%, n=1501), and SLTEC (1.24%, n=1366). The average bacterial counts of *Salmonella* (MPN/100 ml) and *Campylobacter* (CFU/100 ml) were not significantly higher in samples that exceeded the (SSM) for either indicator *E. coli* ($p=0.44$, $p=0.25$ respectively) or *Enterococcus* ($p=0.39$, $p=0.08$ respectively). Sampling season proved to be a strong predictor for the occurrence of SLTEC when coupled with exceedance of the *Enterococcus* SSM ($p=0.014$). Rainfall driven seasonal variations appear to influence the occurrence of both indicator bacteria and bacterial pathogens. While further sampling may prove beneficial to Delta stakeholders, this study is one of the most comprehensive examinations of microbial water quality in the California Delta to date.

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EFFECTS OF WATERBORNE LIPOPHILIC CONTAMINANTS FROM LOCATIONS IN THE SAN FRANCISCO ESTUARY ON RESIDENT FISH

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In a collaborative research project with United States Fish & Wildlife Service Contaminants Division, USGS and California Department of Fish and Game we investigated the effects of waterborne contaminants on resident fish species using striped bass (*Morone saxatilis*) as a surrogate for endangered endemic species. The United States Fish and Wildlife Service deployed semi-permeable membrane devices (SPMD) at five sites in the Delta year-round. SPMDs mimic fish bioaccumulation of lipophilic contaminants over a 30 day period. Once retrieved the SPMDs contents are extracted and chemical analysis is performed. Half of the SPMD extract is prepared in a manner suitable for injection into control juvenile striped bass to assess potential physiological effects caused by any lipophilic contaminants from the site. To assess these effects five biochemical and two molecular biomarker assays, histopathology & immunohistochemistry was used. Results indicate 60% of sites were positive for CYP450-1A1 induction indicating sublethal contaminant exposure, vitellogenin expression was found at 25% of sites indicating exposure to estrogenic compounds or their mimics and metallothionein expression at 10% of sites indicating heavy metal exposure or severe oxidative stress. Multiple biomarkers were positive at 35% of the sites demonstrating that several types of xenobiotic exposure were occurring simultaneously. In addition molecular biomarkers HSP-70 and MX were significantly upregulated in 25% and 10% of the sites respectively and likely biologically significant at additional sites. Results from these studies will help characterize spatial and temporal patterns of xenobiotics in the Delta's water and identify potential adverse effects on resident endangered fish species.

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USE OF A RESIDENT FISH FOR ASSESSMENT OF ENDOCRINE DISRUPTION AT SELECTED SITES IN THE SACRAMENTO-SAN JOAQUIN DELTA

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Here we present the development of *Menidia beryllina*, the Atlantic Silverside, for use as a bioindicator of the presence of estrogenic endocrine disrupting compounds. Two sites within the Sacramento-San Joaquin Delta were chosen for this assay: the Napa River and Walnut Grove on the Sacramento River. This assay detects the presence of the inappropriate expression of the choriogenin protein via a polyclonal antibody specific to *Menidia*. Choriogenin is not normally produced in juvenile or male fish, therefore its presence is indicative of exposure to estrogenic compounds in the water. For example, previous exposures to pyrethroid pesticides in the laboratory showed induction of choriogenins in *Menidia*. The purpose of this study was to assess choriogenins in *Menidia* from Delta field sites as well as in cultured juvenile *Menidia* exposed to site water in the laboratory. Adult males were seined from each site. Juvenile fish were exposed to water collected from each site, or to clean spring water as a control, for two weeks with daily renewal under laboratory conditions. Whole-body homogenates from lab-exposed juveniles and plasma from field-collected adults were then analyzed for presence of choriogenin. Results will be part of a larger study that also assessed vitellogenin response in medaka and rainbow trout tissues/cells following exposure to water from the same sites. Expression of choriogenin in these resident fish appears to be a useful indicator of exposure to estrogenic compounds in Delta waters, and can likely be utilized in other areas, as *Menidia* are found in rivers and estuaries nationwide.

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OVERVIEW OF THE SOUTH BAY SALT POND RESTORATION PROJECT AND APPLIED SCIENCE FOR AN ADAPTIVE MANAGEMENT PLAN

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The South Bay Salt Pond Restoration Project (www.southbayrestoration.org) is the largest wetlands restoration project on the West coast of the United States. It is unique not only for its size-- over 15,000 acres—but for its location in the middle of one of the nation's largest urban areas, home to over 3 million people. The Project is intended to restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation. We have identified long-term alternatives for the Project, each representing a continuum toward different end-states: one end-state at 50% of the existing ponds converted to managed ponds for waterbirds and 50% restored to salt marsh habitat, and the other end of the continuum at 10% of the existing ponds converted to managed ponds and 90% restored to marsh habitat. The final mixture of managed ponds to salt marsh habitat will depend upon the outcome of the Adaptive Management Plan, which will be implemented over the next 50 years and will allow for lessons learned from earlier phases and applied studies to be incorporated into subsequent stages as management plans and designs of future actions are updated. This presentation will provide an overview of the key uncertainties in this first phase of the restoration, and how applied science is being used to address these uncertainties. Key uncertainties include sediment dynamics, bird use of changing habitats, effects on non-avian species, legacy mercury, water quality, invasive and nuisance species, and impacts of public access.

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SEDIMENT FLUX IN THE SOUTHERN REACH OF SAN FRANCISCO BAY: IMPLICATIONS FOR HABITAT RESTORATION

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The South Bay Salt Pond Restoration Project is restoring about 6,000 hectares of former commercial salt-evaporation ponds to tidal marsh or managed wetlands in the southern reach of San Francisco Bay (SFB). As a result of groundwater overdrafts prior to the 1970s, much of the project area has subsided below sea-level and will require about 32 million cubic meters of sediment to raise the surface of the subsided areas to tidal marsh elevations. However, previous estimates of sediment flux between northern SFB and the southern reach using data from five bathymetry surveys conducted decades apart are insufficient to estimate the natural sediment supply from the bay. The specific purpose of this study is to quantify the continuous suspended-sediment flux (SSF) past Dumbarton Narrows. Data from two optical turbidity sensors and an acoustic Doppler current profiler mounted in the cross-section are collected every 15-minutes. Water discharge and velocity-weighted cross-sectionally averaged suspended-sediment concentrations (SSC) are measured during monthly site visits. Using the “index-velocity” method for discharge and a combination of turbidity and acoustic backscatter calibrated to SSC, a continuous (15-minute interval) record of SSF at the measurement cross-section is computed. Additionally, a high-accuracy pressure transducer and water-quality sonde are deployed on an adjacent intertidal mudflat to measure wave-height and turbidity, which provide evidence about the physical processes controlling SSF. Results suggest that, from November 2008 to October 2009, net sediment transport into southern SFB was from the north. Seasonality in SSF shows the largest southerly flux in the spring during periods of high SSC and not during the summer when strong diurnal winds from the north originally were thought to control the annual SSF. Understanding physical controls on sediment flux for this large wetland restoration project can explain how southern SFB and the project are linked to the rest of the estuary.

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USING REMOTE SENSING TO MAP THE EVOLUTION OF MARSH VEGETATION IN THE SOUTH BAY OF SAN FRANCISCO

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The South Bay Salt Pond (SBSP) Restoration Project is the largest Federal restoration effort outside of the Everglades. The accretion of sediment and subsequent colonization of vegetation by endemic marsh vegetation is a crucial component of the restoration effort. Classic field mapping efforts to cover the vast geographic area included in the restoration project would be extremely time consuming and costly, especially over time. We have implemented a semi-automated approach to mapping vegetation and sediment on a yearly basis by using supervised classification (maximum likelihood) of 1 meter Ikonos multispectral imagery accompanied by extensive ground truthing using sub meter GPS. Our ground truthing includes efforts at characterizing vegetation associations found in salt, brackish and fresh water marshes within the study area are supplemented by an iterative systematic manual review of supervised classifications. After verification of the result of our “habitat model” during year one (of a three year project), we have achieved approximately 90% accuracy for deriving sediment and slightly greater than 80% for our vegetation classes. An important challenge is accurately characterizing the spatial and taxonomic range of vegetation in our classifications that are appropriate to project needs but within the spectral and spatial limits of the imagery. Despite our difficulties with timing the satellite acquisition with Mean Lower Low Water (MLLW) as well as issues with atmospheric effects over time, our semi-automated remote sensing model has great potential to track changes to marsh vegetation at geographic scales relevant for assisting with the larger adaptive restoration effort.

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SEDIMENT DYNAMICS AT THE ISLAND PONDS: INDICATIONS FROM EARLY SALT POND RESTORATION

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Many potential wetland restoration sites, including the South Bay salt ponds, have subsided substantially; if levees are breached, significant sediment accumulation will be necessary to reach threshold elevations for plant establishment. In order to evaluate the early phases of salt pond restoration, we monitored sediment dynamics at the Island Ponds, with spatially intensive sampling at Pond A21 (westernmost pond) and less intensive sampling at A20 and A19 (easternmost). We measured vertical rates of sedimentation using both the gypsum layer that is present across these ponds as a sediment marker and sediment pins. Measurements were made at 1, 3, and 6 mo and then annually at A21 and annually at A20 and A19. Over the first year, we measured mass-based rates of short-term sedimentation at A21, using a modified filter-paper method over two-week tidal periods every two months. We also monitored plant recruitment through general observations at the ponds. There has been substantial sediment accumulation within Pond A21 since breaching in 2006, with approximately 12-14 cm of sediment accumulating over the first year in most of the southern half of A21, and variable but lower rates in the northern half of the pond. Short-term, mass-based accumulation rates over the first year reflected similar spatial variability across A21. Sedimentation rates at A21 decreased in the second and third year but still were high compared to well-established marshes. On the broader spatial scale, sediment accumulation rates decreased from the west to east, with high rates at A21 and A20 and the lowest rates at A19 across all years. Plant recruitment was highest at Pond A21; in year two, recruitment within A21 was patchy with plants growing primarily along channel and barrow ditch edges. Substantially more vegetation recruited in year three at Pond A21, but vegetation remains very patchy at A20 and A19.

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WILL RESTORATION CAUSE LOSS OF MUDFLATS IN SOUTH SAN FRANCISCO BAY?

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A key question in salt pond restoration in South San Francisco Bay is whether sediment sinks created by opening ponds will result in the loss of mudflats. If sediment supply is insufficient, existing mudflats will erode. A decrease in habitat area and altered inundation regime may result in changes in food webs on the mudflats that could reduce their value for migratory birds. The likelihood of salt pond restoration causing mudflat erosion is being evaluated based on long-term and seasonal mudflat changes. A series of bathymetric surveys collected from 1858 to 2005 reveal long-term changes in mudflat area in both space and time that can be used to better understand the pre-restoration system. For example, the mudflat south of the Dumbarton Bridge on the west side of the Bay adjacent to the Ravenswood restoration project narrowed approximately 200 meters from 1858 to 1931. Since then this mudflat has accumulated sediment and is now wider than it was in 1858. At this same site, pre-restoration seasonal bathymetric surveys were collected from 2008 to 2010 using a state-of-the-art interferometric sidescan sonar for swath mapping in extremely shallow water. These high-resolution surveys provide a pre-restoration baseline and indicate that, on average, there is little seasonal change on mudflats adjacent to the Ravenswood ponds. Continued surveying is planned to document changes that occur during restoration. The causes of the spatial and temporal variability in historical mudflat area offshore of the Ravenswood ponds are not fully understood, but appear related to sediment redistribution from north to south in the bay and sediment available to deposit on the flats. Improved understanding of sediment input and redistribution within the Bay are needed and will aid in separating restoration effects from more regional effects and help in managing restoration of South San Francisco Bay salt ponds.

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EFFECTS OF MANAGEMENT ON AVIAN POPULATIONS IN THE SOUTH BAY SALT PONDS: DENSITY CHANGES FROM 2003-2010

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A long-term goal for the South Bay Salt Pond Restoration Project (SBSRP) is to restore a mix of habitats ranging from tidal marsh to open ponds that balance needs of marsh species with migrating waterbird populations. As the SBSRP enters its first phase, it is important to take stock of the effects of early management efforts on avian populations. We conducted monthly waterbird counts and sampled salinity and dissolved oxygen in three SBSRP salt pond complexes since 2003 (53 ponds in Alviso, Eden Landing, and Ravenswood), and in two salt production pond complexes since 2005 (22 ponds in Newark and Mowry). We used generalized least-squares regression for clustered data with pond as a random effect to assess temporal trends in average avian densities, salinity, and dissolved oxygen over years, after adjusting for seasons, and as a function of pond complexes and pond management types. Over a common temporal period (2005-2010), small and medium shorebirds and dabbling and diving ducks had higher densities in restored than production ponds but there were no significant ($p < 0.05$) density changes over years. Gulls, terns, fish eating birds and eared grebes had similar or higher densities in production ponds with few trends over time but gulls decreased in restored ponds and eared grebes decreased in production ponds over the time period. Over the longer period in restored ponds (2003-2010), small and medium shorebirds densities were relatively high but decreased in Ravenswood and increased in Eden Landing. Medium shorebirds and dabbling ducks increased in breached ponds. Dabbling and diving ducks had highest densities in Alviso intake ponds; both dabbling duck and fish eater densities increased substantially in Alviso ponds over the study period, perhaps related with increased dissolved oxygen and decreased salinity. Results from this study will help managers assess how changing pond characteristics influence avian populations.

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INCREASE OF THE CALIFORNIA GULL POPULATION IN THE SAN FRANCISCO BAY AND THE IMPACTS ON WESTERN SNOWY PLOVERS

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California Gulls first bred in the San Francisco Bay in 1980, when 12 nests were found on a dry salt pond. In 2009, over 43,000 California Gulls were breeding in the Bay. Meanwhile, the breeding population of the federally threatened Western Snowy Plover in the Bay has remained at approximately 130 individuals, well below the recovery goal of 500 for the region. California Gulls in San Francisco Bay depredate the eggs and chicks of waterbirds, but their impacts on breeding Snowy Plovers are unknown. To determine the extent of gull predation on Snowy Plover nests, we deployed nest cameras in 2009 and 2010 at Eden Landing Ecological Reserve (ELER). We tested the effectiveness of habitat enhancements to reduce predation on plover nests by placing treatment plots (oyster shells) at ELER using a randomized block design. California Gulls accounted for 25% of Snowy Plover nest predators captured on camera. The oyster shell enhancements were successful, with 66% of Snowy Plover nests in the oyster shell plots hatching compared to 50% of nests outside the plots. Only 8% of the nests in the oyster shell plots were depredated compared to 44% of outside the plots. Despite the success of the oyster shell enhancements, the growing California Gull population may threaten the recovery of Snowy Plovers in San Francisco Bay. Over 25,000 California Gulls currently nesting in a former salt pond (Pond A6) will be displaced when it is restored to tidal marsh under the South Bay Salt Pond Restoration Project. Our results, along with the recent documentation of the first California Gull nest in ELER, where 60% of Snowy Plovers in the Bay nest, suggest that gulls may increase predation on waterbird nests and chicks or encroach on the breeding habitat of other waterbirds once displaced from Pond A6.

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MERCURY BIOACCUMULATION AND TOXICITY TO BIRDS IN SAN FRANCISCO BAY ESTUARY

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Mercury contamination in waterbirds is a significant concern in the San Francisco Bay-Delta because the Estuary has a legacy of mercury contamination from mercury and gold mining and waterbirds rely heavily on wetland habitats that are known to produce methyl mercury, the most toxic and bioavailable form of mercury. We examined mercury bioaccumulation and effects on avian reproductive success in waterbirds that breed within the Estuary and found impaired reproduction in several species and lifestages. Upon arrival within the Estuary, birds rapidly accumulated mercury prior to and during the breeding season. We found sublethal effects of mercury on adult birds, including demethylation of mercury in bird livers. Methylmercury in adults was then transferred proportionately to offspring, potentially impairing reproduction. In fish-eating Forster's Terns, we found that: 1) failed-to-hatch eggs and abandoned eggs had higher mercury concentrations than randomly sampled eggs, 2) the prevalence of embryo malpositions increased with egg mercury concentrations, 3) hatching success of eggs decreased with mercury concentrations, and 4) nest survival decreased with mercury concentrations. In invertebrate-eating Black-necked Stilts, we found that dead chicks had higher mercury concentrations than live, randomly sampled chicks of similar age. Altogether, these results suggest that mercury contamination may currently be impairing bird reproduction and, perhaps, population growth within the Estuary. In order to ensure that restoration efforts of the South Bay Salt Pond Restoration Project are successful, it will be valuable to establish a long-term, annual monitoring program for waterbird mercury concentrations and reproductive success.

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MONITORING THE RESPONSE OF FISH ASSEMBLAGES TO RESTORATION IN THE SOUTH BAY SALT PONDS

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Problem Statement: Greater than 90% of wetland habitats in SF Bay have been lost due to land reclamation for agricultural and urban development. In South Bay, the largest wetland restoration effort in the U.S. was established to restore a diversity of habitats in historic salt ponds. The effects of this restoration on fish fauna is a priority goal of the South Bay Salt Pond Restoration Program and its effects are currently unknown. **Approach:** In this study we are developing a flexible, comprehensive monitoring program to evaluate the effects of restoration on the fish species assemblages and sentinel species health in salt pond habitats located in the Alviso complex in South San Francisco Bay, California. We employed several commonly used and new fish sampling techniques in restored pond habitats and adjacent marsh and slough habitats to monitor salt pond habitats of different restoration age to assess the temporal trajectory of pond restoration effects on fish assemblages. We also conduct detailed investigations into the health of the sentinel species *Gillichthys mirabilis*, measuring indicators of health such as growth, reproductive output, feeding condition, and survival in pond A8. Our interdisciplinary approach to assessing fish health will provide novel diagnostic evidence of the potential impacts of re-introducing legacy contaminants into the environment from restoration activities. This study will develop a comprehensive, state of the art monitoring program for the Salt Pond Restoration Program. **Relevance:** This study provides vital information to the Delta Authority on the effects of intertidal wetland restoration on fish fauna in SF Bay, and could be used to guide future restoration efforts and facilitate the effective implementation of the Bay Delta Conservation Plan.

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PUBLIC ACCESS AND WATERBIRDS: RESEARCH MANAGERS CAN USE

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Public access opportunities in and adjacent to wildlife habitats are increasing due to agency mandates and public demand. Projects, such as the South Bay Salt Pond Restoration Project, have the dual, and potentially-competing, objectives of providing quality public access and supporting healthy wildlife populations. We have undertaken a series of studies designed to assist managers throughout the San Francisco Bay area in meeting both these goals. Current findings focus on foraging shorebird and waterfowl response to human use of trails located on levees adjacent to foraging habitat. At 3 tidal locations around the Bay, we observed shorebirds foraging on mudflats adjacent to trails and adjacent to sites without trails. Despite major differences in human activity, we found no statistically significant differences in the number of shorebirds, species richness, or proportion of shorebirds foraging at trail versus non-trail sites. When comparing weekdays to weekend days, the number of shorebirds showed a decrease as use at trail sites increased. This study provides information on foraging shorebirds in response to human use at well-established trails. We are currently investigating shorebird response to human use of trails at sites not previously open to the public. We also studied waterfowl response to experimental trail use at 4 former salt ponds in the South Bay not open to public access. Findings showed that diving ducks moved between 106m and 140m away from levees in response to trail walkers adjacent to the ponds. At distances up to 120m from the trail, the number of birds and species richness were statistically significantly lower after walkers passed compared to before the disturbance. Managers can use these data in trail location and design. We are extending this study to investigate waterfowl response to well-established trails, adding to the information on how birds respond to different trail use conditions.

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EXCEPTIONAL TIDES, DEVASTATING EFFECTS: TIDAL MARSH DYNAMICS AND SPECIES' HABITATS

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Sea-level rise poses direct long-term threats to tidal marsh persistence and species habitat availability. However, the occurrence and synergistic effects of extreme events may prove to have more devastating consequences in the near future. The San Francisco Bay estuary provides important habitat for federally and state listed species, including the salt marsh harvest mouse (*Reithrodontomys raviventris*), California clapper rail (*Rallus longirostris obsoletus*), and California black rail (*Laterallus jamaicensis coturniculus*). Increases in maximum tide heights, storm frequency and intensity may create bottleneck events in the form of increased predation and increased nest failure. We have deployed several water loggers at 11 sites throughout the San Francisco Bay estuary. Using elevation and vegetation models derived from high resolution RTK-GPS surveys and species habitat use data we discuss site-specific inundation patterns, extreme tide events, and potential consequences to tidal marsh habitats and the species reliant upon them.

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (I) - Order: 1

THERMAL VARIABILITY WITHIN A COMPLEX BRANCHING ESTUARINE SYSTEM

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California's Sacramento-San Joaquin Delta is a complex assemblage of rivers, sloughs, and flooded islands that confounds simple modeling efforts for resolving small-scale advection and mixing processes within it. These processes determine the creation and breakdown of gradients of ecologically important scalars (e.g. salt or temperature). In light of this, field measurements and work is necessary to inform the effects of within channel transport and mixing on the region's thermal environment, including the effects of exchanges between intersecting channels or between channels and shallow habitats. We present results of two field campaigns to assess thermal mixing processes within the Cache Slough/Liberty Island complex. For both campaigns, we deployed thermistors; conductivity, temperature, and depth (CTD) sensors; and an acoustic Doppler current profiler (ADCP). We observed the creation and breakdown of large thermal gradients, both vertically and horizontally, on a variety of time scales. Principal component analysis indicates that although much of the vertical gradients are due to local heating and cooling, fluxes of thermal gradients from adjoining channels and from shallow habitats are also important. This work leads to an improved understanding of transport and mixing in Delta channels near channel junctions and adjacent to channel/island intersections; these features are some of the dominant physical forms of the Delta.

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SPATIAL CLIMATE CHANGE SCENARIOS FOR SAN FRANCISCO BAY TIDAL MARSH HABITATS

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Climate change will affect wetlands in San Francisco Bay through sea-level rise and seasonal salinity increases. These changes are likely to convert tidal freshwater and brackish wetlands into more fragmented saline systems and result in greater inundation of tidal marshes, changing plant species composition and habitat structure for birds and other wildlife. To implement effective conservation strategies, we must understand the potential landscape-scale effects of climate change on tidal marshes and the birds that depend on them. We adapted a dynamic marsh accretion model to non-linear sea-level rise projections to develop spatially explicit projections (maps) of tidal marsh extent and elevation in 20-year intervals over the next 100 years. Using these projections in combination with projected changes in salinity, we modeled potential change in the tidal-marsh plant community. Drawing upon our knowledge of bird and plant associations, we modeled potential changes in the distributions of tidal marsh birds of conservation concern. To provide detailed information to land managers, conservation planners and policy makers, we have developed summaries and web-based decision-support tools to allow users to interactively 1) assess and query the potential effects of climate change on tidal marsh habitats, plants, and bird populations under various scenarios of sediment availability, salinity, sea-level rise, and levee condition, and 2) identify priority sites for wetland conservation and restoration. The primary objective of this tool is to facilitate conservation of tidal-marsh habitat in the context of a rapidly changing environment. Initial results show that the vertical accretion rates necessary for tidal marshes to keep pace with sea-level rise are strongly affected by our regional assumptions of future sediment availability. In addition, we found that the potential for landward tidal marsh migration will likely be extremely limited due to topographic and anthropogenic constraints.

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PRELIMINARY RESULTS OF A PALEOSALINITY MODEL FOR THE SACRAMENTO–SAN JOAQUIN DELTA

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The extensive marshes in the Sacramento-San Joaquin Delta, which started forming around ~6,700 years ago, are currently freshwater tidal, however, it is unknown whether the salinity regime in the Delta has varied over time between brackish and fresh conditions. This information is important to managers considering major changes to the flow regime in the Delta, because such changes could impact the future sustainability of flora and fauna. The goal of the Rates and Evolution of PEat Accretion through Time Project (REPEAT II) is to reconstruct paleosalinity at several locations in the Delta throughout the last 6000+ years. The approach of REPEAT II is to use geochemical analyses of peat cores to reconstruct Delta paleosalinity through time and space. Preliminary analyses of sodium and strontium concentrations in peat indicate a salinity peak between 1450 CE to 350 BCE at Browns Island and Franks Wetland. In addition, vertical peat profiles of sodium and strontium concentrations show a spatial trend of decreasing salinity from west to east (i.e., Browns Island > Sherman Island > Franks Wetland/Bacon Channel Island). Currently, we are developing a quantitative model of paleosalinity using strontium isotope signatures ($^{87}\text{Sr}/^{86}\text{Sr}$) of peat, ocean water, and sediment from the Sacramento and San Joaquin rivers. Application of this model to recent peat is complicated by Gold Rush-derived sediments, which dramatically altered the isotopic and chemical signatures of Sacramento River sediment during the past ~160 years. The next step in developing a salinity model is to determine the $^{87}\text{Sr}/^{86}\text{Sr}$ signatures of peat organic matter, peat sediment, and fresh marsh plants to confirm that plants, which ultimately become incorporated into peat, effectively integrate the isotopic signal of the ambient salinity in the Delta.

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GETTING TO THE BOTTOM OF IT: PLANNING FOR SUBTIDAL HABITATS IN SAN FRANCISCO BAY

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Tidal estuaries are intricately linked to the Ocean and Delta and provide numerous ecosystem services that both contribute to and impact overall ecosystem health. Subtidal habitats are fully submerged areas that are intrinsically connected to mudflats, wetlands, creeks, and uplands. Human uses such as fishing, marinas, shipping and ports, dredging, sand mining, transportation projects, recreational use, and industrial uses have direct impacts on the subtidal habitat of the Bay. This “hidden underbelly of the bay” is often considered to be a featureless mud bottom in our urbanized estuary. Despite multiple anthropogenic alterations to the estuarine floor, the bottom of the bay still includes a suite of unique habitats that provide diverse three-dimensional structure including: sand waves more than three meters high; eelgrass and shellfish beds that act as ecosystem engineers and provide reproductive substrate and food resources for species such as herring and salmon; rocky outcrops covered in seaweeds and invertebrates; and the mixed sediments in shoals and channel banks utilized by a variety of species. The San Francisco Bay Subtidal Habitat Goals Project will establish a comprehensive and long-term vision for research, restoration and management of the subtidal habitats of the San Francisco Bay. The Project is a collaborative interagency effort between the Bay Conservation and Development Commission (BCDC), the California Ocean Protection Council/State Coastal Conservancy, National Oceanic and Atmospheric Administration (NOAA), and the San Francisco Estuary Partnership. The Project has created the first set of conceptual models and regional comprehensive GIS maps of subtidal habitats, and specific bold recommendations to protect and sustain subtidal habitats over the next 50 years. This presentation will highlight key recommendations on adaptive management, implementation of future projects, and targeted restoration site opportunities that will be included in the Final San Francisco Bay Subtidal Goals Document and website to be released in November 2010.

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BUILDING A (MORE) SUSTAINABLE DELTA: LESSONS FROM PLANTS

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Pre-gold rush Delta plant life contributed to long-term sustainability by forming the basis of primary production and species diversity for the food web; sequestering carbon and capturing sediment that resulted in an accreting land surface elevation concomitant with global seawater rise; and attenuating physical forces such as wave and current energies. These plant resources are now greatly diminished. Replenishing these plant resources are one component for overall restoration needs of the Delta. The appropriate plant species for restoration can be gleaned from descriptions of the original flora and vegetation still extant on remnant habitats, such as in-channel islands and scattered sites that haven't been "reclaimed". Existing research shows distinctive plant assemblages - freshwater, brackish, and higher salinity suites of characteristic species - that vary by regions of historic salinity zones; by micro-site elevations; and by areal watershed characteristics. These data need to be incorporated into realistic appraisals of overall restoration planning efforts. The role of plants in levee stability needs to be given higher visibility to both ecosystem efforts and to flood control activities. A variety of techniques and approaches include "soft" plantings and brush boxes, to planting techniques compatible with rock revetment, berms, and stone breakwaters. Minimizing risks of flooding and Delta-wide hydrologic "regime changes" can be partially lessened by levee plant restoration and thru re-configuration of internal island levees and plantings. Arresting further island subsidence can be enhanced through gradual replacement of farming on some highly subsided islands with tule restoration. Working with the farming community, through implementation of a carbon credit initiative program will be needed. Incorporating green engineering and sustainable ecosystem management practices will require a cultural shift from a highly reductionist, Cartesian perspective to a more holistic approach.

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (II) - Order: 1

SEDIMENT TRANSPORT ISSUES IN STREAM RESTORATION -- 12 YEARS OF GEOMORPHIC MONITORING IN LOWER CLEAR CREEK

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Clear Creek below Whiskeytown Dam has endured 46 years of flow and sediment impairment and the historic geomorphic impacts of gold dredging and gravel mining. Critical flow and sediment issues in Clear Creek include: incomplete routing of coarse sediment, channel armoring, fine sediment delivery, incision to bedrock, simplified channel form and reduced alluvial function. Highly impaired geomorphic function threatens many species of concern including several anadromous salmonid species. Restoration strategies to address these impacts include: pulse flows; channel realignment; floodplain lowering and gravel injection. Twelve years of geomorphic monitoring were used to evaluate the effectiveness of these strategies. Sediment sampling stations were used to develop sediment budgets; repeat topographic and longitudinal surveys to track channel form; particle size analyses to monitor bed texture and bed mobility studies to predict alluvial function. Gravel injection and channel/floodplain modification have restored up to 46% of channel, increasing the areal extent of spawning gravel by over 500% in one two-mile reach. Floodplain and channel restoration projects have increased the frequency of overbank flows, increased the deposition of silts on floodplains and reduced incision to bedrock and lowered thresholds of bed mobility. Following recent wildfires and subsequent management activities, tributary delivery of fine sediment has dramatically increased. Bulk sample analyses reveal increases in fine sediment that degrade the quality of injected spawning gravels. Tracer gravel studies below gravel injections indicate a reduction in the critical shear stress required to previously-armored mobilize riffles. Measured annual bedload discharges ranged from 392 to over 6,800 tons/yr and indicated complete routing through restoration areas. Understanding the relative role of various sediment sources and rates of transport is paramount to making informed choices regarding gravel additions and planning restoration designs in Clear Creek. Restoration planning must shift to include upslope actions to promote the continued success of mainstem projects.

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (II) - Order: 2

THE INFLUENCE OF LATERAL EXCHANGE WITH PERIMETER HABITAT ON THE STRATIFICATION AND MIXING OF SALT IN A TIDAL CHANNEL

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In this study we investigate the impacts of habitat restoration on the salinity dynamics of a tidal slough in the South San Francisco Bay. The Island Ponds, which are a cluster of three adjacent salt ponds, were breached to tidal action via Coyote Creek, a macro-tidal channel, in early 2006 as part of the South Bay Salt Pond Restoration project. We collected oceanographic data, such as flow velocities, salinities, and depths, in Coyote Creek and one of the Island Ponds (A21) in order to characterize the exchange between them and the influence of this exchange on the salt field of Coyote Creek. Our results indicate that interaction with the former salt ponds causes a drastic modification to the pattern of vertical mixing and density stratification that would normally be expected for a partially-mixed estuary. Instead of a stratified water column on ebb-tides, which is what estuarine theory predicts, we have observed well-mixed conditions on ebbs in Coyote Creek. We hypothesize that this is due to a particular sequence of events: the ponds temporarily trap water on each flood tide and release it out of phase with the main channel on the ebbs; the difference in phasing sets up cross-channel gradients in salinity; the flow through the breach on the ebbs strains the lateral salinity gradient, producing convective instabilities and energetic turbulent mixing. This pattern of stratification could have important implications for the recovering salt marsh. For example, the salinity of the water highest in the water column may determine the types of vegetation that establish at the upper elevations of the inter-tidal region. Under typical circumstances when the ebb tide is stably stratified, the freshest flows are able to reach the high marsh. However, if ebbs are well-mixed as we've observed, saltier water will be inundating this region.

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (II) - Order: 3

FLOODPLAIN RECONNECTION POTENTIAL ON THE SAN JOAQUIN RIVER AT GREAT VALLEY GRASSLAND STATE PARK, MERCED COUNTY, CALIFORNIA

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Great Valley Grasslands State Park (GVGSP) preserves one of the few intact native grasslands (including stands of native bunchgrass prairie) in the California Central Valley. However, these grasslands have been invaded by exotic species, which has been attributed at least in part to the disconnection of the grasslands from inundation by high flows from the San Joaquin River. The California Department of Parks and Recreation is investigating the potential to reconnect the San Joaquin River and portions of GVGSP to restore floodplain-dependent fluvial geomorphic and ecological processes, with the primary intention of controlling exotic species invasion and recreating more natural ecological conditions in the park. The Project Team utilized hydraulic models and geospatial analyses to evaluate the potential for floodplain reconnection by assessing the range of flood stages and flood frequencies required to restore an adequate flooding regime to the park, determining preliminary sizing and preferred locations for two levee breaches, quantifying the range of hydraulic forces likely to occur at the levee breaches, and characterizing the hydrodynamics on the inundated floodplain (including residence times of flood waters, extents and depths of flooding, and the potential for stranding of fish on the floodplain as waters recede.) The results of this investigation provide valuable insights on the range of considerations and potential benefits of floodplain reconnection in the Central Valley, an ecosystem restoration approach that is widely cited in ongoing efforts related to the Delta including the Bay Delta Conservation Plan (BDCP), the Delta Plan, and the Central Valley Flood Management Planning Program (CVFMP).

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (II) - Order: 4

CRITICAL ROLE OF SEASONAL TRIBUTARIES FOR NATIVE FISH AND AQUATIC BIOTA IN THE SACRAMENTO RIVER

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Due to the Central Valley's Mediterranean climate, the Sacramento River has an abundance of small tributaries that contain water only during the winter/spring wet season. Over the past 8 years we examined the ecology of these tributaries in terms of native fishes and aquatic macroinvertebrates and will highlight the critical role this underappreciated habitat plays in the overall functioning of the entire riverine ecosystem. In this talk I discuss and summarize data from five individual studies examining ecological aspects of this habitat. In a study of juvenile Chinook growth in seasonal tributaries using otolith microstructure we find that fish grow bigger and faster on the abundant food and warmer temperatures in seasonal tributaries. In a four-year study on the spatial distribution and abundance of native fish larvae in tributaries of the upper Sacramento River we find that certain critical tributaries (Mud Creek) produce almost an order of magnitude more native fish larvae than nearby permanent streams. In a study comparing the distribution and abundance of aquatic macroinvertebrates in a seasonal tributary with a nearby permanent stream we find the seasonal tributary contains unique taxa as well as higher drift densities and an ecologically distinct community. In a cross-watershed comparison of larval fish drift density we find that a seasonal tributary (Mud Creek) produces more larvae on a per volume basis than all other streams/rivers we examined. In a comparison of juvenile Chinook growth morphology between seasonal and permanent streams using geometric morphometrics we find that salmon growth is characteristically different in seasonal tributaries, possibly leading to a better and healthier fish morphology. Taken together, this extensive body of work highlights the critical importance of this habitat and strongly suggests the need for watershed conservation directed at this neglected aspect of Central Valley stream ecology.

Tuesday, September 28, 2010: Room 307 Sustainable Habitats (II) - Order: 5

PROPORTION OF HATCHERY-ORIGIN FISH AMONG FEATHER RIVER CHINOOK SALMON SPAWNERS, 2002-2008

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Problem Statement: In-river spawning of hatchery-origin Chinook salmon is known to compromise the genetic integrity of natural-origin populations through outbreeding depression and genetic homogenization. The abundance of natural-origin Chinook in most Central Valley tributaries is currently unknown. The recent implementation of a constant fractional marking program, where 25% of hatchery fall run Chinook are coded wire tagged (CWT) and adipose fin clipped, is expected to improve future estimates of hatchery composition. However, complexities of accounting for tag loss, inter-basin straying, age composition, and intermingling of hatchery fish with different tagging rates (e.g. 100% marking and tagging of Feather River spring run Chinook, and Mokelumne River/Merced River Hatchery fall run Chinook) mean that precise estimates of natural-origin fall run Chinook abundance may remain elusive in the absence of alternate methods. The precise and rapid assessment of natural-origin Chinook population status is essential for resource managers evaluating habitat restoration efforts, managing hatcheries, operating water projects, and planning harvest regulations. **Approach:** To help address these resource management challenges for Feather River fall and spring run Chinook, we analyzed microstructure and microchemistry of otoliths collected during seven years of salmon carcass surveys. Specifically, we analyzed calcium architecture and the Sr isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) to determine the proportion of hatchery and wild origin fish spawning, and the spatial distribution of hatchery and wild origin fish spawning in the river. **Results:** Our results show that a significant proportion of in-river spawning Chinook salmon are hatchery-origin fish. High rates of in-river spawning hatchery-origin Chinook documented in our study indicate that fitness of natural origin Chinook may be significantly impaired and suggest that introgression between hatchery and natural origin Chinook may be a factor contributing to the depressed status Central Valley Chinook salmon. **Conclusions:** This study supplies managers critical information regarding the influence of hatchery Chinook salmon on the Central Valley spring and fall run Chinook population, and highlights the urgent need for better management and monitoring of salmonid hatcheries.

Tuesday, September 28, 2010: Room 308-310 Fish Migration and Survival (I) - Order: 1

QUANTIFYING THE CONTRIBUTION OF JUVENILE MIGRATORY PHENOTYPES IN A POPULATION OF CHINOOK SALMON *ONCORHYNCHUS TSHA WYTSCHA*

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Chinook salmon is an anadromous species that varies in size at freshwater emigration, which is hypothesized to increase population resiliency under variable environmental regimes. In California's Central Valley (USA), the majority of naturally spawned juveniles emigrate in 2 pulses: small juveniles (referred to as fry), typically ≤ 55 mm fork length (FL), emigrate from natal streams in February–March, whereas larger juveniles (smolts), typically > 75 mm FL, emigrate in mid-April–May. In some river systems, there is a smaller pulse of emigrants of intermediate size (parr), typically 56 to 75 mm FL. Although the relative contribution of these migratory phenotypes to the adult population is unknown, management activities focus on survival of larger emigrants and most artificially produced fish (98%) are released from hatcheries at parr and smolt sizes. We reconstructed individual length at freshwater emigration for a sample of adult Central Valley Chinook salmon from 2 emigration years using chemical (Sr:Ca and Ba:Ca) and structural otolith analyses. The adult sample was comprised of individuals that emigrated as parr (mean = 48%), followed by smolts (32%) and fry (20%). Fry-sized emigrants likely represent natural production because fish ≤ 55 mm FL comprise $< 2\%$ of the hatchery production. The distribution of migratory phenotypes represented in the adult sample was similar in both years despite apparent interannual variation in juvenile production, providing evidence for the contribution of diverse migratory phenotypes to the adult population. The contribution of all 3 migratory phenotypes to the adult population indicates that management and recovery efforts should focus on maintenance of life-history variation rather than the promotion of a particular phenotype.

Tuesday, September 28, 2010: Room 308-310 Fish Migration and Survival (I) - Order: 2

**PATHWAYS, TIMING AND RATES OF MIGRATION FOR HATCHERY
AND NATURAL ORIGIN STEELHEAD, ONCORHYNCHUS MYKISS,
FROM THE LOWER MOKELUMNE RIVER, CA**

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The lower Mokelumne River (LMR), in the Central Valley of California, supports a population of natural *Oncorhynchus mykiss*, and the Mokelumne River Fish Hatchery contributes hatchery produced smolts to the system annually. We compared migratory patterns of LMR *O. mykiss* of natural and hatchery origin over a three year period. Specifically we looked at timing, rates, and pathway utilization under variable release locations in tidal and non-tidal habitats in the Mokelumne River and Sacramento San Joaquin Estuary. Data reported is recovered from receiver locations deployed in the non-tidal reaches of the LMR, as well as receivers deployed throughout the Estuary by participants of the Central Valley Fish Tracking Consortium. Our study provides valuable information on differences in hatchery and wild *O. mykiss* migration characteristics and provides unique insight into migratory behavior of little studied non-Sacramento River origin salmonids.

Tuesday, September 28, 2010: Room 308-310 Fish Migration and Survival (I) - Order: 3

POST-RESCUE MONITORING OF BUTTE CREEK SPRING-RUN CHINOOK SALMON

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During mid June of 2008 and 2009, some Butte Creek Spring-run Chinook salmon ceased volitional upstream migration towards critical upstream summer holding habitat, resulting in agency rescue operations where the stalled salmon were trapped and trucked upstream. In May 2009, regulatory agencies signed a memorandum regarding fish rescues, proposing a set of post-rescue strategies and acknowledging the lack of information concerning the fate of rescued fish. The monitoring pilot studies of 2008 and 2009 are a step toward better understanding the outcomes of fish rescues with respect to the strategy of immediate upstream release. In 2008, 352 adult spring-run Chinook salmon (~3.5% of the estimated return) were rescued and marked by pelvic fin clip. In 2009, 26 adult spring-run Chinook salmon (~1% of the estimated adult return) were rescued and implanted with esophageal radio tags and temperature loggers. In both years, fish were trucked 2.5 miles upstream. Pre-spawn and spawn carcass surveys during 2008 recovered 36 of the 352 marked fish, with the remaining 316 fish having an unknown fate. Radio tags for 23 of the 26 fish were recovered in 2009. In both years, greater than half of the recovered fish and tags were recovered within two weeks of release. Only five of the fish were recovered during the spawning season in 2008. All tag recoveries for 2009 were made within five weeks of the rescue release, significantly before the spawning season. In both years, pre-spawn mortality of recovered rescued fish was greater than 85% compared to ~5-10% for non-rescued fish.

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DO SALMON HATCHERY ‘SOURCES’ LEAD TO IN-RIVER ‘SINKS’ IN CONSERVATION?: IMPLICATIONS FOR INTEGRATED HATCHERY MANAGEMENT IN CALIFORNIA

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Maintaining viable populations of salmon in the wild is a primary goal for many recovery programs. The frequency and extent of connectivity among natal sources defines the demographic and genetic boundaries of a population. Yet the role that immigration of hatchery fish may play in altering population dynamics and fitness of natural populations remains largely unquantified. Quantifying whether natural populations are self-replenishing, function as sources (births > mortality; $r > 1$), or potentially sinks (births < mortality; $r < 1$) is often limited by an inability to determine how immigration and emigration influence population processes.

Tuesday, September 28, 2010: Room 308-310 Fish Migration and Survival (I) - Order: 5

A SYNTHESIS OF 22 TELEMETRY STUDIES TO EVALUATE CHINOOK SALMON SMOLT MIGRATION AND MORTALITY IN CALIFORNIA'S SACRAMENTO – SAN JOAQUIN DELTA

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Detailed information on juvenile Chinook salmon (*Oncorhynchus tshawytscha*) behavior, migratory pathways, and survival in the Sacramento – San Joaquin Delta in relation to complex hydrodynamic conditions and other environmental parameters have been insufficient to implement specific remedial actions (e.g., water project operational changes) to increase numbers. As a result, from 1996 through 2010, Natural Resource Scientists, Inc. conducted 22 separate research projects on juvenile salmon (including four studies of predatory fish) using acoustic or radio telemetry as a means to gain an improved understanding of fish movements and mortality. The study techniques adaptively evolved based on technological breakthroughs and extensive field observations throughout the Delta. Recently, highly detailed assessments of telemetered fish movements included: 1) a near-field environment within the fish transmitter detection range of telemetry receivers; 2) medium-field observations of movements in a fine-time scale between receivers in close proximity; and 3) far-field examinations of movements throughout Delta-wide telemetry arrays. These data were integrated with flow measurements, site-specific characteristics in migration corridors, and knowledge acquired from prior telemetry studies. Detailed data on fish route selection, reach survival, mortality sites, and behavior were acquired. Recent results concluded that numerous detections were actually dead salmon (or the transmitters) inside predatory fish. Research findings indicate that smolt survival assumptions and models must incorporate these new conclusions to avoid misinterpretation of data and improve quantitative estimates of fish survival and movements. To achieve this important goal will require a new approach, perhaps by seeking changes in the telemetry technology to determine predation. However, in the absence of a technological breakthrough, highly detailed data on the behavior of predatory fish movements as compared to juvenile fish movements remain critically necessary. If implemented and analyzed properly, data derived from this technology will continue to be a powerful analytical tool to study fish movements in the Delta.

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SURVIVAL AND ROUTE SELECTION OF JUVENILE CHINOOK SALMON IN THE SOUTHERN SACRAMENTO-SAN JOAQUIN RIVER DELTA, 2009

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Chinook salmon smolts have low survival through the Sacramento-San Joaquin River Delta. Identifying management actions to improve survival requires detailed information on the migration routes salmon take through the Delta, and on reaches with high mortality. To address these questions, in 2009, 933 juvenile hatchery fall/spring Chinook salmon smolts were tagged with HTI micro acoustic tags and released in the San Joaquin River approximately 12 miles upstream of the confluence with Old River, as part of the Vernalis Adaptive Management Program. Tagged smolts were monitored at 18 fixed-site acoustic receivers located throughout the south Delta. Acoustic-tag detections were analyzed with a release-recapture model to estimate route entrainment probabilities at the head of Old River and survival probabilities in key reaches of the San Joaquin and Old rivers. Mortality from the release point to the head of Old River was estimated to be high (0.55, SE = 0.02) in 2009. Approximately half (53%, SE=3%) of the fish that arrived at Old River entered that river. Of those fish, an estimated 11.5% (SE=2.3%) subsequently arrived at the water export facilities, and less than 1% were detected downstream of the facilities. For the smolts remaining in the San Joaquin River, estimated survival was lowest from the Stockton Navy Bridge to Turner Cut (0.10, SE=0.03), but was moderately high through the city of Stockton (0.78, SE = 0.04). Overall, estimated survival through the south Delta was 0.06 (SE=0.01). The low survival may be related to high predation pressure from non-native fishes in key locations in the San Joaquin and Old rivers, possibly intensified by low flow conditions. Our information can be used to inform management on the roles of flow and reach specific survival on the passage of juvenile salmon migrating through the south Delta from the San Joaquin basin.

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HABITAT–SPECIES ASSOCIATIONS AND BEHAVIOR OF OUTMIGRATING JUVENILE STEELHEAD (ONCORHYNCHUS MYKISS) AND CHINOOK SALMON (O. TSHAWYTSCHA) IN THE LOWER SACRAMENTO RIVER, CALIFORNIA

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Levee repair efforts on the lower Sacramento River (California) include mitigation measures intended to provide or improve habitat for juvenile salmonids. We identify habitat features and levee design types most conducive to successful rearing and residency of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*), and least conducive to potential predators. Acoustic telemetry data on residency of tagged hatchery juveniles were obtained at 12 levee repair and 6 naturalized sites between RM 12.5 to 91.9, from late November 2008 to late April 2009. Fish assemblage data were collected by electrofishing 15 sites above RM 20. Analysis included the use of generalized linear models (GLM) and canonical correspondence analysis (CCA) to relate electrofishing catch and residency to levee repair designs and habitat variables (e.g., floodplain inundation ratio, bank slope, and instream woody material (IWM)). Residency was characterized as the likelihood of a fish staying at a site (>12 h), and for fish that did stay, their residency duration. Results from the GLM analyses showed that catch of 0+ juvenile Chinook salmon was positively related to floodplain inundation ratio and reduced bank slope. In addition, CCA showed a positive relationship between Chinook salmon and larval lamprey with increasing aquatic vegetation and quantity of IWM. In contrast to Chinook salmon, there were positive associations between catch of resident basses and bank slope, based on both GLM and CCA. For tagged 1+ steelhead, the probability of staying at a site was positively related to overhead shade and reduced bank slope. IWM diameter increased the probability of staying for tagged 1+ Chinook salmon. Residency duration for juvenile Chinook salmon and steelhead was positively associated with some measures of IWM. Our findings help explain habitat use and behavior of critical species in the Bay-Delta system, and can inform management strategies for habitat mitigation and conservation.

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AN EXPERIMENTAL EVALUATION OF FLOW AND PREDATION EFFECTS ON THE SURVIVAL OF JUVENILE CHINOOK SALMON

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Non-native predators are thought to significantly reduce through-Delta survival of juvenile salmonids. However, the factors which mediate predation in the Delta are poorly understood. For example, flow, turbidity and predator density are all known to influence predation, yet no experiments have evaluated the relative influence of these factors. An improved understanding of Delta predation is critical to developing and testing effective management actions. For example, predator management is considered a promising strategy for improving salmon production, yet we lack the data necessary to make defensible quantitative assessments. Similarly, the influence of Delta flows (particularly river discharge vs. tidally driven flows) on predation mortality is a critical issue for water project operation planning and for ESA recovery efforts. In order to address these issues, we conducted a Before-After Control-Impact (BACI) experiment to test the effect of flow and predator densities on the survival of hatchery Chinook implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) tags. Our study included two reaches on the North Fork Mokelumne River, including one predator-removal reach (impact) and one non-predator removal reach (control). Fish were released both before and after predator removal treatments for comparisons. Control and impact sites were also used before and after the DCC was opened to test for flow effects on predation. In total, 512 fish were released during the study, consisting of 16 groups of 32 fish. Predator removal was accomplished using electrofishing and took place on the North Fork adjacent to Dead Horse Island (approximately 1.8 miles downstream of the DCC) and estimation of predator numbers was made via a three-pass electrofishing depletion method. In total, 657 predators were removed during the study period, consisting of 22 species. Acoustic data were retrieved for this study from five acoustic receivers placed along the study reaches between May 13 and June 15, 2010.

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EVALUATING CONSEQUENCES OF UNSCREENED DIVERSIONS ON POPULATION PERFORMANCE OF BUTTE CREEK SPRING-RUN CHINOOK SALMON

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At present there are more than 3,000 unscreened water diversions in the Central Valley of California. The enormous expense to screen all of these diversions because of a perceived threat to ESA-listed salmon viability makes this solution impractical. An alternative approach is to evaluate priorities for screening based on their consequences to population abundance and productivity. We describe a modeling approach that evaluated 50 small, unscreened pump diversions and three large, unscreened gravity diversions in lower Butte Creek for their effect on Butte Creek spring-run Chinook salmon. This population is the largest self-sustaining natural population of spring-run Chinook in the Central Valley. We modeled the complete life history of Butte Creek spring-run Chinook under a variety of water year types and screening alternatives. The model incorporates an assessment of fish entrainment losses at individual diversions based on several physical, operational, and biological factors affecting entrainment risk. Also included in the model were environmental attributes affecting Chinook survival throughout their freshwater residence (juveniles and adults). Monthly entrainment losses at individual diversions ranged from less than 0.1% for small pumps to 4.6% for gravity diversions. Potential entrainment losses were highest in the spring of dry and critically dry years because of increased irrigation demands and temporal overlap in diversion and juvenile emigration seasons. Life history modeling suggests that screening all diversions would increase adult abundance by 3% in wet and average water years and 9-10% in dry and critically dry years. The results supported a recommendation to screen a subset of diversions in combination with an integrated flow management and operations agreement among water users.

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EFFECTS OF TIDES, RIVER FLOW, AND GATE OPERATIONS ON ENTRAINMENT OF JUVENILE CHINOOK SALMON INTO THE INTERIOR SACRAMENTO-SAN JOAQUIN DELTA

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Recent acoustic telemetry studies have revealed that survival of juvenile late-fall Chinook salmon depends on the migration route fish use to negotiate the Sacramento-San Joaquin River Delta. Fish entering the interior Delta, where pumping stations are located, survive at lower at a rate than fish using other routes. Consequently, the proportion of the population entrained into the interior Delta affects population-level survival. We examined the effect of tidal fluctuations, river inputs, and operation of the Delta Cross Channel gates on entrainment of juvenile salmon from the Sacramento River into the interior Delta via the Delta Cross Channel and Georgiana Slough. We found that the probability of entering the interior Delta depended strongly on the tidal stage when fish arrived at the river junction, especially when mean daily discharge was low. Fish arriving at the river junction during flood tides had a high probability of entering the interior Delta whereas fish arriving during ebb tides had a low probability of entrainment. As mean river discharge increased, tidal forces were dampened, which reduced the effect of flood tides on entrainment. Closing the Delta Cross Channel gates decreased the probability of fish entering the interior Delta, but by less than expected given the reduction in flow entering the interior Delta. We illustrate how our migration routing model can be used to evaluate the effect of alternative water management actions on entrainment of fish into the interior Delta.

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CONCEPT OF POTENTIAL ENTRAINMENT INDEX (PEI) AND ITS APPLICATIONS FOR THE SACRAMENTO-SAN JOAQUIN DELTA MANAGEMENT

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The Pelagic Organism Decline (POD) including the decline of delta smelt in the Sacramento-San Joaquin Delta continues to be a major concern, and water exports from the Delta is suggested as one of the causes of the POD. Because of this, estimating the likely effect of water exports on Delta organisms is important for healthy Delta management, and the concept of the Potential Entrainment Index (PEI) is introduced as an indicator of the impact to the overall population of organisms in the Delta. The PEI, given a distribution of organisms throughout the Delta and hydrology within the Delta, estimates the overall potential percentage of particles entrained by the exports. The concept is tested for delta smelt larvae and juvenile fish in various Delta situations. Both DSM2-PTM simulations and regressions derived from simulation results are used to calculate PEIs, and studies show possibility of the PEI as an additional tool for the Delta management and fish protection. The PEI can be applied on a near real-time basis as soon as fish and relevant information is updated, and such a quick response is crucial for fish protection. There are limitations that can be significant in using this method including the uncertainty in the estimate of fish abundance provided in fish surveys and the assumption that the fish do not exhibit behavior. Thus, the PEI should be adopted carefully as an indicator, not a predicted actual entrainment, with the uncertainties, and more effort to reduce the uncertainties is necessary, e.g. obtaining higher quality of fish survey data, developing better numerical models, and understanding more of fish behaviors.

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EVALUATION OF FISH FACILITY EFFICIENCY AND PRE-SCREEN LOSS FOR DELTA SMELT IN THE STATE WATER PROJECT

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The long-term decline of fish catches in the upper San Francisco Estuary has been linked to water conveyance and export operations by the State Water Project (SWP) and Central Valley Project (CVP). The uncertain connection between reported delta smelt salvage and underlying entrainment losses has precluded basic understanding on the magnitude and variability of entrainment losses and their population level effects. We conducted the first mark-recapture evaluation of the relation between delta smelt salvage at the Skinner Fish Facility (SFF) and underlying entrainment losses at the SWP in the south Delta. We conducted mark-recapture experiments using cultured delta smelt in February and March 2009 (adults) and June 2009 (juveniles) to estimate: 1) the percent of fish recaptured at SFF of the total released at the entrance of SFF (fish facility efficiency); 2) the percent of fish recaptured at SFF of the total released at the entry point of Clifton Court Forebay (CCF), a reservoir for SWP exports (percent recovery); 3) the fish losses in CCF (pre-screen loss). All fish released (n) were calcein-marked; adults were additionally photonicallly- and strontium-marked. Fish facility efficiency declined in successive releases: February (52.0%, n = 400), March (44.0%, n = 200) and June (24%, n = 800). The percent recovery of fish released in CCF declined greatly over time: February (2.98%, n = 5,707); March (0.42%, n = 2,849) and June (0.03%, n = 14,413). Pre-screen losses increased in consecutive releases: February (94.2%); March (99.0%) and June (99.9%). We concluded that: 1) delta smelt can be readily mass-marked to quantify entrainment losses; 2) pre-screen loss was overwhelmingly the largest source of mortality for delta smelt; 3) entrainment monitoring in CCF seems essential to quantify the connection between salvage statistics, residence time in CCF and the magnitude and variability of direct delta smelt losses.

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EVALUATION OF PREDATION AT SALVAGED FISH RELEASE SITES

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Predation on fish throughout the salvage process may reduce the benefit of the state and federal facilities that are operated to protect fish from entrainment into the export projects. Predation by piscivorous fish has long been suspected as having a major impact on the survival of fish in the salvage process. This study was designed to document the magnitude of predation that occurs during the final “release” phase of the CHTR process at the fish salvage facilities. Using multiple complementary sampling and observation methods (electrofishing, avian point counts, hydroacoustics, acoustic and Floy tagging, and DIDSON observations) the presence, abundance, and behavior of piscivores at 3 fish salvage release sites and 2 control sites in the central Delta were examined from August 2007 through March 2008. Results indicate that Sacramento pikeminnow (*Ptychocheilus grandis*), largemouth bass (*Micropterus salmoides*), striped bass (*Morone saxatilis*), cormorants (*Phalacrocorax* spp.), and gulls (*Larus* spp.) are the predominate predators of salvaged fish at the release sites. Predatory fish were observed throughout the study but were present in greater numbers during the summer and fall, correlating to periods when the greatest numbers of salvaged fish are released. An exact rate of predation mortality was not developed as the amount of biomass being salvaged and released may vary dramatically from day to day. However, study results suggest that predation at the release site could have a substantial effect on the number of fish surviving during the release phase of the salvage process depending on the season and quantity of biomass released. The results of this study include recommendations and guidelines to improve release operations and suggestions for physical changes to the existing release sites. The results will also aid in establishing guidelines for locating and designing future fish release sites and may have important implications for predator management efforts in the Delta.

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TRANSLATING FISH SALVAGE AT THE DELTA PUMPS INTO ABUNDANCE OF CHINOOK SALMON SMOLTS

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Fish salvage data at the state and federal pumps in the Delta represent a long time series of sampling that has been variously used to index the timing, abundance, and mortality of juvenile Chinook passing through the Delta. Interpretation of the salvage data has been confounded by large fluctuation in the rates of pumping and by uncertainty in the proportion of smolts that pass through Delta routes proximal to the pumps. I used smolt sampling data from other stations in the Delta to establish the temporal correlations of fish density, hatchery origin, size, and genotype to those of fish salvaged at the pumps. I found comparisons among stations to be useful for discriminating which independent sampling provided a meaningful index of fish density in the Delta for fish of similar size and origin to those salvaged at the pumps. The abundance index accounted for much of the variability in salvage at the pumps, and also made it possible to estimate the fraction of change in salvage that could be associated with each of two factors related to pumping rate: (1) the proportion of local water volume sieved at the salvage facilities, and (2) the additional proportion of fish drawn into the pump vicinity in response to flow drawn to the pumps.

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FINE SCALE MOVEMENT, LIFE HISTORY AND SURVIVAL OF WILD ONCORHYNCHUS MYKISS OF THE MOKELUMNE RIVER, CA

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Steelhead, the anadromous life history of *Oncorhynchus mykiss* are at risk of extinction in Bay-Delta tributaries even when they coexist with rainbow trout, the resident life history. Understanding the conditions that favor anadromy in *O. mykiss* is important to the maintenance of life history diversity and the recovery of steelhead populations. The fine-scale movement patterns and survival of one hundred thirty wild *O. mykiss* were monitored using acoustic telemetry in the Lower Mokelumne River in 2007 and 2008. Fish were captured by boat electrofishing and rotary screw traps. After recovering from surgical implantation of Vemco V9 pingers all fish were released at their capture site. Large-scale movement patterns were recorded using stationary tag readers placed throughout the Lower Mokelumne River and the Bay-Delta area. Fine-scale movement patterns were recorded bimonthly using a handheld hydrophone while boating a 39km standardized survey from Camanche Dam, the upstream limit of anadromy to tidal influence. This technique greatly increased our understanding of *O. mykiss* movement patterns, and strengthened our estimates of survival. Most individuals only moved short distances or not at all. Less than six fish emigrated from the freshwater section of the Mokelumne River each year and only one smolt successfully made it to sea in 2008. There was a strong positive relationship between number of moves per life and mortality in 2007, presumably due to increased risk of predation. Movement across the population peaked February through April and again in August highlighting the importance of providing sufficient flows seasonally to benefit migration. By documenting movement related mortality and low rates of anadromy this study points to current conditions favoring the resident life history in the Mokelumne River. This study also emphasizes the need to investigate management regimes to benefit anadromy and the recovery of steelhead as mandated under the Endangered Species Act.

Tuesday, September 28, 2010: Room 308-310 Fish Physiology and Behavior - Order: 1

ENVIRONMENTAL DISRUPTION IN THE THYROID ENDOCRINE SYSTEM OF WILD FISH IN SAN FRANCISCO BAY

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The thyroid endocrine system is essential for normal growth and development in vertebrates, among other critical physiological functions. Therefore, environmental disruption of this endocrine system poses a significant threat either through lethal or sub-lethal effects. In our studies of the San Francisco Bay region, substantial alterations in plasma levels of the two thyroid hormones, thyroxine (T4) and triiodothyronine (T3), have been observed in resident fish including shiner surfperch and Pacific staghorn sculpin. Significant reductions in T4 are observed in both species when sampled from contaminated locations such as Oakland Harbor or nearby San Leandro Bay, as compared with locations representing relatively lower impacts (e.g., Bodega Bay, Redwood City, Catalina Island). T3 levels also exhibit significant differences relating to sampling location. Measurements of tissue organic contaminant concentrations within the same fish indicate that polychlorinated biphenyls (PCBs) are particularly prominent in exhibiting significant correlations with thyroid endocrine parameters. T4 concentrations are inversely correlated with several PCB congeners (most all non-coplanar, lower-chlorinated forms), while in contrast T3 and T3/T4 ratio are positively correlated. The increased T3/T4 ratios indicate possible PCB effects in altering the peripheral 5'-deiodinase system (which converts T4 into the more active T3). However, in follow-up experiments, it is clear that thyroid gland function is also compromised, since treatment of PCB-contaminated fish with pituitary thyroid-stimulating hormone (TSH) fails to exert its normal action of activating T4 production. In conclusion, this work demonstrates that wild fish residing in contaminated San Francisco Bay locations exhibit significant disruptions in their critically important thyroid endocrine system. The work also demonstrates that measurement of thyroid hormones is effective in elucidating location- and contaminant-related environmental impairment. (Support by SFEI-RMP for Water Quality in SF Bay; NOAA-USC Sea Grant Program/California Coastal Conservancy; Pacific Coast Environmental Conservancy).

Tuesday, September 28, 2010: Room 308-310 Fish Physiology and Behavior - Order: 2

A KINETIC ANALYSIS OF SE UPTAKE, DISTRIBUTION AND EXCRETION IN WHITE STURGEON

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A novel combined technique of stomach intubation, dorsal aorta cannulation and urinary catheterization was used to characterize the 48 hr kinetics of common Se forms at an ecologically relevant dose (500 ug/ kg body weight) in juvenile white sturgeons. Selenium in the forms of selenite, selenocysteine (SeCys), selenomethionine (SeMet), Se-methylselenocysteine (MSeCys) or selenoyeast (SeYeast) were orally intubated into groups of five white sturgeons. Blood and urine were collected through-out and tissues were taken at 48 hr for total Se analysis. A five compartmental model was developed for describing Se uptake, distribution and excretion - gut; two blood pools (protein and non-protein bound Se); tissue; and urine. All fluxes were based on mass-action kinetics. The model has six structural parameters: rates constants for absorption (k_a), transfer between blood pools (k_{32} , k_{24}), body tissue (k_{42}) and urine (k_e) and a blood volume parameter (vol). The control fish were used as a baseline for tissue Se level for all fish but were not used in the kinetic analysis. The data analysis was undertaken in WinBUGS using the Wbdiff ordinary differential equation solver interface. The statistical model was specified as a three level hierarchy: the first described the within fish variability; the second described the between fish variability; and the third specified the non-informative priors for all parameters expect for the volume, which was established from literature. The posterior means for the population mean parameters are: 0.022 (SE = 0.00292) h^{-1} , 1.6 (SE = 0.14) h^{-1} , 0.0041 (SE = 9.89E-4) h^{-1} , 0.27 (SE = 0.0345), 0.011 (SE = 0.00144) h^{-1} , 37.6 (SE = 5.43) ml for k_a , k_{32} , k_{42} , k_{24} , k_e , and vol , respectively. From our model, we have showed that the uptake, distribution and excretion of Se are significantly different among forms and Se is preferentially distributed into metabolically active tissues. Urinary excretion of Se was also found to be form dependent.

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DEPTH SHIFTS: CONSEQUENCES TO THE STRIPED BASS POPULATION IN THE SAN FRANCISCO ESTUARY, CALIFORNIA

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ABSTRACT: Erosion of sediments has resulted in the deepening of the San Francisco Estuary since the 19th century, with poorly understood consequences to fishes. I investigated changes in sampling depths at fixed otter trawl sampling stations in Suisun Bay (CDFG Bay Study Survey) from 1980 to 2008 to determine if observed declines in juvenile striped bass abundance could be related to depth changes. Significant increases in sampling depth were observed in 9 of 11 Suisun Bay monitoring sites, consistent with the continued erosion of bay sediments. The increase in sampling depths resulted in greater representation of deep water sites (>7 m), which by the end of the study outnumbered shallow water sites (<7 m) by a 2:1 ratio. Juvenile bass declined significantly in all depths, but 70-94% of the catch occurred in shallow water samples. The temporal shift in site depth and the low catch in deep water samples have affected the comparability of annual abundance estimates for striped bass, as well as the accuracy of long term abundance trends. These findings point out that a change in the physical characteristics of the SFE can influence a species' apparent long term trend and should be considered when evaluating the results and effectiveness of monitoring programs.

Tuesday, September 28, 2010: Room 308-310 Fish Physiology and Behavior - Order: 4

MATING CALL OF THE PLAINFIN MIDSHIPMAN AS AN INDICATOR OF STRESS DUE TO ANTHROPOGENIC NOISE AND OTHER ENVIRONMENTAL FACTORS

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The plainfin midshipman (*Porichthys notatus*) is a common finfish in the Eastern North Pacific. Parental males move to estuaries to form mating aggregations to attract females with low-frequency, long-duration acoustic calling produced by rubbing specialized muscles against the swimbladder. We have analyzed acoustic recordings from a hydrophone deployed from the Romberg Tiburon Center research pier in the north San Francisco Bay. Strong signals from singing midshipman are detected during summer months, and sound from passing ships is easily identified. Since the frequency band of ship sound overlaps that of midshipman singing, we propose to determine if masking of singing by ship sound alters midshipman mating behavior. We have studied the intensity, frequency and other features of this humming to determine possible relationships to environmental factors such as water temperature, chemical contaminants in the water, and anthropogenic underwater sound. We find that the diel pattern of midshipman humming is approximately complimentary to the diel distribution of shipping noise, with the midshipmen humming principally at night when shipping traffic is at a minimum. These results indicate that the night-time humming of the midshipman may be a response to the presence of shipping noise during the day, which masks the humming and makes mating more difficult. It may be possible to use this behavioral response to measure the loss of time for mating or other behavioral metrics as a function of the level of shipping traffic. These metrics can be used in management of shipping noise. In addition, we have observed a sharp increase in humming in response to heavy rainfall, which may be due to the presence of chemicals in runoff. Understanding these issues surrounding the survival of native species will help to preserve biodiversity in the Bay-Delta estuary.

Tuesday, September 28, 2010: Room 308-310 Fish Physiology and Behavior - Order: 5

ARE JUVENILE LONGFIN SMELT ABANDONING THE SUISUN BAY NEIGHBORHOOD? ...THE REST OF THE STORY

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The longfin smelt is one of four pelagic fish species whose abundance declined sharply after 2001 and has generally remained low since based on Fall Midwater Trawl Survey sampling. These fish declines and associated changes in the upper estuary food web became known as the Pelagic Organism Decline (POD). Before the POD decline and after the establishment of *Corbula amurensis*, longfin smelt shifted their distribution toward higher salinity water during summer and fall and away from Suisun Bay. I examine this distribution shift in more detail and whether such a shift could partially explained some of the declining abundance during the POD years, as would be the case if a larger fraction of the population inhabited regions outside the Fall Midwater Trawl Survey sampling area. I also provide evidence of a recent increase in the age structure of spawners and conjecture regarding how this shift came about, its potential link to a shift in distribution and its effect on total fecundity.

Tuesday, September 28, 2010: Room 311-313 Pelagic Organism Decline (I) - Order: 1

THE SPAWNING MIGRATION OF DELTA SMELT IN THE UPPER SAN FRANCISCO ESTUARY

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Abstract. While there is substantial information about the upstream migration of commercially and recreationally important fishes, relatively little is known about the upstream migration of small-bodied species, particularly through estuaries. In the San Francisco estuary, there is a major need to understand the behavior of delta smelt *Hypomesus transpacificus*, a small pelagic fish listed under the state and federal endangered species acts. The spawning migration period may be critical as upstream movements can result in entrainment in water diversions. In general, delta smelt live in the low salinity zone of the estuary and migrate upstream for spawning. During the fall pre-migration period, delta smelt remain primarily within the low salinity zone in the western Sacramento-San Joaquin Delta and Suisun Bay. There were no significant upstream shifts of fish into fresher water during late fall, suggesting that delta smelt do not show pre-migration staging behavior. Following winter “first flush” flow events that appear to trigger migration, upstream movement rates are relatively rapid, averaging 3.6 km/d, a finding consistent with results from particle tracking simulations, laboratory studies, and other fishes. Like some other native fishes, delta smelt apparently “hold” in upstream areas following migration; most do not spawn immediately. Overall, delta smelt fit the pattern of a diadromous species that is a partial seasonal reproductive migrant. Emerging data suggest that there is variability in the migration behavior of delta smelt; some offspring may not leave spawning areas, a pattern contrary to the reigning viewpoint that smelt all migrate in winter.

Tuesday, September 28, 2010: Room 311-313 Pelagic Organism Decline (I) - Order: 2

RECONSTRUCTING INTER-ANNUAL VARIABILITY OF DELTA SMELT LIFE HISTORY WITH OTOLITHS

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Problem Statement: The delta smelt population has experienced dramatic declines in the past and has continued to precipitously drop in recent years. The cause(s) of the decline have yet to be determined, and is likely the result of multiple impacts on the population (e.g. food limitation, contaminants, freshwater exports from the estuary), which can operate spatially. **Approach:** To look back on the processes that result in poor recruitment, we are investigating the spatial extent of the population structure through otolith geochemistry for juvenile and adults collected during monitoring surveys, including the relative impact that the freshwater exports may have on the delta smelt population structure. In addition we are investigating growth rate variability of successful recruits to test the hypothesis that reduced zooplankton prey abundance has resulted in reduced growth rates. **Results:** In this study we investigated the spatial and temporal variability of birthdate, natal origin and growth of delta smelt recruits from 1999-2008 and for exported larvae in 2000, 2001, 2008 and 2009. Overall, a majority of fish originated from Sacramento River water, while a small proportion originated in San Joaquin River water and the low-salinity zone. Juvenile rearing habitats varied with X2, with most of the successful recruits using the freshwater delta when X2 was at the confluence. Fishes residing in San Joaquin River water during the juvenile stage showed relatively poor growth and recruitment from summer to fall. During wet years (e.g. 2000), the exports preferentially effect early born San Joaquin River cohorts, while in dry years (e.g. 2001) the exports have a larger relative impact on the entire population by entraining water and smelt from the Sacramento River. **Conclusion:** This study provides important information regarding the spatial variability associated with recruitment and infers a potential problem with fishes residing in San Joaquin River water. In addition we show that exports can have qualitative impacts on the population structure, which may result in impacts beyond absolute entrainment loss.

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CONSERVATION GENETICS OF LONGFIN SMELT

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The demographic independence of the longfin smelt (*Spirinchus thaleichthys*) population inhabiting the San Francisco Bay-Delta is unknown, yet it may be geographically isolated from populations occurring further north along the Pacific Coast. Longfin smelt are an anadromous fish inhabiting estuarine and nearshore marine waters along the western Pacific coast and there exists potential for them to migrate between coastal populations. Genetic information can provide insight into the gene flow between fish from different locations, and the spatial and temporal scales at which longfin smelt collections are differentiated is a critical uncertainty that influences how the species is managed. We developed seventeen microsatellite DNA loci to assess genetic diversity within and among longfin samples from the SF Bay-Delta and Lake Washington, WA. In a preliminary screen of these collections, 5 to 16 alleles per locus were detected, the expected heterozygosity ranged from 0.33-0.93, and moderate levels of differentiation were found. Results from broader temporal samples will be discussed in this presentation to determine the population structure of longfin smelt, and an update about sample collection for other Pacific Northwest locations will be given. The diversity observed in these collections suggests management of longfin smelt may increase sustainability of the population by focusing on segments of the species scaled relevant to natal estuaries along the west coast.

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MORE BIG BASS: UNDERSTANDING THE ROLE OF LARGEMOUTH BASS AS TOP PREDATORS IN THE LITTORAL ZONE

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While numerous pelagic organisms in the Sacramento-San Joaquin Delta have declined precipitously in recent years, abundance of non-native centrarchids in the littoral zone has increased substantially. Sharp inclines in the largemouth bass (LMB) populations, with an apparent particular increase in large, piscivorous LMB, are of special interest due to the potential for direct impacts on native fishes via predation. The aims of this study were to address potential reasons for the population increase in LMB by determining abiotic and biotic factors influencing LMB distribution and abundance in the Delta, and to assess the diet composition of LMB across seasons. Previous studies have hypothesized that LMB and other non-native fishes have benefited from an expansion of submerged aquatic vegetation (SAV) in the Delta; thus, a specific goal was to quantify the relationship between SAV and prominent resident fishes in the littoral zone, particularly LMB. To address these questions, we have conducted bimonthly boat electrofishing surveys and characterized SAV species composition and biomass at 33 locations throughout the Delta since October of 2008. Results indicate that SAV favors recruitment success of juveniles for many resident fishes, including LMB, likely by promoting secondary productivity in SAV beds that in turn supports the diets of juvenile fishes. Adult LMB diet is composed primarily of vegetation-associated prey (e.g. sunfish and crayfish) throughout the year, suggesting that foraging excursions into pelagic areas are rare. Instead, SAV may promote the abundance of key diet items for adult LMB, thus facilitating an increase in the numbers of large LMB. This study provides new insight into how SAV may provide a mechanism for population increases for many littoral, non-native fishes. In addition, quantification of LMB and other species' responses to SAV biomass provides important information to managers interested in modeling how control of SAV may influence resident fish abundance.

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FINE-SCALE MOVEMENT OF LARGEMOUTH BASS, AN INTRODUCED PREDATOR

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The largemouth bass (*Micropterus salmoides*) is an introduced, generalist predator in the Sacramento-San Joaquin Delta. The top-down pressure exerted by this and other non-native predators has been suggested as one of the potential factors in the decline of a group of pelagic fishes (POD species: delta smelt, longfin smelt, threadfin shad, striped bass). While largemouth bass are associated with shallow-water habitats, it is not known to what extent they also use open-water zones, and thus what degree of predation pressure they could potentially exert on pelagic species in these areas. Here we use acoustic telemetry techniques to assess fine-scale bass movement over the course of a year. As of June 2010, we have fifteen adult bass implanted with acoustic telemetry tags, and have recorded their fine-scale movements with a Vemco Positioning System in a flooded agricultural island in the south-central Delta. Additionally, we are measuring the extent, density, and composition of the submerged aquatic vegetation within the shallow-water zone. Movements will be analyzed for proximity to submerged aquatic vegetation, conspecific avoidance, core-use areas, and daily/seasonal patterns in these behaviors. Preliminary results from August and September 2009 suggest that while bass do appear to make rare forays into open-water areas (>75m from vegetation beds), the majority of time is spent within or at the edges of the submerged aquatic vegetation. More complete knowledge of the movements and habitat use of *M. salmoides* in the Delta, when combined with information on the distribution and habitat use of declining pelagic species, will allow us to better assess the role that predation pressure plays in the Delta ecosystem. We hope that this understanding will aid managers in future efforts to aid declining populations and rehabilitate critical habitats.

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DETECTING PREDATION OF LARVAL DELTA SMELT BY MISSISSIPPI SILVERSIDES AND OTHER PREDATORS USING GENETIC ANALYSIS OF GUT CONTENTS

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“Top down” predation effects are an important part of the Pelagic Organism Decline (POD) conceptual model and thus are theorized to have substantial impacts on the threatened delta smelt (*Hypomesus transpacificus*). Particular interest has been placed on Mississippi silversides (*Menidia audens*) because their numbers have been increasing over recent years, and they readily consume delta smelt larvae in captivity. Thus, there is a need to evaluate whether wild silversides are impacting, or have the potential to impact, delta smelt recruitment. Given the difficulty of morphologically identifying larval fish remains in stomach contents, we developed a genetic assay to look for delta smelt DNA in the guts of putative predators of larval smelt. The assay was tested for cross-reactivity with a suite of delta fishes, and Mississippi silversides were utilized for captive feeding trials to characterize the assay and model the degradation of DNA in the predator guts. Additional sensitivity analyses demonstrated the assay’s ability to detect 0.1 picograms of target DNA in 100 nanograms of predator DNA. Upon development of the assay, beach seines were conducted in the Sacramento deep water ship channel to sample silversides and other predators (centrarchids and striped bass) for gut analysis. A total of 658 silversides, 13 striped bass, 11 yellow-fin gobies, and two centrarchids were collected for genetic gut analysis. Development and characterization of this genetic assay will provide a cost-efficient and powerful tool for researchers studying top-down effects on POD species in the delta, and it will have broad applications for detecting delta smelt presence. Results from the analysis of the guts of putative larval smelt predators will provide valuable insight into the impacts of predation on early life stages of delta smelt.

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BIOENERGETIC MODELING OF SAN FRANCISCO ESTUARY STRIPED BASS

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Striped bass (*Morone saxatilis*) are the top predator in the San Francisco Estuary (Estuary) and therefore have the potential to strongly structure communities of lower trophic levels. In this study, we (1) developed a method to estimate abundances of sub-adult (age 1 and age 2) striped bass, (2) applied a bioenergetics model of sub-adult and adult striped bass to quantify long-term consumption patterns from 1969 through 2004 in the Estuary, (3) evaluated how consumption varied by age and sex, and (4) identified factors impacting the resulting consumption estimates. On a 'per capita' basis, individual total and prey fish consumption increased after 1994 for age 2 cohorts, and individual prey fish consumption increased after 1990 for age 1 cohorts. Conversely, individual total and prey fish consumption by adult (age 3+) striped bass decreased over the period analyzed. This decline in individual consumption over the study period appeared to be related to a decline in size-at-age of adult cohorts. As expected, both population total and prey fish consumption by all cohorts (ages 1 through 6) of striped bass were highly correlated to population abundance estimates. Hence, the long-term trends in population consumption by each cohort closely followed their respective population abundance trends. Population total and prey fish consumption by sub-adult (age 1 and age 2) striped bass was found to be similar to the population consumption by adult striped bass, due largely to the population numbers of sub-adults. Unlike adult striped bass that are known to emigrate and forage in the ocean, the majority of sub-adult striped bass reside permanently within the Estuary, creating the possibility that consumption by the relatively abundant sub-adult population could have significant impacts upon estuarine prey species.

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FEEDING, GROWTH, AND SURVIVAL OF LARVAL DELTA SMELT: IMPACTS OF INTRODUCED PREY

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Populations of planktivorous fish in the San Francisco Estuary (SFE) are in a state of decline. Declines in several species have been correlated to changes in the abundance and distribution of their zooplankton prey. These correlations provide indirect evidence that changes in food supply are contributing to the decrease in fish abundance. Over the past two decades, there has been a shift in the species composition of zooplankton from a community dominated by numerous species of calanoid copepods to one dominated by a single introduced cyclopoid copepod, *Limnoithona tetraspina*. Since its introduction, *L. tetraspina* has become the most abundant copepod, at times outnumbering all other copepods by a factor of ten. Additionally, because *L. tetraspina* is approximately 1/20th the biomass of the historically dominant calanoid species (i.e., *Eurytemora affinis* and *Pseudodiaptomus forbesi*), there has been a corresponding decline in the accessibility and total biomass of available prey. To test for an effect of prey type on growth and survival of delta smelt (*Hypomesus transpacificus*), we conducted long-term rearing trials with first-feeding (6 days old) and 30-day-old larvae. Each age-group was reared for 30 days on one of three diets: cyclopoid copepods (*L. tetraspina*), calanoid copepods (*P. forbesi*) or a control diet (rotifers and *Artemia* sp.). Field-collected zooplankton were size fractionated appropriately for each age-group of fish tested. Each prey category was offered in excess but at relative densities similar to those observed in situ. Both age-groups of larvae grew faster (fork length) when fed *P. forbesi* than *L. tetraspina*; however, larval survival did not differ significantly among diets. This information supports claims that high abundances of *L. tetraspina* may provide suboptimal nutrition to the delta smelt population, and that this shift in prey composition may be contributing to the decline of pelagic organisms in the SFE.

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BIOGEOCHEMICAL PROCESSING OF ANTHROPOGENIC AMMONIUM IN THE SACRAMENTO RIVER AND THE NORTHERN SAN FRANCISCO ESTUARY

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Like estuaries around the world, the San Francisco Bay estuary (SFE) receives large anthropogenic loads of inorganic nutrients as a result of increased population growth; inorganic nitrogen (N) comes primarily from municipal wastewater treatment plant (WWTP) discharge in the form of ammonium (NH_4). In contrast to other eutrophic estuaries, the SFE generally does not exhibit nuisance blooms or localized hypoxia but rather phytoplankton respond to increased NH_4 loading with diminished nutrient uptake, reduced primary production and biomass, and altered phytoplankton community composition all of which potentially act to reduce food web support for pelagic organism decline (POD) species. The present study investigated the consequences for river and estuarine phytoplankton of WWTP discharge along a 150-km transect in the Sacramento River and northern SFE. Consistent with previous results for the northern SFE, phytoplankton nitrogen uptake shifted from a nitrate (NO_3)-based system to one supported by NH_4 immediately downstream of the WWTP discharge and the sum of inorganic N uptake and carbon uptake declined with elevated NH_4 . The result was a U-shaped pattern of primary productivity and chlorophyll with maxima found in the river above the outfall and at Suisun and San Pablo Bay to the west and a minimum found in the river downstream of the WWTP, essentially a mirror image of distribution of NH_4 concentrations. Phytoplankton NH_4 uptake rates and nitrification rates were insufficient to appreciably reduce NH_4 concentrations in the Sacramento River resulting in a large export of anthropogenic NH_4 to habitats critical for POD species in the SFE Delta and in Suisun Bay. These results suggest an unintended consequence of the Clean Water Act of 1972 and the conversion of sewage treatment to the secondary level discharging N as NH_4 .

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THE PELAGIC FOODWEB OF THE UPPER SAN FRANCISCO ESTUARY: CHANGING CONDITIONS AND CHANGING UNDERSTANDING

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A contributing factor to the Pelagic Organism Decline may be the low abundance of copepods in the low-salinity zone (LSZ), which may limit growth or survival of delta smelt and other pelagic fish. This low abundance is believed due to low productivity of the LSZ foodweb. A multidisciplinary study over the last four years has provided some insights into the functioning of this foodweb. Primary production was lower than expected from chlorophyll concentration, a finding consistent with the low carbon:chlorophyll ratio of ~20 in 2006-2007. About 60% of the primary production was in particles smaller than 5 μm , near the lower limit of particle size grazed upon efficiently by copepods or by the clam *Corbula amurensis*. Both of these findings indicate a shift toward smaller, slower-growing phytoplankton. Ciliates were consumed at high rates by both copepods and clams and were apparently limited more by predation than by food supply. Copepods, by contrast, were persistently food limited. Specific growth rates in summer were low for *Limnithona tetraspina* and variable but usually low for *Pseudodiaptomus forbesi*, while egg production rates of both species were always low. Calculated consumption of phytoplankton, ciliates, and *P. forbesi* by clams exceeded the reproductive capacities of all groups, requiring transport from other regions of the estuary. Taken together, these results show a foodweb that is severely limited in its capacity to support pelagic fish and that may degrade further if subsidies from other parts of the estuary become impaired.

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TURBIDITY DECLINES AND SUBMERGED AQUATIC VEGETATION EXPANSION IN THE SACRAMENTO – SAN JOAQUIN DELTA

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We investigated interactions between submerged aquatic vegetation (SAV) and turbidity in the Sacramento-San Joaquin Delta, California. Feedback dynamics were examined using in situ turbidity and velocity meters and SAV maps derived from airborne imaging spectroscopy. We then analyzed historical turbidity data from the Delta, which showed a decline in turbidity coinciding with an expansion of SAV. Turbidity significantly declined from 1975-2008 (-1.3%/year), and the decline was highly correlated with SAV cover ($R^2=0.9$, $p=0.003$). To determine if SAV contributed to the increased water clarity, we used quantile regression to model the limitations of SAV cover on high turbidity. We found that annual maximum velocities exceeding $0.49 \text{ m}\cdot\text{s}^{-1}$ constrain SAV distribution, and that SAV cover has a negative linear relation with turbidity, and limits high turbidities at 13.8-15.8 NTU. We hypothesize that diminishment of the hydraulic mining sediment pulse, armoring of the Sacramento River channel, and sediment trapping in reservoirs and flood bypasses has reduced sediment supply and favored SAV expansion. Turbidity declines after 1975 were promoted by the expanding SAV cover in the Delta. We estimate that the expansion of SAV cover after 1975 provides a relative contribution of 21-70% of the total declining trend in turbidity. Furthermore, the relations between velocity, SAV, and turbidity indicate potential feedbacks, suggesting the possibility of an irreversible shift in the ecosystem state from a low SAV-high turbidity ecosystem to a high SAV-low turbidity ecosystem. Lower turbidity conditions have negatively impacted delta smelt habitat, however, removal of the vegetation may not lead to increases in turbidity that restore habitat due to the loss of sediment supply.

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WATER TOXICITY MONITORING IN THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA: 2006-2010

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Following the decline of numerous pelagic fish populations residing in the Sacramento-San Joaquin Delta of California, USA, a monitoring program was initiated to identify the extent and distribution of toxicity. Biweekly toxicity tests were performed on water samples from sixteen sites using the resident amphipod, *Hyaella azteca*. In addition, during March - May, water from five sites (340, Cache-Lindsay, Hood, Light 55, and Suisun) was tested with larval delta smelt (*Hypomesus transpacificus*). In situ monitoring was conducted at two DWR water quality monitoring stations (Rough & Ready Island on the San Joaquin River and Hood on the Sacramento River) using *H. transpacificus*, fathead minnows (*Pimephales promelas*), and *H. azteca*. Invertebrate tests were performed with and without the addition of PBO. Toxicity data obtained to date suggest that water quality is at times compromised in some areas of the Delta. Insecticides and ammonia and/or other effluent-associated contaminants likely contributed to the observed toxicity to *H. azteca*. The results of this project will be used to geographically focus management actions in the Delta and assist in identifying the sources and quantifying the effects of contaminants on aquatic species of concern.

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MOLECULAR BIOMARKERS IN ENDANGERED SPECIES: RESPONSES TO SUBLETHAL AMMONIA EXPOSURE IN THE ENDANGERED DELTA SMELT; HYPOMESUS TRANSPACIFICUS (FAM. OSMERIDAE)

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The delta smelt (*Hypomesus transpacificus*) is a pelagic fish species endemic to the Sacramento-San Joaquin Estuary in Northern California, listed as endangered under both the USA Federal and Californian State Endangered Species Acts and acts as an indicator of ecosystem health in its habitat range. Interrogative tools are required to successfully monitor effects of contaminants upon the delta smelt, and to research potential causes of population decline in this species. We use molecular biomarkers to investigate genome-wide effects in fish exposed to delta water samples with a focus on locations that are impacted by contaminants, and quantitatively link expression of select biomarker genes to ecologically relevant endpoints such as the ability to swim normally. Effects of wastewater effluent toxicity were further assessed and compared to those elicited by ammonia/um alone. An ammonium transporter gene (RHCG), expressed in gills, was significantly upregulated correlating with ammonia concentrations in a dose-dependent manner, as were genes involved in neurological activity (aspartoacylase) and muscular atrophy (atrogin-1). Furthermore, a developmental gene, expressed in vertebra (collagen XI alpha) was significantly downregulated. Results suggest a synergistic effect of ammonia with other contaminants present in wastewater treatment effluent. Evaluation of swimming performance demonstrated decreased activity and erratic behavior; effects explained by the neuromuscular responses measured using the molecular biomarkers. The results of this project will assist in identifying the sources and extent of contaminant impacts on larval delta smelt, thus guiding future management actions. Results will allow a comparison of contaminant profiles arising from agricultural and other anthropogenic activities that may directly affect delta smelt development and as such population dynamics.

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EFFECTS OF MATERNAL SIZE ON LARVAL GROWTH AND SURVIVAL OF DELTA SMELT DUE TO TEMPERATURE, PESTICIDE EXPOSURE, AND STARVATION

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Three experiments were initiated to investigate differences in reproductive performance and survival of delta smelt (*Hypomesus transpacificus*) due to maternal size. The studies include: 1) larval survival produced from big and small females cultured at water temperatures of 16 °C and 20°C, 2) effects of starvation on maternal size, and 3) effect of permethrin exposure on larvae spawned from big and small females. Results indicated larger females had higher fecundity, fertility, and egg hatching success than smaller females. While the size and age (0 and 5 day-post-hatch) of larvae were not affected by maternal size, the yolk/oil globular ratios decreased at a faster rate in larvae spawned from smaller relative to larger females. Survival was higher for larvae raised at 16°C compared to 20 °C. All larvae were similarly affected by the toxic effects of permethrin regardless of maternal size. However, larvae spawned from smaller females had higher mortality when deprived of food for 4 days, relative to those from larger females. Overall, these findings indicate that larval survival after exposure to the pesticide was independent of maternal size, while under deprived food conditions, larvae from larger females had higher growth and survival than the larvae from smaller mothers. Such maternal effects are known to have an important influence on year-class recruitment. Because larval survival are maternally-size dependent and spawning of larger females tend to occur at the beginning of the spawning season, restoration and water conveyance measures that benefit delta smelt can be improved by targeting larger females that produce viable larvae.

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WHAT REALLY HAPPENED TO DELTA SMELT? WATER EXPORTS AND HABITAT CONDITIONS DRIVE PATTERNS OF SELECTIVE MORTALITY AT ECOLOGICAL AND POSSIBLY EVOLUTIONARY SCALES

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Decades of research attest to the futility of “silver bullet” explanations for the collapse of fish populations. Multiple interactive factors typically act subtly in systematic or stochastic ways to reduce survival of individuals before an effect is observed on the population. Moreover, if mortality from human or natural sources repeatedly affects certain individuals over multiple generations, it can drive evolution. We addressed these issues by implementing an approach for quantifying age and growth (from otoliths), with indicators of poor feeding success and exposure to toxic chemicals, (from liver and gonad histopathology), for individual delta smelt caught during routine monitoring. Multiple measurements were made on about 1,500 individuals from 1999-2007, the period of decline. We evaluated patterns in size selective mortality among years, while controlling for temperature effects on growth, with the relative influences of environmental conditions (freshwater outflow) and human activities (toxic exposure, water export operations) using nonlinear mixed models. Before the decline (1999-2001) individuals surviving to the adult stage (in December) were generally larger at hatching, or had higher than average growth rates, and were spawned in early spring. However, after the decline (2005-2007), patterns of selective mortality were more complex and generally opposite. The few early-spawned adult survivors initially grew slower, but then faster than average after mid-summer, and the mean size of adults also declined. Although these patterns are consistent with adverse effects on early spawned larvae by water export operations, a possible evolutionary effect may be confounded by the overall deterioration of summer habitat conditions that also occurred over time. Overall, our findings have significant implications for management of water export operations, because this interactive sequence of human and natural factors likely played a significant role in the decline of delta smelt.

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APPLICATION OF AN INDIVIDUAL BASED MODEL OF SAN FRANCISCO ESTUARY STRIPED BASS TO EXPLORE POSSIBLE MECHANISMS ASSOCIATED WITH THE OBSERVED DISCONNECT BETWEEN JUVENILE AND ADULT POPULATION ESTIMATES

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In the San Francisco Estuary (Estuary) abundances of striped bass (*Morone saxatilis*) have fluctuated greatly over time, with a sharp decline beginning around 2000. Coincident with similar declines in several other pelagic fish species, the continued decline of these species became known as the Pelagic Organism Decline (POD). One unique feature of the POD specific to striped bass is a disconnect between the “Age-0” Fall Midwater Trawl (FMWT)/ Summer Towner Survey (TNS) abundance indices and adult abundance measures. Specifically, as the FMWT/TNS indices declined in the mid- 1990’s, adult abundance indices remained relatively stable. Several mechanisms have been proposed as possible causes to this observed disconnect, including changes in adult striped bass sex ratios and changes in egg/larval mortality. Changes in adult sex ratios, specifically the loss of adult females, may have contributed to a decreased egg supply, subsequently leading to declines in the FMWT/TNS indices. At the same time, a compensatory decrease in mortality in the Age 1/Age 2 life-stages may have led to the stable adult abundances. Alternatively, an increase in egg/larval mortality rates may have led to the declining FMWT/TNS indices, and a compensatory decrease in mortality in the Age 1/Age 2 life-stages led to the stable adult abundances. In the study presented herein, we first apply an individual-based model (IBM) of San Francisco Estuary striped bass to evaluate the relative roles that changing adult sex ratios and egg/larval mortality have upon the “Age-0” and adult abundance measures. Next we apply the IBM to evaluate three possible mechanisms that may contribute to observed changes in adult sex ratios: (1) skipped years in spawning, (2) changes in female mortality rates, and (3) changes in sex ratios at hatch.

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USING AN INDIVIDUAL-BASED MODEL TO EVALUATE THE FACTORS AFFECTING POPULATION DYNAMICS OF DELTA SMELT

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Delta smelt has become increasingly controversial due to its long-term decline and the more recent pelagic organism decline (POD). To address some of the questions related to the causes for the decline, we developed an individual-based population dynamics model. The model tracks thousands of individuals on the same spatial grid as used by Department of Water Resource's DSM2 hydrodynamics model. For computational reasons, we use a super-individual approach, whereby each model individual represents a number of identical population individuals. Daily water temperature, salinity, turbidity, and the densities of six zooplankton prey types are represented on the spatial grid. The model follows the reproduction, growth, mortality, and movement of individuals over their entire life cycle. Reproduction is evaluated daily and egg cohorts are tracked until hatching. New model individuals are introduced as individual yolk-sac larvae. Growth of later stages is based on bioenergetics and zooplankton densities. Mortality includes a constant rate plus mortality due to starvation, turbidity, and entrainment. Movement of individuals is by particle tracking for the larval stages and behavioral algorithms for juveniles and adults. We simulated the population decline using 1995 to 2005 conditions, and explored the relative influence of historical changes in food, entrainment, and female size on delta smelt population dynamics. Simulations indicate that all of these factors have an effect on delta smelt, with the potential for interactive effects causing unexpectedly large population responses. Increased understanding of how environmental conditions and pumping-related entrainment affect delta smelt population dynamics will inform the ecosystem restoration objective of restoring and protecting the habitats of native species. The modeling can be used to filter the many possible management actions that could be taken, helping to identify effective and efficient options from an ecological perspective.

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AN ECOTROPHIC-BASED MODEL OF THE SACRAMENTO-SAN JOAQUIN DELTA

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Ecosystem modeling provides a useful framework for organizing ecosystem data. Investigating the quality of the data in such models provides an objective measure of the model's ability to replicate the system and how management decisions may affect ecosystem functionality. We have developed a mass-balanced trophic model for the Sacramento-San Joaquin Delta using Ecopath with Ecosim (EwE 6) software to explore ecosystem dynamics of the pelagic organism decline. The model uses parameters such as biomass, production, and mortality estimates of 40 functional groups, including birds, fish, benthic invertebrates, zooplankton, phytoplankton, and detritus. Model parameters were calculated from published and unpublished local data, taken from the literature, or, if necessary, estimated. We use this initial data in the static, mass-balanced Ecopath model to establish the initial conditions for the model. We then used these initial conditions in a simulation modeling approach to explore ecosystem drivers. To investigate the quality of the data for initial conditions, we use Monte Carlo simulations to allow a subset of the initial parameters to vary randomly by 50% and determine what percent of the simulation runs deviate from the general trends. Monte Carlo simulations for parameters that result in high deviation suggest that the model is sensitive to these parameters and improvements in monitoring and research for these parameters would improve our understanding of Delta ecosystem dynamics.

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COLLABORATIVE WORKGROUP EFFORTS TO MODEL SPECIES, STRESSORS, AND PROCESSES IN THE UPPER SAN FRANCISCO ESTUARY

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Since May 2007, collaborative workgroups facilitated by the University of California, Santa Barbara in partnership with the Interagency Ecological Program have sought to better understand patterns and drivers of the decline of pelagic fishes in the upper San Francisco Estuary and the status and trend of the ecosystem. Workgroups have focused on ecosystem modeling, contaminants effects, and interactions between the near-coastal ocean and San Francisco Estuary. The ecosystem modeling group examined trends in abundance of delta smelt, longfin smelt, threadfin shad, and striped bass. Participants evaluated evidence for abrupt changes in abundances and whether selected covariates were correlated with those changes. Additionally, participants are modeling the static and dynamic food web of the ecosystem. The contaminants group investigated whether assessment of the cumulative effects of pesticides on species or ecological functions might be transferred more effectively to decision makers. The group reviewed the spatial overlap between life stages of pelagic fishes and the mechanisms by which contaminants may contribute to declines. Furthermore, the group is examining land-use change in the region from 1990 to 2006 and chemicals associated with urban runoff in key locations occupied by pelagic fishes. The near-coastal group is exploring how a pronounced shift in climatic forcing of the Pacific Ocean, measured as the North Pacific Gyre Oscillation, may affect populations of species that migrate between oceans and estuaries. We are documenting data and metadata to ensure that scientific sources and methods are transparent and, where applicable, repeatable. We also are pursuing mechanisms other than scientific journals to communicate results to a broad audience of end users, including stakeholders and policy makers.

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DEVELOPING REAL TIME QUANTITATIVE PCR (Q-PCR) FOR RAPID AND RELIABLE IDENTIFICATION OF DELTA FISH AND INVERTEBRATES

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Q-PCR is a technique based on conventional PCR, which is used to amplify and simultaneously quantify a targeted DNA molecule. It enables both detection and quantification (as absolute number of copies or relative amount when normalized to DNA input) of one or more specific sequences in a mixed sample. A common method for detection of products in Q-PCR is based on the design of sequence-specific DNA probes consisting of oligonucleotides labeled with a fluorescent reporter, which permits detection only after hybridization of the probe with its complementary DNA target. PCR based identification of prey items and Q-PCR based detection of prey items is a proven technique (King et al. 2008, Rose et al. 2002) and is already in use by CFS/IEP/UC Davis staff to identify Delta Smelt, Longfin Smelt, and Wakasagi Smelt in the stomachs of Delta piscivores. High throughput technology based on Q-PCR methods are currently available for the development of a “gene chip” which will enable rapid, cost effective assessment of available and consumed biomass for all (dozens to hundreds) of Delta prey items (including zooplankton, macro invertebrates, fish and mollusks). The Fluidigm® BioMark™ Real Time PCR system allows for the simultaneous detection of up to 96 individual species for 96 samples in the same time it currently takes to detect 1 species. This platform for species identification will enable the processing of 9216 assays on 1 “gene chip.” Use of a “gene chip” will make it possible to provide a detailed assessment of available prey and diet composition among Delta fish species. Results are superior to classic visual identification of stomach contents because genetic methods allow even degraded or cryptic species in fish stomachs to be identified with a high degree of certainty.

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AN INTEGRATED GENETIC STOCK IDENTIFICATION AND PARENTAGE-BASED TAGGING PROGRAM FOR CHINOOK SALMON USING SNPS

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Populations of West Coast Chinook salmon (*Oncorhynchus tshawytscha*) have been on the decline over the last decade. Of particular concern is the recent crash of Central Valley (primarily Sacramento River) fall-run Chinook, the main contributor to the commercial and recreational fisheries of California and Oregon. As the situation has become more dire, management agencies are under increasing pressure to tightly monitor and critically evaluate actions meant to preserve the species. This includes not just monitoring and regulating ocean fisheries, but also evaluating the effectiveness of current hatchery practices, the relative fitness of hatchery produced fish, and the impacts of hatchery fish on wild populations. The aging coded wire tag (CWT) program has been informative towards these goals, however it is expensive and current efforts to mass mark all hatchery fish will further impede the program's effectiveness. In an ideal management world, we would like to pick up a salmon - as a juvenile migrating seaward, in ocean fisheries, or during spawning at hatcheries or instream - and ask the question, "Where did you come from?" The integrated Genetic Stock Identification (GSI) and Parentage-based Tagging (PBT) program described here provides two distinct ways to answer this question by simply collecting a fin clip (non-lethally) and genotyping the individual with a single panel of 96 single nucleotide polymorphism (SNP) markers. GSI provides the origin of an individual by comparing its genotype to baseline samples collected from the primary drainages and rivers to which the fish can be assigned. Alternatively, a PBT program depends on the collection of genotype information from a parental generation, either the broodstock at a hatchery or even wild spawners at a weir. This data is entered into a parent database. When offspring are subsequently sampled, genotyping is followed by high-confidence parentage assignment wherein the inherited genetic tags are used to locate the parents in the database, thereby identifying the stock and cohort of origin. A PBT program also provides some collateral benefits: reconstruction of large pedigrees, mapping of genes for phenotypic traits, precise estimates of variance in family size, and the ability to evaluate different hatchery practices. This talk will focus on the following: 1) SNP discovery at the NOAA SWFSC Santa Cruz Lab 2) marker selection and panel construction 3) status of the GSI SNP baseline for West Coast Chinook salmon 4) GSI results from mixed ocean fisheries: past and present 5) status of broodstock sampling for PBT at California salmon hatcheries 6) results from an applied PBT program at the Feather River Hatchery for spring-run Chinook

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PROGRESS IN MOLECULAR DISCRIMINATION AMONG CALIFORNIA'S CHINOOK SALMON RUNS: CONTRASTING MICROSATELLITES, CLOCK-GENES AND SNPS

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The application of DNA based markers towards the task of discriminating among California's Central Valley runs has evolved in accord with ongoing genomic developments. A host of innovations in this field has increasingly enabled us to resolve which genetic markers associate with important life history differences among runs. Accuracy for identification of most likely source population encountered at salvage or water monitoring facilities has far reaching consequences for improving measures for Chinook management, restoration and conservation. We thus continue to focus on developing new tools to provide the greatest statistical power for run identification. In accord, improved methods for identification of threatened or endangered stocks at sites where they might be at risk for loss allows water policy measures to affect most prompt response to changes in encounter rates. As a proof of concept for these claims, we conducted a blind test of over 500 known origin Chinook to compare and contrast the ability of different molecular markers (including microsatellites, clock-genes and single nucleotide polymorphisms (SNPs)) to correctly resolve the identity of these test samples. Pleasingly, we demonstrate that overall power continues to increase, while cost to run genetic assays has decreased.

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COMPREHENSIVE CONSTANT FRACTIONAL MARKING PROGRAM FOR CENTRAL VALLEY FALL-RUN CHINOOK SALMON

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Over 32 million fall-run Chinook salmon are produced each year at five hatcheries in California's Central Valley. This production contributes to major sport and commercial fisheries in ocean and inland areas. Until 2007, only experimental releases of fall-run Chinook were externally marked and coded-wire tagged on a consistent basis. In recent years, the Central Valley Project Improvement Act (CVPIA) program, the Bay-Delta Program, and other state and federally-mandated programs have provided significant funding for salmon habitat restoration programs, with the goal of increasing natural production in the Central Valley. Due to the current low rates of marking/tagging of hatchery fish, evaluation of these restoration programs, and harvest management programs, is limited by the inability to assess the relative contribution of hatchery and natural production of fall-run Chinook in the ocean harvest, inland harvest, in-river spawning escapements, and hatchery returns. In 2006, the CALFED Ecosystem Restoration Program funded the implementation of a Central Valley-wide Constant Fractional Marking/coded-wire tagging program for hatchery production releases of fall-run Chinook salmon. Based on statistical studies, the program targeted marking/tagging at a consistent 25% rate. Specific goals of the program include: 1) Evaluation of the the contribution rates of hatchery fish to Central Valley Chinook salmon populations, 2) Evaluation of the Central Valley propagation program's genetic and ecological effects on natural Chinook populations, 3) Estimation of exploitation rates of hatchery and natural Central Valley Chinook salmon in ocean and inland fisheries, 4) Evaluation of the success of restoration actions designed to increase natural production of Central Valley Chinook salmon, 5) Evaluation of the recovery of listed stocks of Chinook salmon. Due to the short period of time and large numbers of fall-run Chinook that needed to be marked/tagged, traditional manual marking/tagging was not be feasible at the 25% rate. Four automated marking/tagging systems, AutoFish Systems, were purchased to mark/tag production releases. Marking/tagging was conducted each spring from 2007 through 2010 (Brood Year 2006 through 2009 fall-run Chinook) at Coleman National Fish Hatchery, Feather River Hatchery and Annex, Nimbus Hatchery, and Mokelumne River Hatchery. Approximately 32 million fall-run were processed each year through the automated trailers; approximately 8 million fish were marked/tagged. Preliminary analysis of coded-wire tag data from spawning returns in the fall of 2008 and 2009 indicate a highly variable proportion of hatchery-origin fish in the spawning escapement in Central Valley streams. Results also indicate a variable straying rate of hatchery fish to out-of-basin areas. This program will provide the Bay-Delta Program with specific information needed to evaluate ecosystem restoration actions and goals related to improving conditions for Central Valley Chinook salmon. Specifically, the project will provide the basis for (i) evaluating and revising Central Valley salmon hatchery operations to result in population augmentation without detrimental effects on wild populations; (ii) being able to track restoration of all races of Chinook salmon; (iii) tracking whether targets for population restoration of Chinook salmon are being reached.

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CONSERVATION GENETICS OF DELTA SMELT (*HYPOMESUS TRANSPACIFICUS*): POPULATION GENETICS, HYBRIDIZATION & CAPTIVE POPULATION GENETIC MANAGEMENT

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Delta smelt (*Hypomesus transpacificus*) are endemic to the San Francisco Bay-Delta (SFBD). Once abundant, numbers of delta smelt declined dramatically in the early 1980's, and the species has been listed as threatened since 1993. To assess wild delta smelt population genetics and to analyze the genetic signature of the decline, we conducted a population genetic study using sixteen microsatellite DNA markers to assess the geographic and temporal population structure of delta smelt, assessed hybridization between delta smelt and wakasagi and longfin smelt, and genetically monitored the captive delta smelt refugial population. We genetically analyzed samples collected by the California Department of Fish & Game from the 2003, 2005, 2007 & 2009 Spring Kodiak Trawl Survey, consisting of delta smelt collected from fourteen unique geographic locations and from three generations in captivity. For the hybridization study, we genetically analyzed fish using the 16 microsatellite markers and sequenced all three species and potential hybrid fish for nuclear and mitochondrial DNA loci. To test the null hypotheses, we analyzed the number of alleles per locus, observed heterozygosity, expected heterozygosity, allelic richness, Hardy-Weinberg equilibrium, linkage disequilibrium, F-statistics, and utilized the program STRUCTURE. The null hypotheses are as follows: 1. Populations of delta smelt in the SFBD do not vary geographically or temporally in genetic diversity and/or population structure, 2. Delta smelt hybridization with longfin smelt and/or wakasagi smelt is not prevalent throughout the SFBD, and 3. Genetic management of the captive delta smelt population maintains genetic diversity effectively. The relevance of this study to Bay-Delta management includes the potential need for dynamic management of delta smelt populations, including hybridization control, as well as increased support for the effectiveness of the genetic management plan of the captive delta smelt population, which aims to preserve the species in the event of extinction in the wild.

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FORECASTING FISH RESPONSE TO LEVEE REPAIR FEATURES OF THE SACRAMENTO RIVER BANK PROTECTION PROJECT

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The Sacramento River Bank Protection Project was authorized to protect more than 1700 kilometers of levees and flood control facilities. A key component of the levee repair work is the incorporation of environmental features that restore riparian and fish habitat function. Presently, the primary tool for planning the incorporation of these features is the Standard Assessment Methodology (SAM). SAM uses a combination of field data, riparian and geomorphologic models to assess proposed project impacts, but there still remains uncertainty regarding the function and value of the incorporated features for benefiting the target fish species. To improve the assessment ability of SAM and better understand the benefits of the constructed habitat features, we are collecting two-dimensional fish movement data using acoustic tags and developing models supporting the use of Eulerian Lagrangian Agent Method (ELAM). The ELAM extends the use of computational fluid dynamics models because virtual fish are released inside the model field where they can react to habitat alterations such as levee repairs. The fish movement tracking data can be used to calibrate and validate ELAM output, which can be used to model generalized results to produce site-specific habitat suitability curves that can be incorporated into the SAM and improve assessment and forecasting capabilities. The combination of the SAM with ELAM is a promising approach that could improve the planning and execution of ecological projects.

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BAY AREA BASE MAP OF AQUATIC RESOURCES

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The single-most important technical tool for coordination of environmental regulation, management, science, and education is a common base map. A common map helps define and visualize environmental problems and alternative solutions; organize multiple projects for mutual benefit and overall effectiveness; track projects and associated data; and understand a given project in the context of other aquatic resources and projects. This is especially important for land use and watershed planning and management. Water quality and flood control, water supply planning, sediment and stormwater management, species recovery and habitat conservation are difficult to coordinate unless represented spatially on a common base map. Few comprehensive, regional maps created with standardized methods are available to assist planning efforts. When maps exist, they frequently lack consistent mapping standards for habitat and feature classification, minimum mapping units, source data, and even scale. Both the California Wetland Monitoring Workgroup and the State Water Board's proposed Wetland and Riparian Area Protection Policy call for a standardized Base Map. SFEI and SCCWRP are piloting regional base map standards for the Bay Area and Southern California coast. The pilot maps include extensive classification of all mapped features needed to accurately represent all surface waters and their riparian areas. The Base Map's level of detail and accuracy were specified to ensure resolution and quality to meet the needs of the region's agencies and scientists. The Bay Area Base Map will be integrated into the State's Wetlands Portal, a publicly available repository for tracking changes in the extent and condition of aquatic habitat as affected by environmental projects, land use, and climate change. This will improve site-specific and watershed-specific data and information sharing. We will discuss mapping standards and the modeling methodology used to estimate riparian extent based on vegetation and hillslope processes. The Wetlands Portal will be demonstrated.

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MULTISCALE VALIDATION OF A SPATIALLY EXPLICIT DEMOGRAPHIC MODEL OF FREMONT COTTONWOOD ON THE SACRAMENTO RIVER

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Fremont cottonwood is a foundational species for riparian plant and animal communities of the Sacramento River. Predicting the long-term prospects for restoring and protecting this signature species requires an understanding of the physical and biological mechanisms that drive cottonwood recruitment and survival. Field data and conceptual models have contributed to this understanding, but do not allow long-term quantitative predictions. To address this limitation, we combined a process-based river meander migration model with a model of cottonwood population structure to generate predictions of cottonwood forest dynamics. To ensure that model predictions yielded robust results we (1) conducted a global sensitivity analysis, (2) improved the model based on these results, and (3) validated the model using a multi-scale approach. Our global sensitivity analysis found that uncertainty in the three physical parameter estimates: capillary fringe height, floodplain accretion rate and stage-discharge relationship and their interactions had the greatest influence on model predictions. While we were able to improve estimates of floodplain accretion rate and stage-discharge relationships by incorporating systematic longitudinal variation, we found that predictions of capillary fringe height have a large degree of associated error that is challenging to predict. This variability makes it difficult to accurately predict the specific location of cottonwood stands on a large spatial and temporal scale; however, the model can make large-scale predictions of the total area of cottonwood stands along the reach, and can make reasonable spatially-explicit predictions for areas of known sediment texture. Our coupled modeling approach allows us to predict broad-scale cottonwood patch dynamics to inform restoration efforts and to assess the effects of management decisions including climate change predictions, regulated flow adjustments, and floodplain manipulations.

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MODELING RIPARIAN FOREST ESTABLISHMENT ON THE SACRAMENTO RIVER

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Management of riparian forests along the rivers tributary to the Delta requires the ability to simulate the establishment and survival of riparian vegetation. To address this issue the Stockholm Environment Institute, U.C. Davis, and the U.S. Bureau of Reclamation have developed a suite of modeling tools to study the implications of Sacramento River management operations on riparian forest establishment and survival. The models use as input the flow time series generated by the CALSIM model. This nests the analyses made with these models within the broader context of water management planning in California. The models include representations of channel morphology, sediment transport, point bar development, and riparian forest establishment. At the point bar scale the Riparian Habitat Establishment Model (RHEM) was used to simulate plant growth as a function of atmospheric and soil moisture conditions using a modified version of the variably saturated flow model HYDRUS 2-D. Model algorithms were validated for cottonwood seedlings using controlled field experiments. The outputs from RHEM were then utilized in the SRH-1DV model to study riparian forest establishment on the reach of the Sacramento River between Red Bluff and Colusa. Results from this analysis show that forest establishment is sensitive to river management operations and is more likely on portions of the river with favorable bank geometry and sediment texture. Results from this study will provide river managers valuable information on strategies for increasing riparian forest establishment while minimizing impacts to other management objectives.

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SRH-1DV VEGETATION MODELING OF THE SACRAMENTO RIVER

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Alterations in management actions, including flow, can have minimal or broad impact on vegetation and habitat, yet vegetation response to changes in management actions are complex and difficult to predict with conceptual evaluations. Known but complex links between physical and environmental river factors are simulated with Reclamation's SRH-1DV model as part of the North of the Delta Offstream Storage (NODOS) Investigation. This one-dimension model integrates topography and flow, with computations of hydraulics, sediment transport, groundwater surface, and the establishment, growth and mortality of riparian vegetation. Six riparian vegetation types: Fremont cottonwood (*Populus Fremontii*), mixed forest, Gooding's black willow (*Salix gooddingii*), narrow leaf willow (*Salix exigua*), invasive riparian plants, and herbaceous plants are included in a simulation of the Sacramento River floodplain from Red Bluff to Colusa. Results from laboratory studies by the Stockholm Environment Institute on Fremont cottonwood growth and desiccation mortality are used to enhance the model through code and input values. After incorporating improvements, changes in GIS vegetation mapping between 1999 and 2007, are compared to modeled vegetation changes over the same period. Cottonwood growth was calibrated in a previous model to field measurements at three Sacramento River bar sites, and the calibrated values are validated in this study. Four additional vegetation types are calibrated (excluding herbaceous) to the difference between the two sets of GIS vegetation mapping.

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DEVELOPMENT OF A TRANSVERSE CIRCULATION IN A SHOAL-CHANNEL SYSTEM UNDER PARTIALLY STRATIFIED CONDITIONS

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In San Francisco Bay like in many other estuaries, abrupt lateral changes in topography result in sharp transverse gradients of momentum and scalars. These strong gradients both drive and respond to transverse mixing processes, including turbulent diffusive exchange, coherent transverse circulations and event-driven exchanges that may develop within the tidal cycle. Each of these three cases is characterized by a different timescale for the mixing of shoal-channel water masses, with implications for larger scale estuarine transport and dispersion. In particular, these processes have a strong influence on sediment fluxes and redistribution in a shoal-channel estuary like San Francisco Bay. In this talk, we examine shoal-channel exchange directly using transect data with 30 minutes resolution to follow the evolution of longitudinal and transverse velocity and density throughout the tidal cycle. During the winter period, our study site in South San Francisco Bay is characterized by moderate salinity variations, including periodic partial stratification. In this season, we find that a strong transverse density gradient develops during the ebb tide. Late in the ebb, barotropic tidal flows in the shallows are directed obliquely to the channel, where the relatively dense shoal waters meet less dense channel waters. This convergence leads to the downwelling of shoal waters down the slope, which stratifies the edge of the channel. This lateral exchange mechanism, which relies on lateral density gradients and barotropic tidal forcing, would be expected to develop in many shoal-channel estuaries. Finally, using longer timeseries from adjacent moorings, we examine the repeatability and longer-term implications of this mechanism for shoal-channel exchange.

Tuesday, September 28, 2010: Room 314 Tools and Approaches: Physical - Order: 1

IMPROVED AGRICULTURAL WATER USE MODELING IN CALIFORNIA USING REMOTE SENSING

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We present hydro-economic modeling of California agriculture employing a self-calibrated optimization model and remote sensing information. The Statewide Agricultural Production Model (SWAP, <http://swap.ucdavis.edu>) in California's Central Valley calibrates agricultural production to observed values of input use. Remote for fallowing, evapotranspiration, and biomass among other variables from SEBAL (<http://www.sebal.us/>) seasonal satellite imagery post-processing is employed to validate water balance and land use information. Preliminary results contrast SWAP predicted land fallowing and SEBAL actual land fallowing resulting from reductions in contract water deliveries in recent years. The prospects for using such remote sensing data for water management and policy information are also discussed.

Tuesday, September 28, 2010: Room 314 Tools and Approaches: Physical - Order: 2

LEVEE STABILITY PARAMETERIZATION FROM AIRBORNE LIDAR AND HYPERSPECTRAL SENSORS IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

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The Sacramento-San Joaquin Delta has approximately 1,100 miles of levees, which supports agriculture, maintains water exports and protects urban areas and infrastructures. The integrity of these levees is of major importance to land managers and policy makers given the consequence of levee failure. External evidence of levee instability such as slumping at the toe or sliding areas at the top, e.g. due to subsidence, can be used to detect levees prone to failure through a characterisation of the superficial levee configuration. A methodology to quantify levee stability and its relation with vegetation occurrence and distribution for a 16 km reach of the Sacramento River is investigated using high resolution airborne LiDAR combined with hyperspectral imagery. Levee profiles were extracted from a Digital Terrain Model (DTM) generated from the high resolution (1m rasterization) LiDAR data. Geometric structural parameters were calculated including levee crown width, height, width and slope. Deviation of these parameters from the levee design standards, therefore, can be used as a levee stability index. To study the influence of vegetation structure on levee stability, a Digital Surface Model (DSM) from the LiDAR data was generated. We extracted the same surface profiles and calculated vegetation height and density. Vegetation species were identified using a species map obtained from hyperspectral imagery and used to investigate the impact of certain species upon the structural condition of the levees. The combination of LiDAR and Hyperspectral data provides not only an effective method to assess the external state of the levees using airborne remote sensing information and detect prone to failure areas, but an improved insight into the impact of vegetation upon the structural condition of a levee system.

Tuesday, September 28, 2010: Room 314 Tools and Approaches: Physical - Order: 3

USING TIME SERIES DATA FOR SCALAR FIELD INTERPOLATIONS

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Working with Jon Burau, USGS and John DeGeorge of RMA, 34 North will demonstrate Baydeltalive.com, a set of web based tools to visualize, process and analyze REAL TIME sensor data and using these tools to create data models for dynamic management and analysis. The demonstration will review each tool including: BDL GET DATA (an automated sensor data aggregator for CDEC/NWIS), GR (Graphing Application), BDL MODEL BUILDER (a data interpolation engine) and NASA Worldwind (3-D viewer for results presentation). Learn to interpolate the field and analyze temporal and spatial variability as well as create projects from your results and collaborate with colleagues. BDL is a free tool for science collaboration in the California Delta.

Tuesday, September 28, 2010: Room 314 Tools and Approaches: Physical - Order: 4

HOW WELL DO YOU KNOW YOUR LIGHT ATTENUATION COEFFICIENT? A CAUTIONARY TALE OF TWO PAR SENSORS

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The depth of light penetration has large ramifications for aquatic ecosystems as it determines the amount of photosynthetically active radiation (PAR) available to phytoplankton and benthic primary producers. In the San Francisco Bay-Delta (SFBD), the vertical attenuation coefficient for downwelling PAR, KPAR, is regularly used for numerous purposes, such as computation of primary production and as an index of habitat quality. Two types of PAR sensor, cosine and scalar, are commonly used in coastal ecosystems but were designed to measure different radiometric quantities. We caution scientists that it is relevant which sensor is used to calculate KPAR in SFBD. We collected 681 side by side depth profiles of PAR from cosine and scalar sensors during 20 months of regular monitoring cruises throughout SFBD. KPAR was calculated as the slope of the least-squares regression of the natural log of PAR against depth. On average, KPAR from the scalar sensor was 8.2% lower than the cosine sensor and as much as 40% lower in some cases. Undetected, scalar KPAR would have introduced an erroneous trend of reduced system turbidity in our 40 year dataset that historically used cosine KPAR. We calculated daily phytoplankton gross primary production (GPP) for both sensor's KPAR using a biomass-depth-light model built for cosine KPAR. The GPP overestimate from using scalar KPAR was 10% on average and as high as 75% on multiple days. Hydrolight model runs explain the observed sensor differences, and further demonstrate that for this estuary, there is no one simple correction to convert one sensor KPAR to the other that will be spatially and temporally applicable. Consistency of methodology for measuring KPAR is especially significant when considering long term trends and modeling of the Bay-Delta system.

Tuesday, September 28, 2010: Room 314 Tools and Approaches: Physical - Order: 5

COMPARISON OF MODELS FOR PREDICTING FLOW AND WATER QUALITY IN THE SACRAMENTO-SAN JOAQUIN DELTA

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The social and economic importance of the Sacramento-San Joaquin Delta has led to the development and application of several numerical models to predict hydrodynamic and water quality conditions. Yet future challenges to the Delta will require even more demanding applications of these models to simulate climate change, water management, habitat, island failures, and land development conditions. This work presents a rigorous and independent framework for the analysis of several Delta-specific models developed by Resource Management Associates (RMA) and the Department of Water Resources (DWR). This presentation starts with a thorough analysis of the models from the theoretical and numerical points of view. Subsequently, it includes a scenario-driven comparison of each model to historical data and investigates model accuracy and sensitivity to varying levels of export pumping and DICU values, each within extreme dry and wet water years.

Tuesday, September 28, 2010: Room 314 Multi-dimensional Modeling of the Bay-Delta -
Order: 1

PARTICLE TRACKING BASED ESTIMATES OF RECRUITMENT OF ORGANISMS FROM THE COASTAL OCEAN INTO THE LOW-SALINITY ZONE OF THE SAN FRANCISCO ESTUARY

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Abundance or survival of several estuarine species in the San Francisco Estuary is positively related to the position of 2 psu salinity at the bed, known as X2 (Jassby et al. 1995). One of several proposed mechanisms for the observed fish-X2 relationships (Kimmerer 2002), is based on transport processes. In particular, for species that are found near the bed and recruit from the ocean (i.e., starry flounder and bay shrimp), increased gravitational circulation with seaward X2 may result in more rapid landward transport and retention of organisms in their low-salinity rearing habitat. If mortality is lower in the low-salinity zone than during transport, an increased probability of movement up the estuary and faster transport into the low-salinity zone would result in higher survival and subsequent abundance. To investigate this hypothesis, we used the three-dimensional TRIM3D hydrodynamic model and FISH-PTM particle tracking model to estimate recruitment of negatively buoyant particles from the coastal ocean into the low-salinity zone of the San Francisco Estuary. The estimated number of negatively buoyant particles that reached the low-salinity zone increased with increased Delta outflow (decreased X2). In addition, negatively buoyant particles arrived in the low-salinity zone sooner as Delta outflow increased, because of faster transport and reduced distance to travel. These findings support the proposed fish-X2 mechanism.

Tuesday, September 28, 2010: Room 314 Multi-dimensional Modeling of the Bay-Delta -
Order: 2

THE NEED FOR SPEED: 3-D HYDRODYNAMIC AND SALINITY SIMULATIONS USING THE UNTRIM BAY-DELTA MODEL

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The UnTRIM Bay-Delta model is a three-dimensional hydrodynamic and salinity model of San Francisco Bay and the Sacramento-San Joaquin Delta, which extends from the Pacific Ocean through the entire Sacramento-San Joaquin Delta. The UnTRIM Bay-Delta model has been used in studies of San Francisco Bay and the Sacramento-San Joaquin Delta for California DWR, USBR, USGS, and the US Army Corps of Engineers. The model calibration and validation conducted as part of these studies demonstrate that the UnTRIM Bay-Delta model is accurately predicting flow, stage, and salinity in San Francisco Bay and the Sacramento-San Joaquin Delta under a wide range of hydrologic conditions. Recent advances in processor, compiler, numerical, and grid generation technologies have resulted in significant speed-up of 3-D model simulations. The most recent version of the UnTRIM Bay-Delta model simulates 3-D hydrodynamics and salinity from the coastal ocean through all of San Francisco Bay and the Sacramento-San Joaquin Delta at more than 30 times real time on a single desktop workstation computer, allowing for feasible year-long simulations. However, future conditions simulations for the Delta which incorporate sea level rise, flooded islands, and marsh restoration may require even faster 3-D modeling tools. By specifying high resolution bathymetry on a coarser computational grid using a sub-grid approach developed by Vincenzo Casulli (Casulli, 2009), the tools now exist to develop even faster 3-D Delta models using UnTRIM. This presentation will focus on the salinity calibration results of the high resolution UnTRIM Bay-Delta model and present several applications which demonstrate the potential for even faster 3-D UnTRIM Bay-Delta model applications by applying the UnTRIM sub-grid approach to the San Francisco Bay-Delta. Preliminary results show that simulation of 3-D Bay-Delta hydrodynamics at speeds faster than 365 times real time or more on a single desktop workstation computer are feasible, and can provide accurate results.

Tuesday, September 28, 2010: Room 314 Multi-dimensional Modeling of the Bay-Delta - Order: 3

LOCAL AND DELTA-WIDE HYDRODYNAMIC IMPACTS OF LARGE SCALE TIDAL MARSH RESTORATION

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The RMA Bay-Delta model is being used to evaluate changes in tidal flows and transport associated with large scale tidal marsh restoration proposed in the Bay Delta Conservation Plan (BDCP). Restoration areas are represented as two-dimensional depth-averaged flow regions and include Suisun Marsh, Cache Slough, West Delta, East Delta and South Delta regions. Restoration is considered at three time horizons with the largest restored acreage of approximately 65,000 acres occurring 40-50 years in the future. Opening large areas to tidal inundation can have a dramatic impact on flows and stage range in channels near the restoration site as well impacting stage range and net flow balances across the Delta. Adding large new restorations sites can mute the stage range significantly, reducing inter-tidal area in existing tidal marsh and in planned restoration sites when conveyance is restricted. The geometry of the channels and restored area may be expected to change over time through scour or deposition. Increasing the area open to filling and draining with the tides may lead to changes in channel geometry through scour as the channel adapts to the new demand for tidal flow. Subsidence and sea level rise will generally lead to a much larger area open to filling and draining than there was when the levees were originally constructed. This talk will present the approach to tidal marsh modeling, an overview of flow, stage and transport impacts, and investigation of changes to geometry over time.

Tuesday, September 28, 2010: Room 314 Multi-dimensional Modeling of the Bay-Delta -
Order: 4

FLOODED ISLAND ECOSYSTEMS: PHYSICAL DRIVERS OF BIOLOGICAL PRODUCTIVITY FOLLOWING LEVEE BREACHES ON SACRAMENTO-SAN JOAQUIN DELTA ISLANDS

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The Sacramento-San Joaquin Delta is the heart of California's water supply system and the base of an important, but quickly declining ecosystem that includes five native fish species listed as threatened or endangered. A number of factors including sea level rise, seismic activity, continued land subsidence and more extreme climate events will increase the frequency and costs of Delta island failures. Some islands will be deemed too costly to repair and will remain flooded. Flooded Delta islands will vary with their direct and immediate impact on the water quality and ecology of the Delta system. However, with sufficient study, it is possible to manage a flooded island in a way that is more beneficial to the ecosystem. In this study, we use a three-dimensional hydrodynamic and water quality model, SI3DWQ (Doyle 2010), to simulate virtual Delta islands and the surrounding channels. When flooded islands present restoration opportunities, appropriate design and management of the island will be critical to its success as a functional ecosystem component. The objective of this study is to examine the effect of geometric characteristics of flooded islands in the Delta system on productive capacity of the island and to establish the background for scientifically based restoration projects in the Delta. In order to improve the Delta ecosystem, it is desirable to have a flooded island that sustains both a concentration of chlorophyll-a greater than 10 gL^{-1} (Muller-Solger 2002) as well as a flux of chlorophyll from the island to the channel. After simulating over 500 model scenarios that investigated variations in breach location, number of breaches, island depth, island size and orientation, it was concluded that it is possible to manage potentially flooded islands in a way to maximize the concentration and flux. However, without careful monitoring and management of future flooded islands, there could be further degradation of the ecosystem.

Tuesday, September 28, 2010: Room 314 Multi-dimensional Modeling of the Bay-Delta -
Order: 5

OCCURRENCE, FATE AND TRANSPORT OF EMERGING CONTAMINANTS IN THE SACRAMENTO-SAN JOAQUIN DELTA

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The Sacramento-San Joaquin Delta is a major drinking water source for California. Agricultural activities are prevalent in the Delta. In addition, there are nine wastewater treatment plants (WWTPs) that discharge into the Delta. The Delta's fragile ecosystem raises concern about water quality issues, including the occurrence of chemicals of emerging concern (CECs), such as pharmaceuticals and personal care products, from municipal and industrial wastewater discharges and agricultural activities. Recent studies have reported the occurrence worldwide of CECs in WWTP effluents and receiving surface waters, in some cases at levels sufficient to affect aquatic organisms. The objective of this study was to evaluate the occurrence, fate and transport of CECs in the Delta. Samples were collected at the following locations: (1) treated effluent from one WWTP; (2) upstream and downstream locations of several WWTPs; (3) an urban run-off site; and (4) an agricultural drainage site. A suite of more than forty CECs were analyzed. Extensive quality assurance and quality control procedures were applied to ensure that the data obtained were accurate and precise. The most frequently detected analytes were carbamazepine (anti-convulsant), diuron (herbicide), sulfamethoxazole (antibiotic), caffeine (stimulant), primidone (anti-convulsant), and tris(2-chloroethyl)phosphate (TCEP, flame retardant), which were present at ng/L levels. In addition, the fate and transport of these CECs were evaluated. The results can be used by the waste and drinking water industries, watershed and regulatory agencies, and fish and game department for risk assessment, future water resource planning, pollution prevention programs, and public communication.

Wednesday, September 29, 2010: Room 306 Emerging Contaminants - Order: 1

POTENTIAL CONTRIBUTIONS OF CONTAMINANTS TO THE DECLINE OF PELAGIC FISHES IN THE SAN FRANCISCO ESTUARY, CALIFORNIA, U.S.A.

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The San Francisco Estuary has been altered by major hydrologic projects, mining and other land uses, invasive species, and algal blooms. Additional stressors include episodic drought, mixtures of pesticides (>20 million kg pesticide products purchased annually), heavy metals, nutrients, and pharmaceuticals. Around 2000, there were step declines in abundances of multiple pelagic fishes despite some years of high precipitation that were expected to increase recruitment and abundances. Native species of concern include delta smelt (*Hypomesus transpacificus*; listed as endangered under the U.S. federal and California endangered species acts) and longfin smelt (*Spirinchus thaleichthys*; listed as threatened under the California act). Abundances of introduced threadfin shad (*Dorosoma petenense*), a major prey species, and introduced striped bass (*Morone saxatilis*), a popular sport fish, also are declining. We review the spatial overlap between sensitive life stages and the mechanisms by which contaminants in conjunction often exacerbated by non-contaminant stressors may contribute to declines.

Wednesday, September 29, 2010: Room 306 Emerging Contaminants - Order: 2

INDICATORS OF ENVIRONMENTAL STRESSORS, ENDOCRINE DISRUPTION, AND PHYSIOLOGICAL IMPACTS IN WILD FISH OF THE SAN FRANCISCO BAY REGION

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Prior research in the San Francisco Bay region has demonstrated that resident fish are exposed to a variety of contaminant chemicals, from pesticides to polychlorinated biphenyls (PCBs). In several lines of research, we are beginning to elucidate phenotypic effects in fish related to such exposures and which are indicative of maladaptive consequences to physiology and health. As one example, shiner surfperch sampled from contaminated San Francisco Bay locations exhibit a form of endocrine disruption involving the stress and metabolic hormone, cortisol, which is associated with impairments in physiological performance indices relating to growth and defense. The primary disruption effect, an inability of the fish to activate a normal neuroendocrine response to stress, is significantly correlated with exposures of the fish to certain congeners of polycyclic aromatic hydrocarbons (PAHs) and PCBs. In addition to endocrine disruption, important hepatic proteins exhibit altered expression in association with contaminant exposures. Using proteomics technologies, hepatic biomarkers indicative of detoxification processes (e.g., GST, Cyp1A), catabolic physiology (e.g., gluconeogenic and glycolytic enzymes), and cellular responses (e.g., chaperones) have all been identified in impacted fish. Furthermore, protein expression within the endocrine tissue that synthesizes cortisol (interrenal) is being characterized in studies aimed at elucidating the underlying mechanism(s) of the endocrine-disrupted condition. Altogether, these studies contribute to a multi-factorial analysis in environmentally impacted fish, which is building an increasingly integrative perspective on the health status and physiological performance in the subject animals. Development of broader-based “systems” approaches to determining cause and effect are poised to provide more comprehensive and powerful assessments of environmental quality. (Support in part by Pacific Coast Environmental Conservancy, NOAA-USC Sea Grant Program, and SFEI-RMP for Water Quality in SF Bay).

Wednesday, September 29, 2010: Room 306 Emerging Contaminants - Order: 3

FROM OTOLITHS TO OOCYTES: A THREE-TIERED INVESTIGATION INTO ESTROGENIC AND ANDROGENIC EFFECTS IN A CALIFORNIA ESTUARY

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Endocrine disrupting compounds (EDCs) are widespread in the environment and known to impact fish reproduction. A large body of work exists on EDC effects in laboratory species; however, fewer studies have considered resident fish, particularly those found in estuaries. We use *Menidia audens*, a ubiquitous euryhaline atherinid, as an indicator of EDCs in Suisun Marsh, in which a wide range of contaminants, including emerging EDCs (i.e. pyrethroids), are present. Our three-tiered investigation encompasses the receptor, individual and population levels. First, solid-phase extracts from areas exposed to treated wastewater, urban or ranch run-off produce significant evidence of binding to the nuclear estrogen and androgen receptor in receptor-transfected cell lines. Secondly, immunoanalyses reveal that wild males express choriogenin (egg shell protein); outplanting and bioassays indicate choriogenin levels in marsh-exposed and pyrethroid-exposed fish are greater than controls and endocrine-related gene expression differs between field sites and controls. Lastly, sites exposed to different EDCs exhibited significantly different sex ratios and sex-specific size differences throughout 2009. These results suggest that individual-level effects may scale up to population-level consequences.

Wednesday, September 29, 2010: Room 306 Emerging Contaminants - Order: 4

THE EFFECT OF TRICLOSAN ON WHOLE ANIMAL RESPONSES AND GENE TRANSCRIPTION IN LARVAL FATHEAD MINNOW (PIMEPHALES PROMELAS)

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Triclosan is an antibacterial agent that has become more and more prevalent in household products since the 1960s. It is not completely removed during waste water treatment leading to contamination of aquatic ecosystems. Triclosan has been shown to occur in waterways around the world, including the San Francisco Bay and Sacramento River, yet its impact on aquatic organisms is not fully understood. We assessed the effects of triclosan on survival, swimming behavior, and neuromuscular and endocrine related gene expression in larval fathead minnow (*Pimephales promelas*). The nominal 7d chronic median lethal concentration (LC50) was 193 μgL^{-1} . Triclosan had a significant impact on swimming behavior after just 2h that was consistent after 8h, 24h, and 96 h exposures. Quantitative PCR assessments indicate that triclosan exposure elicits downregulation of the ryanodine receptor (RyR) isoform⁻¹, RyR isoform⁻³, and Selenoprotein N, which are involved in Ca^{2+} signaling in either skeletal muscle or the brain. Triclosan also elicited unique endocrine responses in exposed fish. Most notably, fish from lower concentrations had an under expression of Insulin Like Growth Factor (IGF1) while those exposed to 100 $\mu\text{g/L}$ had significantly up regulated IGF1. Another gene that showed a similar expression pattern was the VASA homologue, which has a large role in germ cell localization in early embryonic stages and spermatogenesis and oogenesis in adult fish. Results from these tests will aid in the development of molecular based biomarkers for triclosan toxicity and will help link molecular effects to whole animal responses. Biomarkers will be used to assess triclosan exposure in fish exposed to Sacramento River water upstream and downstream from a wastewater treatment plant (WWTP) to help determine possible risks in the Sacramento-San Joaquin Delta.

Wednesday, September 29, 2010: Room 306 Emerging Contaminants - Order: 5

OCCURRENCE OF PYRETHROID INSECTICIDES IN WATER, SEDIMENT AND BIOTA

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Pyrethroid insecticides are of increasing environmental concern because of their widespread use and high aquatic toxicity. Pyrethroids are frequently detected in California in both agricultural and urban areas and more recently pyrethroids have become a concern in other parts of the United States. Pyrethroid insecticides are highly hydrophobic compounds ($\log K_{oc} > 5$), tend to bind tightly to sediments and have been detected in aquatic organisms. To better understand the environmental occurrence of pyrethroids, sensitive methods have been developed for the analysis of 14 pyrethroids in water, sediment (bed and suspended) and biota (fish, crab embryos and sand crabs). Data from agricultural and urban areas are summarized including nationwide studies conducted by the USGS in 2007 and 2009. Agricultural areas tend to have a greater variety of pyrethroids detected while urban areas tend to have higher concentrations. Preliminary results from much smaller studies on aquatic uptake of pyrethroids indicate that several of the more ubiquitous pyrethroids (bifenthrin, cyfluthrin, cypermethrin and permethrin) were detected in fish, sand crabs and crab embryos from agricultural and urban areas in Northern and Central California. A greater understanding of pyrethroid occurrence and fate can help in determining potential environmental effects.

Wednesday, September 29, 2010: Room 306 Pesticides - Order: 1

ANATOMY OF A RAIN EVENT: URBAN RUNOFF AND TOXICITY IN THE AMERICAN RIVER THROUGHOUT A WINTER STORM

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Work during the winter of 2008/2009 using *Hyaella azteca* toxicity testing documented toxicity in the American River that had not previously been seen in past years of monitoring with *Ceriodaphnia dubia* and fathead minnow. The pyrethroid bifenthrin was linked to the toxicity through chemical analysis and Toxicity Identification Evaluation methods. River flow was particularly low that year, so further studies were conducted in the winter of 2009/2010 to determine if toxicity was again observed and to identify the major sources. This presentation will document the inputs of pyrethroids from a variety of sources during a single storm event in January 2010, and the resulting effect on water quality and toxicity in the main river. Discharge from 11 creeks, drains, and pump stations were sampled, with acutely toxic concentrations of pyrethroids found in 10 of them. The highest concentration was Carmichael Creek, with 32 times the bifenthrin EC50 (concentration that causes paralysis in half the *H. azteca* individuals in a test). On a loading basis, Chicken and Strong Ranch Sloughs were the largest contributors. The combined discharge of urban runoff from all sources during the rain event was approximately 1200 cfs, compared to the base flow in the river of 1460 cfs; in other words, the American River was about half urban runoff at the point it reached the Sacramento River. The portion of the river flowing through Sacramento attained bifenthrin concentrations approximately equal to the EC50 for *H. azteca*. The river remained toxic to *H. azteca* for at least the five-day monitoring period, affirming the ecological relevance of the standard four-day exposure period used in laboratory toxicity tests.

Wednesday, September 29, 2010: Room 306 Pesticides - Order: 2

RECENT ADVANCES IN THE ANALYSIS OF PYRETHROID INSECTICIDES IN SURFACE WATER AND SEDIMENTS

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Recent advances in analytical instrumentation have allowed the development of new analysis methods for pyrethroid insecticides in surface water and sediments. The analytes include seven pyrethroid insecticides used in agriculture and structural pest control in California including bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, fenvalerate, lambda-cyhalothrin, and permethrin. Fortified water samples were extracted by liquid-liquid extraction, sediment samples were extracted using pressurized fluid extraction. Sample extracts were analyzed using negative chemical ionization tandem mass spectrometry (NCI-MSMS) using ammonia ionization gas. Method detection limits have been established for water and sediment that are below the toxicity of the analytes.

Wednesday, September 29, 2010: Room 306 Pesticides - Order: 3

**EVALUATION OF ACUTE TOXICITY OF CHLORPYRIFOS,
PERMETHRIN AND BIFENTHRIN ON THE COPEPODS EURYTEMORA
AFFINIS AND PSEUDODIAPTOMUS FORBESI OF THE SAN
FRANCISCO ESTUARY**

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The calanoid copepods, *Eurytemora affinis* and *Pseudodiaptomus forbesi*, are a critical link between primary producers and fish in the San Francisco Estuary (SFE). Since these mesozooplankton play an important role as food sources to larval fish and pelagic organisms, factors affecting their decrease in recent years warrants investigation. One potential source of decline is exposure to insecticides from agricultural and urban run-off into the SFE. The goal of this study was to determine and contrast the acute effects of three insecticides, an organophosphate, Chlorpyrifos, and two pyrethroids, Permethrin and Bifenthrin, to *E. affinis* and *P. forbesi*. The 96-hour medial lethal concentration (LC-50) of Chlorpyrifos on *E. affinis* (803.2ng/L) is more sensitive than *P. forbesi* (1211.9ng/L). However, *P. forbesi* is almost two-times more sensitive than *E. affinis* Permethrin (LC-50 86.0 and 158.1 ng/L, respectively). For Bifenthrin, *E. affinis* show an LC-50 value of 13.3 ng/L, while values for *P. forbesi* are currently under investigation. *E. affinis* show up to a 100-fold increase in sensitivity to pyrethroid insecticides compared to organophosphate insecticides. Additionally, our data indicate that there are species specific differences in response to insecticides. Shifts in types and timing of insecticide use may cause a decline in copepod abundance, and ultimately have a negative impact on the SFE food web. In addition to determining the chronic effects of insecticides to primary consumers, future research should include the influence of abiotic factors, such as temperature, pH and salinity, on the long term effects of the interaction between calanoid copepods and insecticides at the population and community levels.

Wednesday, September 29, 2010: Room 306 Pesticides - Order: 4

TRENDS IN PESTICIDE CONCENTRATIONS IN FIVE STREAMS OF THE CALIFORNIA CENTRAL VALLEY, 1993-2005

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The Sacramento and San Joaquin Rivers deliver over 1,000 kilograms of pesticides to the Sacramento-San Joaquin River Delta each year. Over the last two decades, millions of dollars have been spent to reduce pesticide transport from agricultural and urban sources. A quantitative understanding of the efficacy of these efforts is lacking, owing to intermittent monitoring and hydrologic variability that make it difficult to assess the changes in pesticide concentrations. To assess pesticide reduction efforts, we have evaluated trends in pesticide concentrations for five streams in California's Central Valley using a parametric regression model that accounts for flow variability and seasonal use. Trends were determined for the organophosphate insecticides chlorpyrifos and diazinon and the herbicides atrazine, EPTC, metolachlor, simazine, and trifluralin. Trends were computed for the period 1993 to 2005. The modeled streams include two large rivers: San Joaquin River near Vernalis and Sacramento River near Freeport, one mid-sized river: Merced River near Newman, and two small creeks: Orestimba Creek near Crows Landing and Arcade Creek near Sacramento. Decreasing trends most often were observed for diazinon, and reflect a variety of regulatory pressures on the chemical during the study period. Consistent trends were observed for several herbicides, including upward trends in simazine at urban-influenced sites, and downward trends in atrazine and EPTC at agricultural sites. The model we used to calculate trends also enabled us to reconstruct daily concentrations for each pesticide during each year of the modeling period. These data can be used to estimate the frequency with which a stream exceeds ambient water quality criteria or regulatory endpoints. Several examples will be presented.

Wednesday, September 29, 2010: Room 306 Pesticides - Order: 5

ASSESSMENT OF EXCESS N₂ AND GROUNDWATER N₂O IN THE SAN JOAQUIN RIVER

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A joint USGS-UCD study monitoring groundwater in the riparian zone of a 59 mile reach of the San Joaquin River between the confluence of Salt Slough and Vernalis documented unexpected nitrogen dynamics. Groundwater samples were taken from 0.3 m and 2 m depths in 30 locations along the river with three cross sections at the 20, 50 and 80% width at each location.

Approximately 90% of the groundwater had nitrate concentrations less than detection (<0.10 mg N/L), with a few hot spots reaching 14.4 mg N/L. In contrast, median ammonium concentrations were 0.42 mg N/L with maximum concentrations reaching 29 mg N/L. Anoxic conditions suggested denitrification was the main factor contributing to low nitrate concentrations in the groundwater. N₂:Ar ratios were measured by membrane inlet mass spectrometry and were used to estimate excess dissolved N₂ concentrations. Excess N₂ relative to Ar can be attributed to the denitrification process. Of the 158 groundwater samples measured, 74% of the samples contained excess N₂ with concentrations up to 8.65 N₂ mg/L. Excess N₂ concentrations displayed a general increase in the downstream direction. Deeper groundwater sites had significantly higher N₂ concentrations coinciding with decreased O₂ and cooler temperatures. The presence of excess N₂ documents the importance of denitrification in removing nitrate from the groundwater. Preliminary studies suggest that the high ammonium concentrations results from anaerobic mineralization of the river bed sediments. Further analysis will focus on evaluating the fate of nitrogen in at three specific sites and measuring coupled N₂O and N₂ rates from riparian soils, surface water, shallow groundwater and benthic sediments.

Wednesday, September 29, 2010: Room 306 Nutrients - Order: 1

SIMULATING SALT AND NITRATE WATER QUALITY IN CALIFORNIA'S CENTRAL VALLEY

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Salt and nitrate management to protect surface water and groundwater quality is a key issue facing both state regulators and water users in the Central Valley. CV-SALTS, a stakeholder initiative, is addressing this issue by facilitating the development of such plans throughout the Central Valley. The Central Valley Salinity Coalition, the funding body of CV-SALTS, sponsored the Salt and Nitrate Source Pilot Implementation Study to develop an accounting methodology and apply it to three pilot study areas, including the Yolo County, Modesto, and Tule River areas. Each area was divided into surface water, land catchments with many land cover classes, near-surface groundwater, and deeper groundwater. Using a multi-disciplinary approach, salt and nitrate were tracked as they were transported and transformed into, within, and out of all catchments in the respective areas. Important processes in the mass-balances included fertilizer and other land application, groundwater pumping for irrigation and municipal use, diversion, irrigation, chemical reactions, surface water inflows, point sources, and flow from near-surface groundwater to surface water and to deeper groundwater (recharge). The Watershed Analysis Risk Management Framework (WARMF) model was used to track salt and nitrate through surface water and near-surface groundwater. Recharge and pumpage results for three groundwater models (e.g., Central Valley Hydrologic Model (CVHM) for the Yolo area and locally applied MODFLOW models for the Modesto and Tule River areas) were provided as inputs to the WARMF model. Detailed land cover processing, particularly for agricultural lands and dairy facilities, was used to define model inputs related to land cover classes. The products of the analyses were closed mass balances that fully accounted for salt and nitrate sources and sinks resulting from different land cover classes, water sources, and hydrologic conditions. The successfully applied methodology provides a template for future mass balance analyses elsewhere in the Central Valley.

Wednesday, September 29, 2010: Room 306 Nutrients - Order: 2

USING A STABLE ISOTOPE MASS BALANCE APPROACH TO IDENTIFY NITRATE SOURCES AND SINKS IN THE SAN JOAQUIN RIVER

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Between 2005 and 2007 a large-scale sampling program was conducted in the San Joaquin River (SJR) and tributaries to identify sources and sinks of organic matter and nutrients which contribute to low dissolved oxygen levels in the Stockton Deep Water Ship Channel. The SJR has numerous water inputs and diversions along its length in addition to potential ground water inputs, and while the sampling plan included all of the major tributaries, it was not feasible to sample all of the minor water inputs. In order to provide constraints on nitrate cycling processes such as algal uptake and denitrification, and to identify the presence of significant unmeasured sources or sinks, we performed mass-weighted stable isotope mixing calculations for individual sections of the SJR. Water isotopic composition ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) was used as a conservative tracer, and predicted water isotope values closely matched the measured values throughout most of the study, indicating that all significant water inputs were usually identified by the sampling approach. Nitrate concentrations and isotope mass balances were then calculated for each river section and transect sampling date in order to identify times and locations where nitrate concentrations and/or isotopic compositions did not follow the predicted conservative mixing model, indicating the presence of unidentified nitrate source or sinks. Nitrate isotope values showed more discrepancies than the water isotope values, and the discrepancies between measured and predicted $\delta^{15}\text{N}$ and $\delta^{18}\text{O}\text{-NO}_3$ values did not follow the same trends. This suggests that a single in-stream process such as algal uptake or denitrification was not the primary control on downstream nitrate composition. The decoupled discrepancies found for $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ suggest that unsampled and/or poorly characterized water inputs such as runoff and small drains & tributaries influenced the concentration and isotopic composition of the nitrate in the mainstem SJR, particularly during high flow periods.

Wednesday, September 29, 2010: Room 306 Nutrients - Order: 3

CAUSES OF TEMPORAL AND SPATIAL VARIATIONS IN NITRIFICATION RATES IN THE SACRAMENTO RIVER AND DELTA

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High concentrations of NH_4 have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline in the San Francisco Estuary (Dugdale et al. 2007). Nitrification of effluent largely derived from the Sacramento wastewater treatment plant (SRWTP) appears to be the dominant process responsible for lowering NH_4 concentrations. Therefore, a better understanding of the biogeochemical and hydrological controls on nitrification rates should facilitate development of improved remediation strategies. We used data from over half of the 30 transects of the Sacramento River conducted July 2008 to April 2010 for our nitrification analysis. Isotope fractionation factors have been compared to nitrification rates for 3 transects. Preliminary analyses using multiple linear regressions to predict downstream NH_4 concentrations at Rio Vista suggest that the main controlling factors are river flow, the volumetric fraction of flow from SRWTP, water temperature, and upstream NO_3 concentration. We calculated rates for both conversion of NH_4 to NO_2 and NO_2 to NO_3 using two approaches, both using travel times calculated with DSM2. One method used a recursive approach to find a decay rate that minimized the percent difference in calculated versus measured concentrations for NH_4 and NO_3 . The average decay rates for NH_4 to NO_2 and for NO_2 to NO_3 were consistent with literature values, and the rates generally decreased downstream of Rio Vista. The second method used the measured changes in nutrients and interpolated travel times between adjacent sites to calculate rates, resulting in a much wider spatial and temporal range of rates. Differences in measured and calculated rates and between the rates of the two different nitrification steps are interpreted in terms of additional sources and sinks of nutrients, using isotope data as constraints. The much greater losses in NH_4 compared to gains in NO_3 and NO_2 between adjacent sites suggests significant additional sinks of nutrients.

Wednesday, September 29, 2010: Room 306 Nutrients - Order: 4

LINKING NUTRIENTS TO SEVERE DELTA EUTROPHICATION, 2009/2010 FINDINGS

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The Problem – The problem we have been examining is the collapse of the Delta food chain, especially in the shallow water zones so critical to supporting plant, insect, and juvenile fish communities.

Approach – We have been monitoring water quality and relative benthic invertebrate abundance in the western Delta regions centering on Big Break and nearby aquatic environs. What makes our monitoring programs unusual is on-site sampling and analyses lasting twelve or more hours per day, which is necessary to observe diurnal changes in the water.

Findings – Our data show a striking relationship between diurnal cycles in dissolved oxygen and pH to concentrations of nitrates, along with the appearance of specific types of aquatic weeds. These data are being evaluated looking at the benthic zones as an unsteady state bioreactor. Inputs to the bioreactor model are nutrient concentrations, relative sunlight intensity and duration, and presence and density of aquatic vegetation. A key finding is the observation of intense cycling of dissolved oxygen and pH in zones. In these zones, normally abundant phytoplankton cling to plant stems and leaves, effectively lowering the turbidity of the water. This then, allows sunlight to penetrate nearly to the bottom, as much as two meters deep, resulting in phenomenal rates of photosynthesis and companion reactions.

Relevance – Our preliminary findings, which are still ongoing, suggest additional measures for Bay-Delta management other than flows within and out of the Delta. Programs that minimize or eliminate nitrate and ammonia discharges to Delta tributaries almost certainly will help. At its simplest could be broad scale education of the public on the benefits of not wasting water and fertilizer to runoff, both at homes and on fields and orchards. Improvement in nutrient removal from treated municipal effluent also needs to be part of the equation.

Wednesday, September 29, 2010: Room 306 Nutrients - Order: 5

REVIEW OF THE POTENTIAL BENEFITS OF CONTROLLING PHOSPHORUS DISCHARGES IN MUD AND SALT SLOUGHS ON SJR/DELTA WATER QUALITY

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The San Joaquin River (SJR) at Vernalis experiences excessive growths of planktonic algae. Those algae cause significant water quality problems in the SJR, SJR Deep Water Ship Channel, and South Delta channels as they die, decay, and deplete oxygen (DO) resources in those waters. The low DO conditions adversely affect aquatic life related beneficial uses of the SJR and Delta. The results of studies by C. Foe, which have been subsequently confirmed by Stringfellow et al., show that Mud and Salt Sloughs (MSS) are the primary sources of the phosphorus loads to the SJR at Vernalis and to the South Delta that support excessive growth of phytoplankton in the SJR and South Delta. The total P and soluble ortho P concentrations in the SJR at Vernalis are a few tenths of mg/L P, well-above algal-growth-rate-limiting concentrations, a condition that may cause some to question the efficacy of P load reduction for controlling the excessive algae. However, studies conducted in the Sacramento River/Delta and the Rhine River (by Van Nieuwenhuysse) and in other waterbodies around the world (by Lee and Jones-Lee) document and quantify how reducing the P loads concentration sufficiently, even when there is surplus P in the water, results in significant reduction in phytoplankton biomass. The Central Valley Regional Water Quality Control Board (CVRWQCB) recently gave the managers of agricultural activities in MMS watersheds 10 years in which to develop a management program for the excessive discharges of selenium to the SJR. Since controlling selenium discharges from agricultural lands in those watersheds may concomitantly reduce the P discharges to MMS, it is recommended that the selenium control program be expanded to include evaluation of the reduction of P loads from those sloughs to the SJR and of the impact of the reduction of P loads on phytoplankton biomass in the SJR at Vernalis. The addition of alum to waterbodies has been widely used to convert algal-available P to unavailable forms for the controlling excessive algae in waterbodies. As part of his service as the PI for the CALFED-support SJR DWSC low-DO TMDL project, G. F. Lee suggested that special-purpose studies be conducted in the MMS watershed to evaluate the feasibility of adding alum to tile drain discharges in the MMS and its efficacy for immobilizing available phosphorus, rendering it unavailable, and thereby reducing the total algal available P load to the SJR. Studies should be undertaken to examine this approach as a means of controlling phytoplankton growth in the SJR. In addition to discussing these issues, this presentation would provide guidance on developing studies to control the excessive growths of phytoplankton in the SJR and South Delta. Additional information on these issues is available on the Lee and Jones-Lee website, www.gfredlee.com in the "Excessive Fertilization" and the Watershed Studies, SJR Watershed Program Delta sections.

Wednesday, September 29, 2010: Room 306 Nutrients and Organic Matter - Order: 1

AGRICULTURAL IMPACTS ON STREAM DOC IN A SACRAMENTO RIVER VALLEY WATERSHED

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Interest in dissolved organic carbon (DOC) cycling in California waterbodies has increased due to drinking water quality concerns (formation of carcinogenic halogenated organic compounds during disinfection), the role of DOC in foodwebs, and as the potential for DOC fluxes and compositions as a diagnostic tool for land use and climate change. During a three-year period from 2006-2008, we undertook an intense study of DOC sources, processing, and fates within the Willow Slough watershed, a typical agricultural watershed in the Sacramento River Valley located in Yolo County near Davis and Woodland. Our objectives were to determine seasonality of DOC fluxes, compositions, and reactivity as well as the impact of various agricultural practices on fluxes and compositions. DOC dynamics in Willow Slough were dominated by three distinct hydrologic regimes, winter baseflow influenced largely by groundwater, spring storms influenced by flushing and overland flow, and summer irrigation influenced by different sources of water as well as irrigation practices. While winter and spring DOC concentrations and compositions were typical for an undisturbed watershed, it was clear that agricultural practices during summer had significant impacts, increasing DOC concentrations by a factor of 2-3 over what might be expected for a natural system (8 mg/L vs. 2-3 mg/L vs. the proposed EPA action level of 3 mg/L). Although there are likely several sources for increased DOC, it appears that flood irrigation practices are a primary source, while desorption from sediments may also contribute to the increase. Compositions of certain constituents (lignin phenols) are strongly correlated with total suspended sediments, an indication of potential controls on DOC by sediment management practices. Vascular plant carbon sources (as indicated by lignin biomarkers) increased during summer, while disinfection byproduct (DBP) potential decreased, in contrast to expected trends since aromatic compounds like lignin are typically assumed to be the primary source of DBP's. However, this disconnect was also observed in biodegradation experiments in which DBP formation potential was not correlated with lignin concentrations. Optical measurements were also investigated as diagnostic tools for DOC composition, with mixed results for DBP and lignin compositions.

Wednesday, September 29, 2010: Room 306 Nutrients and Organic Matter - Order: 2

LINKING TRENDS IN LOW DISSOLVED OXYGEN EVENTS WITH DISSOLVED ORGANIC MATTER QUALITY USING OPTICAL PROPERTIES MEASUREMENTS IN NORTHERN SUISUN MARSH

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Severe low dissolved oxygen (DO) events resulting from environmental conditions and management actions in some managed wetlands adversely impact the aquatic ecosystem of Suisun Marsh. Marsh drainage rich in dissolved organic matter (DOM) stimulates microbial activity increasing the biological oxygen demand in surrounding waters. Dissolved mercury in surface waters is often associated with DOM, influenced by DOM composition. Optical property measurements (absorbance and fluorescence) were used to provide quantitative and qualitative information about DOM. The specific UV absorbance normalized to DOC concentration (SUVA) was used as a proxy for aromatic content. The exponential shape of absorbance spectra (spectral slope, S) was used to identify compositional differences in DOM. Identification of fluorescent pairs or fluorophores in excitation – emission matrix (EEMs) using Parallel Factor Analysis (PARAFAC) further identified qualitative classes of DOM. The fluorescence index (FI) has been widely used to indicate relative contributions of algal versus terrestrial derived DOM. Results of this study indicate a mixture of terrestrially derived DOM sources (soil organic matter, vascular plants and waste water) as primary sources of labile carbon. Optical property measurements show that DOM is most bioavailable in the first few weeks of flooding and point to a mixture of terrestrially derived end-members—soil organic matter, vascular plants and waste water DOM—as primary sources of labile carbon to the wetlands. Changes in DOM amount and quality indicate that labile DOM is consumed in the first few weeks of flooding as biological and photochemical processes take place.

Wednesday, September 29, 2010: Room 306 Nutrients and Organic Matter - Order: 3

SEEING THE LIGHT: APPLICATIONS OF IN SITU OPTICAL MEASUREMENTS FOR UNDERSTANDING WATER QUALITY IN RIVERS, DELTAS, AND ESTUARIES

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A critical challenge for understanding and quantifying the causes and environmental impacts of degraded water quality is making measurements at the time scales in which changes occur in aquatic systems. Traditional approaches for data collection (daily to monthly discrete sampling) are often limited by analytical and field costs, site access, and logistical challenges particularly for long-term sampling at a large number of sites. In situ optical instrumentation offers an opportunity to help overcome these difficulties. The ability to make optical measurements in situ has been around for more than 50 years, but much of the work on in situ absorbance and fluorescence using commercially-available instruments has taken place in only the last few years. We present several examples that highlight the application of in situ measurements for understanding dynamics in river and estuary systems at intervals of minutes to hours, including the Sacramento Delta and San Joaquin River. Examples illustrate the utility of in situ optical sensors for studies over short-duration events of days to weeks (diurnal cycles, tidal cycles, storm events and snowmelt periods) as well as longer-term continuous monitoring for months to years. We also highlight the application of in situ optical measurements as proxies for constituents that are significantly more difficult and expensive to measure at high frequencies (e.g. methylmercury, trihalomethanes, harmful algal blooms). Relatively simple absorbance and fluorescence measurements made in situ could be incorporated into short and long-term ecological research and monitoring programs, resulting in advanced understanding of sources that contribute to water quality improvements or degradation, contaminant and carbon cycling, the occurrence and persistence of harmful algal blooms.

Wednesday, September 29, 2010: Room 306 Nutrients and Organic Matter - Order: 4

**DO RESERVOIRS IMPROVE OR EXACERBATE DRINKING WATER
QUALITY: THE BALANCE BETWEEN LOSS OF TERRESTRIAL
DERIVED MATERIAL AND ADDITION OF ALGAL DERIVED
MATERIAL IN SAN LUIS RESERVOIR**

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Dissolved organic carbon (DOC) is a drinking water constituent of concern because during water treatment a fraction of the DOC pool reacts to form disinfection byproducts (DPBs). To improve the quality of water entering the State Water Project (SWP) and local utilities, there has been considerable focus on identifying management actions that will lower DOC concentrations in the Bay-Delta. However, little is known about the production, transformation and loss of DOC within the SWP itself. We examined changes in both the amount and composition of DOC in San Luis Reservoir, the largest water impoundment of the SWP. While the balance between production and loss determines whether a reservoir is a net sink or source of DOC, changes in chemical composition are also important as such changes affects DOC reactivity with respect to DBP formation. Despite only moderate variation in bulk DOC concentration (3.0-3.6 mg C/L), changes in DOM composition indicate that terrestrial derived material entering the reservoir from the Delta was being degraded and replaced by algal derived DOM produced within the reservoir. There were periods when the reservoir was a net source of DOC due to the predominance of algal production (summer), a period when it was a net sink due to the predominance of degradation (fall/winter), and a period when there was a net balance between production and consumption (spring). Substantial changes in the propensity of the DOM pool to form THMs and HAAs illustrate that the DBP precursor pool was not directly coupled to bulk DOC concentration. Results suggest reservoirs which store water derived from the Delta have the potential to attenuate both DOM amount and reactivity with respect to DBP precursors via degradative processes. However, these benefits can be negated, particularly during summer months, by the production of algal derived DOM.

Wednesday, September 29, 2010: Room 306 Nutrients and Organic Matter - Order: 5

THE RECIPE FOR SUCCESS – WHAT MAKES LIBERTY ISLAND SO ATTRACTIVE TO NATIVE FISH?

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Tidally influenced, freshwater marsh habitat is an important component for the early life stages of many fishes found within the Sacramento – San Joaquin River Delta. Amid possible changes in water development, land-use planning, and levee deterioration this once limited habitat may become more available to native fish species, and in particular, Delta smelt *Hypomesus transpacificus*. Liberty Island is a former artificial island which has been undergoing passive restoration after its levees breached in 1997. The Stockton office of the U.S. Fish and Wildlife Service has been involved with monitoring the fish communities utilizing Liberty Island habitats since the early 2000s. The results of our sampling efforts from 2002 – 2005 indicate that there were significant temporal differences in habitat use by native and non-native fish species of varying life stages. Delta smelt were collected within the island on a year-round basis, representing every significant life stage other than egg. When compared to adjacent Sacramento River beach seine locations, Delta smelt relative abundances were significantly lower in Liberty Island; however, their relative growth rates were significantly higher. This presentation will re-examine our previous sampling efforts in Liberty Island along with highlighting the beach seine and egg and larval trawling that we re-initiated in January 2010. It is not yet known what physiochemical properties of Liberty Island habitats are attractive to Delta smelt and other native species of concern such as Chinook salmon *Oncorhynchus tshawytscha* and Splittail *Pogonichthys macrolepidotus*. Based on these data and our involvement in the Breach III study we hope to gain a better understanding of the habitat use and feeding habits of native fishes within Liberty Island. Having these questions answered would go a long way towards informing future restoration efforts in the Cache Slough and Yolo Bypass areas.

Wednesday, September 29, 2010: Room 307 Cache Slough Complex (I) - Order: 1

EFFECTS OF A RESTORED FRESHWATER TIDAL WETLAND COMPLEX ON PELAGIC HABITAT FOR IMPERILED NATIVE FISH

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The recent collapse of pelagic fish populations in the Sacramento-San Joaquin Delta has led to increased interest in habitat restoration. Successful tidal wetland restoration has occurred naturally in the northern Delta at Liberty Island, where a levee breach inundated the island in 1998 and a highly productive tidal freshwater wetland has developed. Liberty Island and its surrounding sloughs, known as the Cache Slough Complex, are now considered key habitat for endangered native fish species. The Cache Slough Complex is a priority area for future habitat restoration efforts to protect and enhance native delta fishes. In order to develop a baseline understanding of the system, this study examines the hydrodynamic “footprint” of Liberty Island in the Cache Slough complex. Continuous monitoring of flow, temperature, turbidity, and salinity is coupled with quarterly sampling of biological resources over spring and neap tidal cycles. We report seasonal diel patterns in phytoplankton and zooplankton abundance from Liberty Island and surrounding sloughs. Chlorophyll concentration is higher in western sloughs than in the main channels of the Cache Slough Complex. Zooplankton abundance exhibits tidal and seasonal patterns, and overall abundance is high compared with other freshwater regions of the delta. Understanding the patterns of hydrodynamics and productivity is important to describe the habitat of pelagic fishes including delta smelt, and will help to identify and plan future restoration projects in the region.

Wednesday, September 29, 2010: Room 307 Cache Slough Complex (I) - Order: 2

FISH COMMUNITIES AT THE INTERFACE OF TIDAL WETLANDS AND SEASONAL FLOODPLAIN

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The 24,000 ha Yolo Bypass floodplain drains from the Sacramento River watershed into the north Delta, specifically the tidal Cache Slough Complex. For the past 12 years we have operated a rotary screw trap to examine fish communities at the base of this seasonal floodplain at Liberty Island. Over this period we collected a total of 42 species including federally listed species (delta smelt *Hypomesus transpacificus*, Chinook salmon *Oncorhynchus tshawytscha*) and several game species (American shad *Alosa sapidissima*, striped bass *Morone saxatilis*, crappie *Pomoxis* spp.). Like other regions of the estuary, alien fishes comprised a large portion of the individuals in the fish assemblages collected in the Yolo Bypass (73% for screw trap samples). However, we found evidence that the timing of occurrence of native fishes was earlier than alien species, consistent with their life history and data on adult migration patterns. We hypothesize that the Yolo Bypass may especially important to native fish because the inundation of seasonal floodplain typically occurs early in the calendar year, providing access to vast areas of spawning and rearing habitat with an enhanced food web. Moreover, we propose fish and food web production from the seasonal floodplain represent an important energy and biodiversity “subsidy” to the tidal wetlands that it drains into.

Wednesday, September 29, 2010: Room 307 Cache Slough Complex (I) - Order: 3

HABITAT ASSOCIATIONS AND MACROBENTHOS INTERACTIONS OF THE NON-NATIVE, INVASIVE ASIAN CLAM, CORBICULA FLUMINEA, AT LIBERTY ISLAND, A RESTORING FRESHWATER TIDAL MARSH, SACRAMENTO RIVER DELTA

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Initial changes in restoring tidal wetlands are characterized by physical disturbance. While the intent and assumption is that native species will colonize and dominate the new area, non-native species also take advantage of this disturbance after the tidal barriers have been removed. These non-native, invasive species could send restoration sites along different trajectories than originally intended, especially if the actions alter the development of indigenous biota. Changes in landscape and differences in abiotic and biotic factors can affect the ability of non-indigenous, invasive species to colonize an area. Non-native bivalves have been shown to change community structure and ecosystem processes in the areas they invade in ways perceived to be both beneficial and detrimental. The non-native Asian clam, *Corbicula fluminea*, has been shown to have a variety of effects on estuarine communities including altering zooplankton assemblages, changing organic matter cycling, improving water clarity, and altering benthic invertebrate assemblage structure, among others. *C. fluminea* has invaded at a restoring freshwater tidal marsh, Liberty Island, in the Sacramento Delta. My research investigates the habitat associations of *C. fluminea*, comparing the abundances of the clam within different zones of the marsh (vegetation, mudflat, channel) that will inform us about the pattern and rates of *C. fluminea* colonization as restoring tidal marshes become revegetated under different situations. In addition, we have examined *C. fluminea* abundances along a fine scale transect from within vegetation through the prograding edge of the vegetation/mudflat edge. A manipulation study was conducted to determine the growth of *C. fluminea* in various areas of Liberty Island and marsh zones. Understanding the ecology of *C. fluminea* will contribute to body of knowledge about this species, hopefully allowing restoration design projects to evaluate the consequences of its invasion and potentially minimize the colonization or dominance of this invasive bivalve in newly restored sites.

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MONITORING AND MAPPING PLANT ECOPHYSIOLOGY AND VEGETATION SUCCESSION IN A FLOODED ISLAND USING AIRBORNE IMAGING SPECTROSCOPY

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Monitoring vegetation succession and plant community health over large spatial scales is effectively accomplished with remote sensing. Imaging spectroscopy provides both spatial information as well as high-resolution continuous spectroscopic information from visible to shortwave reflected spectrum. This powerful technology provides the data needed to map vegetation communities, plant functional types, and even species. When specific absorption features are analyzed, information about the concentration of plant pigments and water can be quantified. We used airborne imaging spectroscopy (the HyMap sensor) collected during June-July 2004-2008 to map wetland vegetation community changes and plant health in Liberty Island. The results of our study show emergent vegetation expansion into open water areas from 2004 to 2008. Most expansion occurred in the north island, in the “steps.” Plant pigment and water content varied between years, indicating differing levels of stress. This flooded island can be considered a natural experiment under which to examine the successional trajectory of wetland vegetation after a levee breach. Spectroscopic imaging allows inferences about plant ecophysiology and vegetation succession dynamics; the kind of information that is critical to understanding the evolution and ecological trajectory of flooded islands in the Sacramento-San Joaquin Delta.

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THE HISTORICAL YOLO BASIN LANDSCAPE

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Identifying target habitats for landscape-scale restoration of the highly modified Delta presents many challenges. One area of current focus is the Cache Slough/Yolo Basin landscape. Understanding the physical nature of this landscape and the ecological functions that existed prior to Euro-American modification offers a basis for designing sustainable habitat mosaics for the future. To reconstruct the historical landscape, our methods involve compilation and synthesis of 19th and 20th century cartographic, photographic, and textual data using GIS. We hypothesize that large-scale geomorphic, hydrologic, and climatic regimes of the Delta created unique ecological subsystems, within which habitat mosaics varied predictably along smaller scale physical gradients. The historical Yolo Basin is one example. From relatively dense dendritic Cache Slough tidal channel networks in the south to perennial marsh and lakes in the north, the Yolo Basin's complex historical habitats reflect the subsystem's physical gradients, such as hydroperiod. For example, our findings suggest that the historical lower Cache Slough contained channel densities similar to estimates elsewhere in the Estuary's fresher marshes; densities which drop significantly across the transition from tidal to non-tidal floodplains. Large, shallow ponds occupied the transition from marsh margin to upland. Riparian vegetation varied in composition and structure in relation to such factors as the height of natural levees. The habitat mosaic was also strongly influenced by temporal environmental variability. The Yolo Basin received large volumes of freshwater from the Sacramento and its western tributaries in winter and spring, much less so in summer and fall. Many of the habitats were seasonally wet or ephemeral. Our research describes a level of historical habitat complexity and inter-connectivity that is unmatched in the contemporary Delta. Information compiled for this study will provide insight for restoration planning efforts in the Delta, including the Ecosystem Restoration Program and Bay-Delta Conservation Plan.

Wednesday, September 29, 2010: Room 307 Cache Slough Complex (II) - Order: 6

CHANGING AGRICULTURAL PESTICIDE USE AND THE IMPLICATIONS TO NATIVE FISH IN THE YOLO BYPASS

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A variety of different pesticides including organophosphate and pyrethroid insecticides as well as several newly registered fungicides are used in the productive agricultural areas surrounding the Yolo Bypass. This leveed flood control basin in Northern California provides key migration corridors and important rearing/spawning grounds for native fish. In 2004-2005 a study was conducted to evaluate three potential sources of agricultural pesticides to the Yolo Bypass that could potentially impact critical life stages of native fish. Surface water, bed and suspended sediments were collected to assess the direct/indirect inputs of pesticides to the Bypass during high and low flow events. A variety of different current-use pesticides, including several herbicides (hexazinone and simazine) were detected frequently in surface water while the more hydrophobic pyrethroid insecticides (bifenthrin, cyhalothrin and t-fluvalinate) were detected in sediment at relatively low concentrations (<10 ppb). The pesticides detected in sediment and surface water varied by site and were correlated with agricultural application in each watershed. Agriculture and associated pesticide use in the watersheds surrounding the Bypass continues to change from year to year. Sensitive, comprehensive and robust laboratory methods are currently being developed to adapt to shifts in pesticide use patterns. For example, fungicide use, particularly on rice and almonds, has increased and methods have been developed to effectively analyze these newly registered compounds. Between 2004 and 2008 organophosphate use decreased while use of two pyrethroids bifenthrin and esfenvalerate has increased. Adapting laboratory methods and monitoring efforts to reflect changing pesticide use is necessary to update our state of knowledge on the fate and transport of pesticides within the Yolo Bypass. This information is critical for resource managers and fisheries biologists to assess the potential risks of multiple stressors as well as long-term contaminant exposure to fish.

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SEDIMENTATION PROCESSES AND TURBIDITIES FAVORING ENDANGERED FISH, NORTHERN SACRAMENTO-SAN JOAQUIN RIVER DELTA

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The Cache Slough region in the northern Delta has recently been recognized as key habitat for delta smelt, an endangered pelagic species endemic to the Upper San Francisco Estuary and Sacramento-San Joaquin Delta. This region includes a network of dead-end channels and a shallow flooded island (Liberty Island) with multiple levee breaches. We are investigating sedimentation processes that create and maintain high turbidity in the region, which is a key habitat characteristic for delta smelt. The study hypotheses are 1) during moderate-flow years, sediment is deposited in the area, and 2) during high-flow years, flow is unidirectional and much of the delivered sediment is transported through the region without deposition, 3) during low-flow and dry seasons little sediment is supplied to the region and sediment undergoes repeated cycles of resuspension and deposition as a trapped tidally-oscillatory mass, and 4) wind-wave resuspension of sediment on Liberty Island supplies sediment to the region. We continuously monitored water flow and turbidity at four sites in 2008 and 2009, and expanded our data collection efforts in 2010. From continuously deployed instrumentation combined with field samples, we calculated cross-sectional suspended-sediment flux. Preliminary results indicate 1) both the Ulatis Creek and Sacramento River watersheds supply significant sediment to the region, 2) a large portion of the first flush sediment pulse is trapped as a tidally-oscillating sediment mass, 3) strong winds resuspend sediment deposits and increase turbidity during the spring and summer, and 4) flood dominant tides transport some of this sediment further upstream into dead-end channels. The dead-end channels and shallow flooded island are rare habitats in the Delta that appear to retain sediment and have increased turbidity, making the Cache Slough Complex favorable habitat for delta smelt. Understanding the hydrologic and sediment dynamics are critical for restoration planning and Delta management efforts.

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BREACH III PHYSICAL PROCESSES: HYDRODYNAMICS AND WIND/WAVE INTERACTIONS

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Shallow water turbidity and phytoplankton production are recognized as being important for endangered species and regional food web support in the Sacramento-San Joaquin Delta. We are using hydrodynamic numerical modeling and field observations to understand the physical processes that sustain turbidity and phytoplankton production in and around Liberty Island (LI). Hydrodynamic circulation patterns and wind-generated waves are essential physical processes for characterizing the island's current habitat as well as predicting the geomorphic evolution of LI. We are developing a two-dimensional hydrodynamic model (DELFT3D FLOW) of the LI Complex. We will present first phase results of circulation patterns within the open water and tule marsh portions of LI and exchange between LI and the surrounding channel network. To understand the spatial and temporal patterns of wind-waves, we are analyzing existing field data, collecting new wave observations, and modeling wind-waves with the DELFT3D SWAN (Simulating WAVes Nearshore) model. We will present the wind-wave analysis of spatial distributions of wind, waves, and wave-induced erosion at annual and seasonal time scales. Over the course of this three year project, we want to understand how LI will evolve as the result of physical processes and whether site functioning can be improved by management actions. These numerical models will also provide spatial integration of datasets collected by project partners and collaborators and provide a platform for integrated regional analysis. Understanding the physical processes in Liberty Island, and the thresholds that define evolution will inform restoration planning both in Liberty Island and on adjacent areas.

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THE BREACH III STUDY: 1 YEAR DOWN, 2 YEARS STILL TO COME – WHAT WE HAVE LEARNED SO FAR AND WHERE WE HOPE TO BE AT THE END

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Liberty Island has been recognized by researchers, agency work teams and planning processes as refugia for native fish species, a potential source of turbidity and organic matter inputs, and for its hydrodynamic influence within the north delta region. The Breach III study hopes to further inform the planning and decision making process by providing a predictive level of understanding about: 1) how abiotic and biotic factors in a restoring (levee breach) wetland control vegetation colonization and expansion and subsequent responses by native fish and wildlife; 2) the geomorphic and other thresholds that regulate the processes of marsh development; and, 3) how restoration processes influence local flooding and levee erosion over the course of restoration. Since December 2009, our research team has been collecting data for several model inputs including fish and macroinvertebrates assemblages, food web dynamics, primary productivity, vegetation colonization and elevation, sediment accretion and geomorphology, water quality, and wind and wave climates. This presentation will serve to wrap-up the Cache Slough Complex Special Session and highlight some of our preliminary results as well as describe the modeling and synthesis activities that will take place during the remainder of our study. Finally, we will discuss our expected work products and the management tools we propose to develop. Defining these unique wetlands, understanding how they develop, and how they contribute to the surrounding environment are important factors that need to be considered during the planning and management of large-scale restoration projects in the Sacramento – San Joaquin River Delta. The ultimate goal of Breach III is to provide us with our first predictive, modeling tools that integrate this understanding. Given the amount of restoration projects already underway or slated to start in the near term, it is imperative that resource managers have the tools necessary to make informed decisions to base their actions upon.

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THE FRAMEWORK FOR RESTORATION MONITORING AT THE MERCED RIVER RANCH

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The Merced River Ranch (MRR) is a 128-hectare property along the Merced River that was heavily impacted by large-scale aggregate mining activities. In 1998, the California Department of Fish and Game acquired the MRR in the dredger tailings reach of the Merced River with the vision of restoring (i.e., rehabilitate and enhance) channel, floodplain and riparian ecosystem processes and critical habitats for juvenile and adult salmonids. The U.S. Fish and Wildlife Service Anadromous Fish Restoration Program is funding restoration actions to rehabilitate floodplain and channel habitat for juvenile and adult salmonids, and conduct detailed implementation, effectiveness, and validation monitoring. The monitoring program will collect robust data for assessing project success, with potential to inform similar habitat restoration efforts throughout the Central Valley. The monitoring program consists of three conceptual approaches to monitoring: implementation, effectiveness, and validation. The implementation monitoring will determine if the project was installed according to the design standards. The central question is: Was the project implemented according to plan? The effectiveness monitoring will determine if the project was effective in recovering habitat conditions suitable for target species. The central question of effectiveness monitoring is: Was the project effective in meeting its target objectives? The final part of the monitoring program will determine if floodplain restoration projects, like the one at MRR, recover productive habitat for salmonids and riparian vegetation. The central question of validation monitoring is: Are the basic assumptions behind the project conceptual model valid? This question will be addressed with in situ experiments and modeling fish performance based on field-derived data. This presentation describes an overview of the monitoring program and how this monitoring framework helps better understand ecosystem function in restored habitats. This project combines restoration actions, public outreach, and monitoring to better restore habitat in the Merced River, and provide information for other Central Valley rivers.

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CONCEPTUAL APPROACH FOR PROCESS-BASED RESTORATION IN REGULATED CENTRAL VALLEY RIVERS

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Regulated flow management in rivers throughout California's Central Valley has altered ecosystem processes necessary for maintaining critical habitats for native salmonids. Primary impacts include a general reduction in channel maintenance flows and concurrent loss of coarse sediment recruitment. Over time, this primary impact has affected structural processes leading to the following channel responses: scour; over-deepening; loss of gradient; and, reduced sediment mobilization. The cumulative effects of these changing structural processes has increased bank and bed armoring, and contributed to vegetative encroachment resulting in disconnection of the floodplain from the active channel. Additional physical habitat responses include slower velocities and increased fine sediments, further reducing the availability of appropriate substrate quantity and quality to support productive salmonid populations. Moreover, instream and hyporheic water quality is subsequently degraded. All of these altered conditions have negatively affected functional processes by decreasing habitat heterogeneity generally reducing spawning use, embryo production, juvenile survival, and macroinvertebrate community structure and production. Understanding the complex interactions and factors that contribute to habitat degradation is important to identifying the most appropriate management actions for native salmonids. We present a conceptual approach for process-based restoration to recover ecosystem functions while working within current and future management constraints. First, we describe a method for identifying ecological relevant flows (ERF) for important life history periods. Then, we explain how to assess current conditions to identify targeted restoration actions that confer the greatest ecological benefits to critical habitats by enhancing the conditions that promote fish production and survival. Finally, we discuss the importance of developing long-term management plans to ensure continued project success.

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RESTORING RIPARIAN HABITAT ON ALTERED FLOODPLAINS BY INTEGRATING VEGETATION AND AVIAN MONITORING

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Much of the information on riparian habitat restoration in the Central Valley is based on in-tact floodplains with productive soils. The Lower Clear Creek Floodway Rehabilitation Project in Shasta County, California, was designed to restore the stream channel and floodplains that have been severely impacted by aggregate and dredger gold mining and altered flood flows due to Whiskeytown Dam. Floodplains were re-constructed with coarse dredge tailings and floodplain deposits placed on top of an undulating clay pan with a perched water table. Original restoration sites were designed and planted using evenly spaced cuttings of riparian trees (e.g. willows and cottonwood) on topographically uniform surfaces. This approach has been successful in establishing these cuttings, but the low productivity of the coarse soils coupled with sediment-starved post-restoration flood flows has limited the amount of natural recruitment. Monitoring results show these sites are only being used by a limited number of bird species primarily due to a lack of a dense understory typical of early successional riparian habitat. Integrating monitoring results from vegetation and avian monitoring has resulted in changes to restoration design in subsequent phases. Based on these results the most recent phase of restoration has increased the extent of features that have proven successful in prior phases such as save areas of mature vegetation, extensive scour channels, and backwaters. In addition, site assessments are being conducted post-floodplain construction in order to revise planting methods to provide riparian vegetation that provides the necessary nesting habitat for birds. By integrating avian and vegetation monitoring we have been able to adapt restoration designs to ensure that the needs of a suite of riparian-dependent species are being met. The Clear Creek restoration project has provided important information for floodplain restoration using dredger tailings and an effective model of monitoring and adaptive feedback.

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IMPLEMENTING AT THE PROJECT SCALE TO INFORM SCIENCE-BASED REGIONAL WETLAND RESTORATION: THE DUTCH SLOUGH TIDAL MARSH RESTORATION IN THE SACRAMENTO-SAN JOAQUIN DELTA

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The 1,170-acre Dutch Slough Tidal Marsh Restoration Project is seen as a significant step in recovery of the ecological health of the Sacramento-San Joaquin Delta, particularly for recovery of Bay-Delta fishes. It is the largest restoration designed to recreate the freshwater tidal marshplain and channels characteristic of the historic Delta. It's also an important learning opportunity. The project partners worked with an interdisciplinary group of scientists to integrate adaptive management experiments with restoration. What we learn from these experiments is intended to inform regional restoration design and implementation. The Dutch Slough restoration will include large-scale experiments to test the relationship of tidal marshplain elevation and marsh size/scale to the growth and survival of juvenile salmon and splittail. The plan will also include smaller-scale experiments related to wetland production of methyl mercury and dissolved organic carbon, and tidal channel formation. During planning, project partners and scientists grappled with the following questions: Which parameters are both most uncertain and most important to test? Which are most likely to affect ecosystem benefits and management decisions related to cost and selection of future restoration sites? How important is experimental replication? How many experiments can we realistically include? Which parameters require testing at a large scale? Which can be tested on a smaller scale? How do we balance trade-offs between learning and restoration? The Dutch Slough project is being planned by the California Department of Water Resources, California State Coastal Conservancy, Reclamation District 2137, and American Rivers with funding from the California Bay-Delta Authority.

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IMPROVING WATERSHED HEALTH THROUGH LARGE-SCALE WETLAND RESTORATION

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Wetlands are believed to play many important functions for both wildlife and humans. However, these functions are lost when wetlands are altered. Located directly north of San Francisco Bay, Tomales Bay lost 50% of its wetlands in the 1940s when a large marsh was leveed for a dairy ranch operation. In 2000, the National Park Service bought this dairy for a 613-acre wetland restoration project, which was implemented in 2007-2008. The Park Service believed that restoration could not only improve quality of the degraded wetlands within the ranch, but improve overall watershed health by increasing habitat for wildlife, as well as improve downstream water quality. While Tomales Bay is often viewed as pristine and is a Ramsar Wetland of International Importance, its waters have been impacted by leaking septic tanks, agriculture, mercury, and oil spills and are designated as impaired under Section 303(d). Two-thirds of the Bay's freshwater input and principal contaminant source comes from tributaries upstream of the Giacomini Ranch, which will now be able to be filtered by the reconnected floodplains. To determine restoration success, the Park Service developed an innovative long-term pre- and post-project monitoring program that incorporates both the Project Area and reference wetlands. Monitoring in the first year after restoration indicates that many of the improvements anticipated to occur over the long-term after conversion of pastureland to marsh are already occurring, including substantial reduction in pollutant concentrations; increases in bird and other wildlife use; changes in the species using the Project Area; reductions in non-native species; and rapid replacement of pasture grasses with marsh plants. With so many of the San Francisco Bay –Delta restoration projects still in the planning or early implementation phase, this recently completed project provides important comparative information to improve planning and implementation of Bay-Delta restoration efforts.

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THE LARINIER FISH PASSAGE: IMPLEMENTING “NEW” TECHNOLOGY TO FACILITATE STEELHEAD FISHERIES RESTORATION IN ALAMEDA CREEK FLOOD CONTROL CHANNEL

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Steelhead restoration efforts within the Alameda Creek Watershed initially targeted Rubber Dam 2, which is owned and operated by Alameda County Water District, for removal. However, a hydraulic analysis of the creek system indicated that the dam’s concrete foundation provides channel stabilization and grade control and therefore cannot be removed. The concrete foundation creates a three foot grade drop within the channel, which causes delay for steelhead migrating through the flood control channel. Traditional fish passage technologies were evaluated and eliminated due to the low-flow design requirement of 20 to 100 cubic feet per second and ephemeral characteristics of the creek. Non-traditional fish passage technologies were also evaluated. The Super-Active Baffle Fish Passage, also referred to as the Larinier Fish Passage, was identified as a possible technology. This passage is commonly used in France, England, and Wales but there are no known installations in North America. The baffles within the Larinier Fish Passage create helical currents that rapidly dissipate energy, thus decreasing the flow velocity throughout the baffled area. This drop in velocity allows fish to pass through the baffled area if their ability to swim, which is species specific, matches the passage design. A hydraulic model was developed to confirm that the Larinier Fish Passage could be designed to meet the flow regimes in Alameda Creek Flood Control Channel. These results, along with empirical data from the installations in Europe, were sufficient to gain approval to install the Larinier Fish Passage from stakeholders and regulatory agencies. Design and construction was completed in October 2009. The Larinier Fish Passage is a “new” fish passage concept that can be utilized to facilitate steelhead fisheries restoration. It has the potential to be particularly effective in California, where ephemeral flows are common.

Wednesday, September 29, 2010: Room 307 Restoration and Fish - Order: 1

HABITAT RESTORATION IN THE SAN FRANCISCO ESTUARY TO INCREASE SALMONID SMOLT FORAGING OPPORTUNITIES

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Salmonid smolts migrating through the San Francisco Estuary have limited foraging opportunities as indicated by a reduction in their Condition Factor (CF), reduced body lipid content and where nearly half have empty stomachs as they leave the Golden Gate. Extensive mud flats provide limited foraging opportunities for salmonid smolts. The loss of habitat complexity and vertical structures in the Estuary has reduced the potential for a robust community of organisms that could provide more salmonid smolt foraging opportunities. Two large artificial reefs have been constructed in central San Francisco Bay specifically to provide foraging habitat for migratory salmonid smolts. Data collected on the community of organisms found in the reef systems compared to control areas and acoustic fish tracking demonstrate the increase in foraging opportunities and the extended utilization of the reefs by late fall-run Chinook, steelhead and green sturgeon. A conceptual model of the reef system function in the San Francisco Estuary provides a tool for management consideration of methods to increase salmonid survival through the Estuary and improve physiological readiness for ocean phase survival.

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EVALUATING A SPAWNING HABITAT ENHANCEMENT PROJECT: IMPROVING BENTHIC MACROINVERTEBRATE PRODUCTION IN GRAVEL AUGMENTATION AREAS TO BENEFIT JUVENILE SALMONID REARING HABITAT QUALITY

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Coarse sediment recruitment and other related ecosystem processes have been interrupted on regulated California Central Valley rivers resulting in a general deficit of substrates appropriate for spawning salmonids. Within these areas, gravel augmentation has generally improved conditions for salmonid spawning, egg incubation and embryonic development. Benthic macroinvertebrate production is also enhanced and colonization of new gravels occurs relatively rapidly; however, these conditions don't necessarily confer optimal benefits to potential prey items available to rearing juvenile salmonids, which also utilize these areas. In general, benthic macroinvertebrate communities respond to complex associations and interactions at the microhabitat scale, including water depth and velocity and substrate size. As a result, we hypothesized that by varying these parameters for target benthic macroinvertebrate species within ranges suitable for spawning salmonids, we would increase the amount of available prey appropriate for rearing juveniles, further improving these habitats. We utilized existing juvenile steelhead and Chinook salmon diet information from the lower American River to identify the top 4 most prevalent prey species, and the most appropriate prey size classes and life stages for fish at various sizes. We then used benthic macroinvertebrate samples collected across various habitat conditions (e.g., substrate size/type, depth, velocity) from previous investigations conducted in the lower American and Mokelumne rivers to develop suitability criteria to inform experimental gravel placement in the lower American River. We tested the effects of substrate size on the production of selected benthic macroinvertebrates by creating patches of larger substrate within newly placed gravel. We sampled areas with suitable velocities and depths for the selected prey species within those patches. These results were compared to data collected from control samples in the general augmentation area. Our results demonstrate increased target species biomass (per unit area) associated with the treatment patches compared to the control areas. This model will be developed as an adaptive management tool to establish design standards for planning future spawning gravel augmentation on the lower American River with potential for use throughout the Central Valley.

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EVALUATING A SPAWNING HABITAT ENHANCEMENT PROJECT: RESTORING ECOLOGICAL PROCESSES AND IMPROVING HABITAT QUALITY TO BENEFIT NATIVE SALMONIDS

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We evaluated the effects of spawning gravel augmentation on habitat conditions for Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the lower American River. A site with a high potential for anadromous fish spawning use was selected for habitat enhancement on a regulated portion of the lower American River. Cleaned and sorted gravel material from local floodplain tailings were utilized to augment and improve existing riffle habitat conditions by decreasing average depths and substrate size while increasing average velocities. We employed a Before-After, Control-Impact (BACI) design structure to test differences between un-enhanced and enhanced areas (i.e., Control-Impact) by subjecting these areas to replicated sampling over time (i.e., Before-After). We used the following metrics to assess the effectiveness of the implemented augmentation on local salmonid populations: 1) changes in habitat quality (i.e., substrate composition and hyporheic water quality); and, 2) habitat use (i.e., spawning and rearing) versus availability. Placed gravel was composed of appropriately sized substrate for spawning salmonids in the lower American River. Chinook salmon spawning was observed within six weeks, and steelhead trout spawning was subsequently documented at the enhanced site in the first season following augmentation. Juvenile salmonid rearing was significantly higher along stream margins and inundated floodplain habitats adjacent to enhanced habitat areas. These results suggest that newly created riffle habitat can produce immediate ecosystem benefits and demonstrate rapid biological responses. Continued success depends upon the integration of future projects at the reach scale to adaptively manage existing and proposed projects to achieve programmatic goals and objectives.

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MONITORING THE EFFECTIVENESS OF CVPIA DEDICATED YIELD IN REDUCING REDD DEWATERING

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The problem we are trying to solve is quantifying the benefits of using CVPIA dedicated yield to reduce redd dewatering. The approach is to map out the locations of shallow redds, using RTK GPS, in previous two-dimensional hydraulic and habitat sites on the Sacramento and American Rivers and Clear Creek. After we have determined the amount of CVPIA dedicated yield used to reduce redd dewatering and what flows would have been in the absence of CVPIA dedicated yield used to reduce redd dewatering, the locations of the redds are used in the two-dimensional hydraulic and habitat models to predict how many of the redds would have been dewatered if CVPIA dedicated yield had not been used to reduce redd dewatering. In the first year of monitoring, we located 44 shallow fall-run redds on the Sacramento River and 231 shallow fall-run redds and 35 shallow steelhead redds in the American River. The scientific and management implications of the findings are that the results will inform the benefit of using CVPIA dedicated yield to reduce redd dewatering and thus inform to what extent CVPIA dedicated yield should be used to reduce redd dewatering. The relevance of our findings to Bay-Delta management is that the amount of CVPIA dedicated yield used to reduce redd dewatering directly affects how much CVPIA dedicated yield can be used to reduce Delta exports, since there is a fixed total CVPIA dedicated yield of 800,000 acre-feet. The findings provide insights toward how CVPIA dedicated yield can be better used to provide ecosystem sustainability in the near and long term futures.

Wednesday, September 29, 2010: Room 307 Restoration and Fish - Order: 5

CLIMATE CHANGE CHARACTERIZATION IN CALIFORNIA WATER RESOURCES PLANNING STUDIES

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The mission of the California Department of Water Resources (DWR) is to manage the water resources of California, in cooperation with other agencies, to benefit the State's people, and to protect, restore, and enhance the natural and human environments. To fulfill its mission, DWR leads or participates with other agencies in various planning studies. The studies range from the California Water Plan, which provides general long-term information about California water resources, to Environmental Impact Reports for specific water management projects. Many of these planning studies require an analysis of future conditions including climate and hydrology. Historical planning practices that assume that past observations of climate and hydrology were reasonable predictors of future conditions have been called into question because of climate change. As a result, recent water resources planning in California, as in other States, involves the development of new approaches to forecast future climate and hydrology. DWR does not currently have a standard approach or a set of recommended approaches for considering climate change in its planning studies. Of the studies underway, we generally follow one of several approaches that include: 1) A methodology based on 12 Global Climate Model (GCM) simulations selected for the California Climate Action Team 2009 Impacts Report; 2) An Ensemble Informed Approach based on all of the 112 available simulations from the IPCC AR4 (2007); 3) Sensitivity analysis using data from one or a few GCM simulations; 4) Delta approach that superimposes in its analysis the impact variance between alternatives evaluated in another, similar study incorporating GCM based data; and 5) Qualitative approaches. This paper reviews and summarizes these climate change characterization approaches used in recent planning studies conducted by DWR and participating agencies. The information is intended for use by DWR and others to consider how to include climate change analyses in different studies and identify opportunities for developing and using common approaches for studies with similar goals and assumptions.

Wednesday, September 29, 2010: Room 308-310 Addressing Climate Change in Delta Planning and Management (I) - Order: 1

STATISTICAL DOWNSCALING OF CMIP5 GLOBAL CLIMATE MODEL SIMULATIONS FOR USE IN BAY AREA REGIONAL IMPACT STUDIES

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Global climate models (GCM) encapsulate our best understanding of the physics of the climate system, but they operate at spatial scales too coarse to meet the needs of societal impacts researchers and decision makers. In an effort to aid these groups in their endeavors, we are performing systematic spatial downscaling of the global simulations now being generated by modeling groups around the world for the Coupled Model Intercomparison Project (CMIP5). Two statistical downscaling methods are being utilized to add spatial detail based upon fine-scale gridded observations of historical climate: the “Bias-Corrected Constructed Analogs” method and the “Bias-Corrected Spatial Downscaling method.” We will downscale several hundred simulations from all participating models and from several Representative Concentration Pathways. The resulting library of downscaled climate projections will be at a spatial resolution of 12 km x 12 km and will include both monthly and daily averages of minimum and maximum surface temperature, as well as precipitation.

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MODELING EFFECTS OF CLIMATE CHANGE ON CENTRAL VALLEY WATER DEMANDS

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Long term planning for the management of California's water resources requires assessment of the effects of future climate changes on both water supply and demand. Considerable progress has been made on the evaluation of the effects of future climate changes on water supplies but less information is available with regard to water demands. This study addresses water demands by examining the effects of climate change on plant transpiration, growth and yield for selected types of agricultural and urban vegetation. The assessments are performed for representative groups of agricultural crops growing in characteristic geographic regions of the Central Valley using downscaled climate futures selected to span a wide range of the existing GCM results. The objective of this approach is to produce a data set that can be used by others for planning studies and economic assessments. An existing model, the Land, Air, and Water Simulator (LAWS) has been modified to include algorithms that account for effects of atmospheric temperature, radiation, humidity, wind speed and CO₂ concentrations on plant water use, growth and yield. Using LAWS, the effects of various types of agricultural and urban water demand management actions can be evaluated. Native vegetation can also be simulated. Study results show that atmospheric as well as soil conditions can exert complex and opposing influences on important evaluation metrics such as plant transpiration rates and cumulative water use, initiation and duration of the growing season, biomass production and crop yields. The magnitude of changes relative to historic conditions can be significant. Additional simulations are underway to expand the scope of the results throughout the Central Valley. These results will be directly relevant to the development of climate adaptation strategies effecting future Delta inflows.

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POTENTIAL RESPONSES OF SIERRA NEVADA FLOOD FREQUENCIES TO CLIMATE CHANGE

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California's rugged topography, proximity to occasional heavy moisture-laden storm systems, and a variety of human development and infrastructure in low lying areas make it highly vulnerable to floods. An important question facing the state—in terms of both protecting the public and formulating water-supply management responses to climate change—is “how might future climate changes impact flood risk in California?” To begin addressing this question, we simulated floods under a range of climate-change scenarios in the western Sierra Nevada. The investigation is based upon downscaled daily precipitation and temperature projections from three General Circulation Models (GCMs), fed through the Variable Infiltration Capacity (VIC) hydrologic model. Daily VIC-simulated streamflows, from historical and from projected climate change runs, were evaluated for possible changes in annual maximum 3-day flood magnitudes and frequencies of floods greater than selected historical thresholds. By the end of the 21st Century, all of the projections yield larger floods, for both the Northern Sierra Nevada (NSN) and for the Southern Sierra Nevada (SSN). The increases in flood magnitudes (with 50-years return intervals) are statistically significant (at $p \leq 0.01$) for all the three GCMs in the period 2051-2099. These increases appear to derive several different climatic influences in the projections, ranging from increases in large-storm sizes, storm frequencies, and days with more precipitation falling as rain and less as snow. Increases in antecedent winter soil moisture also play a role in some areas. Thus, several mechanisms typically contribute to the projections of increased flood hazards. As a consequence of the multiple contributions to the simulated flood responses, full hydrologic modeling are likely to be required to make even general predictions, in contrast to some simpler rules of thumb of the sort that might apply to some other hydrologic responses. The problem of changing flood frequencies is complicated by the fact that responses differ from basin to basin depending on topography. This means that projections of flood changes with climate change will also be basin dependent.

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PLANNING FOR WATER RESOURCES SYSTEM RE-OPERATION DUE TO CLIMATE CHANGE

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Climate change is expected to increase temperatures, change the distribution and form of precipitation, and change the timing and quantity of runoff. All of these changes will impact California's water resources systems demanding some form of adaptation. Changing water management practices is a centerpiece of the California Department of Water Resources' adaptation strategies for climate change. In this talk, a review of climate change impacts affecting California's water resources is provided as a backdrop for setting the landscape for system re-operation as a means of adapting to those changes.

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INCORPORATING CLIMATE VARIABILITY, CHANGE, AND MODEL UNCERTAINTY IN SCENARIOS FOR CALIFORNIA WATER PLANNING

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Climate change projections derived from global climate models are becoming more widely used in basin-scale water planning and management. These model projections consistently indicate accelerated warming throughout the 21st century, but the degree of warming varies considerably between models and emission scenarios. For most of California, even greater uncertainty exists in projections of precipitation with some models indicating directionally inconsistent trends. Selection of appropriate representative scenarios of future climate variability and change is important for regional and basin-scale studies. Use of the multi-model ensemble has been shown to be superior to any individual model projection largely through reduction in the “noise” and multi-decadal variability inherent in individual projections. While these findings suggest that as many projections of the ensemble as is possible should be considered, for many applications it is impractical to simulate the impacts of tens to a hundred of climate projections on water resources involving hydrological, biological, estuarine, and fisheries studies for a broad suite of water management alternatives. This paper presents a hybrid technique for climate scenario selection that reflects the full range of uncertainty in climate projections through the use of sub-ensembles. The technique allows for the selection of statistically-representative climate scenarios, derived from over 100 downscaled climate projections, which maintain superiority over individual scenarios while reducing the number of projections needed for complex water management studies. This technique is being applied in planning studies for the Bay Delta Conservation Plan.

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REGIONAL HYDROLOGIC AND WATER MANAGEMENT SYSTEM RESPONSES TO CLIMATE FUTURES

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Recent observed and projected changes in climate and sea level have substantial influence on the regional watershed processes and water management in the Central Valley and Bay-Delta. Not all watersheds are influenced in the same manner and degree. Hydrologic modeling, using the Variable Infiltration Capacity (VIC) hydrology model, of the Sacramento and San Joaquin Valley watersheds has been performed for a range of climate scenarios selected for the Bay Delta Conservation Plan (BDCP). The VIC modeling results suggest important regional and seasonal trends in factors such as precipitation, temperature, snowpack development and melt, soil moisture, and evapotranspiration. Spatial and temporal changes in these parameters, and their culminating net effect on timing and magnitude of streamflow, will be discussed. At the same time, sea level change scenarios and hydrodynamic and water quality modeling suggest a significant changes to tidal and salinity regimes within the Delta. Water management, however, must consider changes to the “system” which are impacted by upstream changes from climate, hydrology, and river water quality conditions; and downstream changes in ocean and estuary responses. The management of this system under a range of climate futures is being analyzed in the BDCP. Integrated physical modeling is being conducted to better inform long-term water management of the Central Valley system and provide insights into adaptive management of the program to balance water supply and ecosystem needs.

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3-D SIMULATION OF SEA LEVEL RISE FOR THE BAY DELTA CONSERVATION PLAN

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As part of the Bay Delta Conservation Plan (BDCP) future conditions are being evaluated which will require accurate prediction of potential salinity impacts resulting from an increase in salinity intrusion into the Sacramento-San Joaquin Delta resulting from sea level rise. The three-dimensional UnTRIM Bay-Delta model was applied to estimate salinity impacts for a range of sea level rise scenarios. The UnTRIM Bay-Delta model was configured to run boundary conditions identical to those used in DSM2 to allow for detailed comparison of salinity intrusion as a function of sea level rise between the UnTRIM and DSM2 models. In order to parameterize the increased salinity intrusion predicted by the 3-D UnTRIM model into the 1-D DSM2 model, dispersion factors in DSM2 are being recalibrated to produce the level of salinity intrusion predicted by UnTRIM for each level of sea level rise simulated. This will allow for the incorporation of the effects of increased salt intrusion into the Delta resulting from sea level rise into the water operations models, such as CALSIM II. The predicted salinity increases resulting from increased salt intrusion into the Delta with increasing sea level rise demonstrate the potential range of expected increases in Delta salinity without operational changes. The 3-D sea level rise simulation results demonstrate that there are many different processes which result in salinity impacts with increasing sea level, including increased gravitational circulation, decreased efficiency of flushing flows, and a slower response in the south Delta to inflow salinity increases.

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SIMULATION OF HYDRODYNAMIC RESPONSES FOR EVALUATION OF INFRASTRUCTURE AND RESTORATION INVESTMENT RISKS UNDER CLIMATE CHANGE

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Under the Bay Delta Conservation Plan (BDCP) Proposed Project, large-scale tidal marsh restoration is proposed for various areas of the Delta with a strong emphasis on areas in the Suisun Marsh and Cache Slough regions. As the major element to water operations, the Proposed Project also includes the development and operation of five new water diversion intakes to be located on the Sacramento River in the vicinity of Hood. Resource Management Associates has performed 2-D hydrodynamic and salinity transport simulations to assess the risks to the proposed tidal marsh restoration and the north Delta intakes due to large-scale levee failure and long-term sea level rise. Two levee failure events have been considered including a three island failure scenario and a larger failure scenario that might be associated with a magnitude 6.7 earthquake on the Hayward fault. For the purposes of the BDCP planning for the Habitat Conservation Plan and associated permit, sea level rise was considered for the period extending to the year 2060 (50-year permit). However, for the evaluation of investment risk it is necessary to consider that the infrastructure (restoration and intakes) will function for much longer than the permit. For this reason the most extreme sea level rise currently estimated for the year 2100 of 140 cm along with increases in tidal amplitude was used in this risk assessment. Model results are analyzed with respect to tidal stage, flows and velocities, as well as salinity distribution changes in the Delta.

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PRISM-BASED DOWNSCALED GLOBAL CLIMATE MODELS FOR CALIFORNIA CLIMATE CHANGE IMPACT RESEARCH

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The PRISM 1km climatology is one of the most widely used historic climate datasets for understanding regional level climate patterns across the United States. We used PRISM to statistically downscale and bias corrected Global Climate Model simulations from 16 models and 3 emission scenarios across California. An advantage of the suite of simulations presented here of alternative regional climate simulations with similar spatial resolutions is that variability among the 16 models can be used to summarize uncertainty in climate projections. We describe patterns of climate projections and uncertainty across CA and discuss applications to climate impact modeling in the San Francisco Bay Area.

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POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE UPPER FEATHER RIVER BASIN HYDROLOGY

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We quantitatively evaluate the hydrologic response of the Upper Feather River Basin to climate change with the physically-based, spatially-distributed PRMS hydrologic models. Starting with the calibrated hydrologic models and historical hydro-climatic dataset, wavelet spectral analysis is performed on historical hydro-climatic time series data which reveals strong seasonal, annual and intra-annual (2-4 years) non-random variability in naturalized streamflow and strong correlations among hydro-climatic variables. Detrending of air temperature forcing data is performed after strong linear trends are identified and estimated at several climate stations. After detrending only the natural variations remains in the historical data, PRMS models forced with this quasi-stationary temperature data are able to produce quasi-stationary hydrologic outputs and the observed strong decreasing trend in April-July fraction of annual flows into Lake Oroville is virtually gone. Temperature-driven sensitivity analysis (+1°C to +4°C) shows that basin-wide snowfall as a form of precipitation will be reduced by -19% to -67% and annual snowmelt will be reduced by -10.8% to -51.9%. While absolute changes in annual streamflow is quite small (less than 2.1%), monthly total runoff is increased by as much as 80% in the winter months and decreased sharply in the summer months by about 60%. Six GCM models with two IPCC CO₂ emissions scenarios (A2 and B1) were chosen to represent a range of climate change projections. All simulations based on the GCM scenarios consistently show reduced snowpack storage, declined summer runoff and increased winter streamflow as air temperature increases. Therefore, the implications for reservoir operation at the watershed outlet (Lake Oroville) is that whether the original operation rule based on historical hydrology can still accommodate a substantial shift in streamflow timing and seasonality and a large reduction in natural snowpack storage.

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ESTIMATING FUTURE HABITAT RESILIENCY AND WATER AVAILABILITY IN THE NORTH BAY REGION USING FINE-SCALE MODELING

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Preparing for climate change in terms of water supply, water quality, flooding, and habitat requires estimating potential changes to climate, hydrology, and ecosystems based on the best science available at the watershed scale. Available climate projections require spatial downscaling for hydrologic model application and when applied at very fine scales, provide the ability to fully characterize the landscape and potential water supply under changing environmental conditions. This project focused on land managed by the North Bay Watershed Association, incorporating the Napa River and Sonoma Creek drainages, and watersheds in Marin County draining to the bay and coast. Climate change projections (NCAR's Parallel Climate Model and Geophysical Fluid Dynamics Laboratory model for two emission scenarios, A2 and B1) for the next century were downscaled to 270-m and used in a regional water balance model to simulate future conditions of runoff, recharge, evapotranspiration, soil moisture, and climatic water deficit to help characterize the full suite of environmental changes that may occur in these watersheds. Results from this fine-scale modeling indicate for all scenarios that the ecosystems will become more stressed, increasing in average climatic water deficit. However, the change is not the same throughout the whole region and connectivity required for habitat resiliency is likely to be maintained in many locations over the next century. Small areas may be available as refugia to maintain vegetation populations and associated fauna. The projected impact of climate change on water availability for fisheries and human use is less certain but water availability likely to be reduced in some basins as it becomes more extreme or variable in other basins.

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CLIMATE CHANGE AND SPRING-RUN CHINOOK SALMON IN CALIFORNIA: SCENARIO ANALYSIS OF FLOW AND TEMPERATURE CHANGES FOR BUTTE CREEK, CALIFORNIA

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Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) would be particularly vulnerable to climate change because adults hold in freshwater for the summer before spawning in the autumn. Our objective was to determine the streamflow and temperature thresholds that would lead to long-term losses in spring-run Chinook salmon in Butte Creek, a stream in the northern Sierra Nevada of California. Our hypotheses were that (1) climate induced changes in flow and temperature will lead to critical reductions in the available habitat of spring-run Chinook salmon, and (2) the loss/reduction of salmon will reduce the diversity and abundance of biota in the riparian corridor. We used WEAP21, an integrated watershed hydrology, water management, and water quality model to simulate potential changes in flow and temperature in response to climate change in Butte Creek, focusing on the critical summer months. WEAP21 outputs were used to drive SALMOD (USGS), a spatially explicit, size/stage structured population dynamics model that predicts the growth, survival, and movement of salmon in freshwater systems. An expert panel was convened to assess impacts on wildlife resulting from changes to the salmon marine-derived nutrient subsidy. We used bias-corrected and spatially downscaled greenhouse gas emission scenarios A2 and B1 for the period 2010 – 2099 for the six global circulation models (GCMs) recommended by the California Climate Change Research Center. Preliminary scenario analysis of summer months for the periods 2010-2031, 2034-2064, and 2064-2099, using WEAP21 outputs indicate a reduction of streamflow in the ranges of 6-30, 13-32 and 33-45%, and an increase in water temperature in the ranges of 1-2.8, 1.5-3.5 and 2-5.7 °C, respectively, relative to the historical period 1986-2005. We used WEAP21 and SALMOD to evaluate potential management options to ameliorate these impacts. Predicted responses of spring-run Chinook salmon and the riparian biota will be presented in additional presentations in this session.

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CLIMATE CHANGE AND SPRING-RUN CHINOOK SALMON IN CALIFORNIA: PREDICTIONS OF SALMON RESPONSES IN BUTTE CREEK, CA FROM COUPLED WATERSHED AND POPULATION DYNAMICS MODELS

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Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are particularly vulnerable to climate change because adults hold in freshwater for the summer before spawning in autumn. Our objective was to determine the streamflow and temperature thresholds that lead to long-term losses or reductions in spring-run Chinook salmon in a California stream, and to evaluate management options to ameliorate these impacts. Our main hypothesis was that climate-induced changes in flow and temperature will lead to critical reductions in the available habitat of spring-run Chinook salmon. We used WEAP21, an integrated watershed hydrology, water and irrigation management, and water quality model to simulate potential changes in flow and temperature in response to climate change for Butte Creek, California. WEAP21 outputs were used to drive SALMOD (USGS), a spatially explicit and size/stage structured population dynamics model that predicts the growth, survival, and movement of salmon in freshwater systems. We calibrated SALMOD to adult over-summer mortality and smolt out-migration. We ran SALMOD for the period 2010-2099, using WEAP output for carbon emission scenarios A2 and B1, for six global circulation models. We will present results on the potential population trends of Chinook salmon, and the life history stages most susceptible to climate change effects. We are currently using WEAP21 and SALMOD to evaluate management options to ameliorate these impacts.

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IMPLICATIONS OF CHANGING SALMON DYNAMICS TO THE BUTTE CREEK FOOD WEB

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Because they accumulate the majority of their biomass in the ocean, salmon deliver large quantities of marine-derived nutrients to upstream ecosystems during spawning, representing an important subsidy to recipient freshwater and riparian food webs. In addition, terrestrial carnivores and scavengers transport nutrients in the form of fish carcasses and digesta from fresh water to land, enriching the riparian food chain and influencing the biology of major terrestrial consumers. Loss of these ecosystem subsidies may have profound implications for aquatic-terrestrial food webs in recipient watersheds. As part of a larger project modeling climate change related modifications to hydrological and water temperature regimes for spring-run Chinook salmon in Butte Creek, CA (see previous two abstracts), we convened an Expert Panel to develop a conceptual model of the Butte Creek food web, discuss the relative importance of salmon-derived nutrients to the Butte Creek food web, and evaluate the potential for changes to the food web under model assumptions. To assist in this effort, species information was compiled through literature searches, consultation with experts, and remote camera image analysis. Preliminary field work indexed the relative abundance of marine-derived nutrients in selected plant and animal species using stable isotope analysis. Taxonomic groups sampled included spring-run Chinook salmon, benthic macroinvertebrates, epilithic material, riparian plants, terrestrial arthropods, amphibians, reptiles, birds, and mammals. Results suggest that salmon-derived nutrients comprise a significant nutrient subsidy in spawning reaches compared with non-spawning reaches and that loss of these nutrients may have substantial effects on the structure and function of the Butte Creek food web. These insights emphasize the value of management efforts to maintain and enhance viable habitat for spring-run Chinook salmon in Bay-Delta tributaries, since losses of this keystone species may have significant and widespread effects on ecosystem structure and function.

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DEVELOPMENT OF WATER EVALUATION AND PLANNING SYSTEM (WEAP21) WEEKLY HYDROLOGIC MODELS FOR WEST-SLOPE SIERRA NEVADA WATERSHEDS

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The impacts of climate change are expected to be particularly acute in mountainous regions such as the Sierra Nevada of California. Increasing temperature and changes in precipitation patterns will result in changes to snow accumulation and melt. These changes will affect a wide range of hydrologic parameters from soil moisture, stream flow, and stream temperature which will in turn affect the natural and human communities that rely on the existing hydrologic regime. Existing hydrologic models of the region do not resolve these changes down to the spatial scale at which many management decisions are made. In response to this, the Center for Watershed Sciences at UC Davis and the Stockholm Environment Institute has developed hydrology models for the western slope of the Sierra Nevada from the Feather to Kern River watersheds. The models were developed to provide hydrologic simulations at a spatial scale useful for assessing the local impacts of climate change on stream flow, stream temperature, and operations management of hydropower and water supply systems. The models calculate many aspects of the hydrologic cycle including snow accumulation, snow melt, and surface runoff. Weekly predictions of unimpaired stream flows were made at 261 locations throughout the 15 watersheds for the time period 1982-2001. Model input included precipitation and temperature which allowed for analysis of climate change scenarios through the alteration of input weather data. Climate change analysis was conducted through increases in average temperature of 2, 4, and 6 degrees Celsius.

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SIMULATING REGULATED FLOWS IN THE WEST SLOPE SIERRA NEVADA WITH UNIFORM CLIMATE WARMING OF 2, 4, AND 6 °C USING WEAP21

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We developed a water management models for the 15 major basins of the west slope Sierra Nevada to better understand how regulated flows might respond to anticipated regional climate warming. The models, built using WEAP21, simulate hydropower, reservoir operations, water supply demand, and some flood control with a weekly time step across a 20-year time horizon. Simulated changes in climate were restricted to increasing air temperature by 2, 4, and 6 °C and maintaining historical patterns of precipitation. Preliminary results demonstrate that flows abstracted for hydropower generation vary by changes in water year type and losses from reservoir evaporation. We discuss how hydropower systems tend to shift abstractions within a year to match alterations in the timing and magnitude in unimpaired runoff to limit annual losses (i.e., generation and revenue) and how evaporation losses from reservoirs change with climate warming. These potential changes in water management will need to be considered when developing long term management strategies for sustaining Sacramento-San Joaquin Delta ecosystems and California water supply.

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CHARACTERIZATION OF THE UNREGULATED SPRING SNOWMELT RECESSION IN THE WESTERN SIERRA NEVADA, CALIFORNIA AND SIMULATED CHANGES IN WEAP21 WITH REGIONAL CLIMATE WARMING FROM THE FEATHER TO THE KERN RIVER

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We recently developed a conceptual model for the ecology and management of the spring snowmelt recession in Mediterranean-montane catchments. This conceptual model focused on three components of the Natural Flow Regime: magnitude, timing, and rate of change. Here we provide a model definition and develop synthetic hydrographs of the spring snowmelt recession for unregulated catchments of the Sierra Nevada, California. By modeling the exponential decay of snowmelt pulses, we explore empirical evidence for stationarity found in unregulated rivers in contrast with regulated river systems. Lastly, we show the results of spring snowmelt recession dynamics for climate altered hydrologies simulated in the WEAP21 rainfall-runoff model for the west-slope Sierra Nevada using increases in air temperature of 2, 4, and 6° C. Our results show that with regional climate warming the present rate of change in the snowmelt recession will decrease in part due to reductions in snowpack (i.e., decreases in magnitude) and increased duration of low flow conditions, but primarily due to a progressive negative shift in the timing of peak snowmelt. These results suggest potential impacts to freshwater and riparian organisms, which currently respond to the spring snowmelt period and accompanying flow conditions as a favorable window of opportunity for reproduction and population expansion.

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**DEVELOPMENT OF RTEMP, A WEEKLY NUMERICAL MODEL
REPRESENTING UNIMPAIRED EQUILIBRIUM WATER
TEMPERATURE CONDITIONS FOR WEST-SLOPE SIERRA NEVADA
STREAMS AND RIVERS**

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The Sierra Nevada Mountain Range (Sierra Nevada) is expected to experience hydrologic changes under global climate change. Future conditions may include different timing, quantities, and distribution of precipitation events (rain and snow), and/or warmer air temperatures leading to earlier runoff of snowmelt from the higher elevations. To assess the possible impacts of a future climatic change on water temperatures in the major rivers of the Sierra Nevada, a regional, equilibrium based temperature model (RTEMP) was developed. RTEMP uses regionally available meteorological data and digital elevation models (DEMs) to develop weekly equilibrium water temperature (EWT) for the Mokelumne River basin in the Sierra Nevada for various stream reaches determined by elevation contours or “bands”. The model utilized a simplified version of the advection dispersion equation, the full form of the heat budget, and retains critical geometric information about the system in question. This approach produced a time series of “dynamic equilibrium temperatures,” wherein water temperature may not achieve complete equilibrium with meteorological conditions over the specified time period. The model required outputs from WEAP (including air temperature, relative humidity, precipitation, snowmelt, and surface runoff volumes, groundwater base- and inter-flows, and solar radiation) and user specified time series inputs (including cloud cover, wind speed, and initial groundwater and snowmelt temperatures), along with constants and coefficients (including emissivity, water surface reflectivity, specific heat of water, etc.), connectivity matrix, and basic basin information.

Wednesday, September 29, 2010: Room 308-310 Addressing Climate Change in Delta Planning and Management (IV) - Order: 19

RIVER TEMPERATURE IMPACTS AND RESILIENCY TO CLIMATE WARMING IN CALIFORNIA'S SIERRA NEVADA

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This study assesses climate warming impacts on stream temperatures in west-slope Sierra Nevada watersheds from the Feather River to the Kern River. Weekly instream flow estimates from WEAP21, a spatially explicitly, one-dimensional, rainfall-runoff model were passed to RTEMP, an equilibrium water temperature model, to estimate river temperatures using the heat budget, coarse river channel geometry, and exposure time of water to atmospheric conditions. Air temperature was uniformly increased by 2°C, 4°C, and 6°C as a sensitivity analysis to bracket the range of likely outcomes for regional stream temperatures. Other meteorological conditions, including precipitation, were left unchanged from historical values. Model results were analyzed to highlight water temperature resiliency, including contributing factors such as elevation, latitude, baseflow, drainage area, and stream order. Overall, water temperatures increase most at middle elevations (1,500 – 2,500 m), where snowfall is expected to shift to rainfall, and rivers may heat by more than 1.5°C for each 2°C increase in air temperature. River temperatures are generally most resilient to climate warming at the high elevations of southern Sierra Nevada watersheds. Future changes to river temperatures are likely to impact instream habitat conditions, altering the distribution and abundance of fish and wildlife. This work improves our understanding of water temperature resiliency to climate warming for rivers in the Sierra Nevada, and provides river temperature estimates for water managers who must balance instream habitat protection with human water uses, such as water supply, hydropower, flood control, and recreation. Future research includes assessing water temperature resiliency with regulated conditions and climate warming because cold-water supplies from large reservoirs may increase opportunities to manage water temperature in Sierra Nevada rivers.

Wednesday, September 29, 2010: Room 308-310 Addressing Climate Change in Delta Planning and Management (IV) - Order: 20

TEMPORAL AND SPATIAL PATTERNS IN BENTHIC INVERTEBRATES IN THE SAN FRANCISCO BAY

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San Francisco Bay (SFB) is a highly urbanized estuary that has lost over 80% of historic tidal marshes. Numerous large scale wetland restoration efforts are underway to benefit a diverse assemblage of species that utilize the tidal marsh and tidal flats. One of the key uncertainties is the short term geomorphological changes in the shoals environment due to restorations and shifting sediment demands in the estuary along with long term changes attributed to sea level rise. Intertidal and subtidal shoals are vital food resources for bird communities. SFB is recognized as an important wintering and stopover site for migratory shorebirds and waterfowl that use the area's tidal mud flat and shoals habitats. We have conducted hydrogeomorphological measurements and biological surveys on the shoals outside Pond SF2 in the South Bay Salt Pond Restoration Project. These surveys enable us to track physical changes through time, and to relate the spatial and temporal dynamics of benthic invertebrate communities to the resulting shifts in avian abundance and distributions. We collected hydrology, bathymetry, monthly benthic invertebrates (Oct 2008-current), biweekly low tide bird surveys, and focal bird surveys. Invertebrate composition and abundance varied by elevation (range: -0.8 m to 1.1 m) and month. Bivalve (predominately *Gemma gemma*) abundance was greatest nearshore, i.e., within the first 200 m from shore (elevation range 0.86m to 1.10m) with avg 5,461 bivalves/m²) compared to mid-shore, i.e., 300-800m away from shore (elevation range: -0.8 to 0.8 m) with an avg of 71 bivalves/ m²). The size frequency distribution of bivalves was skewed towards the smaller size classes: 53% of bivalves were <2mm, 18% were 2-4mm, 8.8% were 4-6mm, 17.6% were 6-12mm, and <1% was > 18mm. Unlike bivalves, amphipod abundance increased with distance from shore (avg 26 amphipods/ m² nearshore and 1040 amphipod/ m² mid-shore), while polychaetes were evenly distributed. These data can help assess invertebrate prey availability with seasonal bird use and mudflat hydrogeomorphology.

Wednesday, September 29, 2010: Room 311-313 Food Webs (I) - Order: 1

ACUTE AND CHRONIC TOXICITY OF AMMONIA ON PSEUDODIAPTOMUS FORBESI

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The calanoid copepod *Pseudodiaptomus forbesi* is an important food source to larval and juvenile stages of fish in the San Francisco Estuary (SFE). The estuary experiences continuous anthropogenic inputs of ammonia from agricultural runoff. Ammonia can cause toxicity to fish but little is known on the effects of ammonia in *P. forbesi*. To investigate the chronic and acute effects of ammonia, the 4 days (d) median lethal concentration (LC50) was determined for unionized ammonia (UA) and ionized ammonia (IA) for 1) pH 7.4, 2) pH 7.8 and 3) constant Total Ammonia Nitrogen (TAN) of 3.71 mg/L for pH 7.0, 7.4, 7.8, 8.2 and 8.6. The effects on survival, growth and reproduction will be determined from the chronic exposure study using 0.25, 0.5, 1, 2 and 4 mg/L of TAN at pH 7.8 for 30 d. Results indicate that ammonia toxicity is dependent on pH levels. *P. forbesi* is more sensitive to pH 7.4 compared to pH 7.8 indicating sensitivity to increasing IA concentrations. At constant TAN, *P. forbesi* is more sensitive at high pH due to increasing UA concentrations. An ongoing experiment will determine the chronic levels of UA and IA and their overall effects on copepod growth and reproduction. These results demonstrate pH effects on ammonia concentrations that will render acute and chronic toxicity to the copepod. By determining threshold levels of ammonia, guidelines for water quality maintenance can be established to protect calanoid copepods and other important food sources of pelagic fish in the SFE from ammonia toxicity.

Wednesday, September 29, 2010: Room 311-313 Food Webs (I) - Order: 2

THE PHYSICAL-BIOLOGICAL FUNCTIONING OF AN EXISTING FLOODED ISLAND: LESSONS FROM A NUMERICAL MODEL

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In the next 50 years, the Sacramento-San Joaquin Delta is likely to be characterized by many more flooded farm tracts than currently exist. The future flooding of Delta islands may be the result of unplanned flood- or earthquake-induced levee failure, or of proactive flooding for habitat restoration and the protection of water quality, property, and human life. Measurement and modeling of physical and biological functions within existing Delta flooded islands can help hone our expectations of future post-flood habitat function, and provide valuable design information to guide planned flooding efforts. A three-dimensional numerical model of hydrodynamics, water temperature, and phytoplankton dynamics was applied to Mildred Island, an existing Delta flooded island. Driven and validated with measurements from intensive field studies, this model performs well in capturing tidally and atmospherically driven dynamics of current velocity, stage, and water temperature. Phytoplankton biomass variability, which is regulated by three-dimensional hydrodynamics as well as by light-limited growth, zooplankton grazing, and clam grazing, is also characterized well by the model. We are using the model to test the sensitivity of this island habitat to changes in geometry, atmospheric forcing, water clarity, and grazing. The goals are to 1) better understand the combination of physical and biological forcings that make Mildred Island one of the most productive habitats in the largely unproductive Delta; 2) assess how this habitat might function in the future; 3) shape our expectations of the functioning of future flooded islands; and 4) provide insights regarding the effects of controllable habitat attributes to inform potential future planned flooding of subsided Delta farm lands.

Wednesday, September 29, 2010: Room 311-313 Food Webs (I) - Order: 3

SPRING 2010 PHYTOPLANKTON BLOOMS IN NORTHERN SAN FRANCISCO ESTUARY: INFLUENCES OF CLIMATE AND NUTRIENTS

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Low primary production and chlorophyll biomass has characterized the northern San Francisco Estuary (SFE) for the past three decades and have been linked to significant declines in higher order pelagic organisms within this ecosystem. Declines have been attributed to climate shifts, invasive species, and changes in nutrient loading. Our previous research indicates that the form of nitrogen making up the dissolved inorganic nitrogen (DIN) pool for phytoplankton growth can determine phytoplankton biomass accumulation and community structure; with high levels of ammonium in SFE inhibiting phytoplankton nitrate uptake, leading to low levels of primary production. During the anomalously wet year (2010), precipitation events occurred late into the spring period, and phytoplankton blooms were observed within the northern SFE. Here we describe phytoplankton bloom events occurring in Suisun Bay during April and May 2010 based on six samplings of seven stations distributed just upstream, just downstream and within Suisun Bay. Extracted chlorophyll values up to 30 $\mu\text{g/L}$ were recorded in Suisun Bay in mid-April, and remained elevated 2 weeks later. Maximal chlorophyll values ($\sim 35 \mu\text{g/L}$) were measured into late May, with Suisun Bay and adjacent Grizzly Bay averaging in excess of 27 $\mu\text{g/L}$. The 2010 bloom was enabled when the ammonium concentration fell to below 4 μM , and rapid phytoplankton biomass increases followed a measured nitrate drawdown. Additionally, salinity was low in the high chlorophyll locations. These two conditions, low ammonium and low salinity were key features in the only other spring bloom we have observed in Suisun Bay (in 2000). Knowledge gained by studying nutrient inputs and phytoplankton community structures, will provide a base for understanding the relationship between primary, secondary, and top producers in the SFE.

Wednesday, September 29, 2010: Room 311-313 Food Webs (I) - Order: 4

NOVEL APPLICATION OF MICROSCALE AGGREGATE CULTURE OF HEPATOCYTES TO SCREEN FOR HARMFUL CYANOBACTERIAL BLOOM TOXINS

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Microcystins comprise a family of over 80 potent hepatotoxins prevalent in harmful algal blooms worldwide. Persistent in freshwater supplies, microcystins are not degraded by boiling. To date, no hepatocellular toxicity assay has been established to monitor for comparative toxicity of microcystins due to the expression of OATP transporters responsible for microcystin uptake in established cell lines. It was hypothesized that aggregate culture of HEPG2 liver cells would increase relevant OATP expression as compared with two-dimensional culture due to increased cell-cell interactions and, thus, confer microcystin uptake and acute dose dependent toxicity in aggregate cultured cells as compared with controls. The specific aims were 1) to evaluate expression of OATP1B1 and OATP1B3 in aggregates relative to control culture, 2) to compare uptake of microcystins in aggregates relative to control, and 3) to compare microcystin toxicity to aggregates relative to control. Preliminary results have shown significantly increased mRNA expression of OATPs in aggregate culture relative to 2D culture ($p < 0.05$, students t-test) at day 3 through day 7 of culture. Increased protein expression in aggregates relative to control is expected. Additionally, aggregate cultured HEPG2 cells are anticipated to demonstrate increased uptake of microcystins as compared with controls and, as such, increased sensitivity to toxicity. Despite identification of over 80 structural congeners, risk assessment and drinking water guidelines (WHO, EPA) are based on one sole congener, MC-LR. Animal deaths have been linked with other congeners. Diverse species effects suggest that mouse bioassay, the sole toxicity assay, may not be sufficient for predicting in vivo toxicity. Upon validation, this approach can be applied to compare toxicity of the congeners and to evaluate diverse species effects in vitro by modifying the approach for additional species cell lines.

Wednesday, September 29, 2010: Room 311-313 Food Webs (I) - Order: 5

METABOLIC RESPONSES TO ENVIRONMENTAL SALINITY IN THE INVASIVE CLAM *CORBULA AMURENSIS*

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Invasive species can have large impacts on food webs if they have higher metabolic demands than extant species. The clam *Corbula amurensis* is believed to have caused a large shift in the pelagic food web in the northern reach of the San Francisco Estuary since its introduction in the 1980s. This shift has been attributed to the clam's high density, high suspension-feeding rates, and ability to thrive in a wide range of salinities. We investigated the metabolic responses of *C. amurensis* following acclimation to constant low, constant high and fluctuating salinities. We measured growth rate, feeding rate, respiration rate, activity of the metabolic enzyme malate dehydrogenase (MDH), and osmoregulatory performance. On average, clams did not grow during a three-month period at either high or low salinity. Clams fed more rapidly following acclimation to high salinity than low. Activity of MDH was higher at high salinity in both foot and mantle tissues. In comparison to other clam and fish species, *C. amurensis* had substantially higher MDH activities. *C. amurensis* had higher metabolic rates in both high and low salinity than in fluctuating salinities. Osmotic pressure of *C. amurensis* tissues was always lower than that in the acclimation water, but clams hyporegulated to a greater extent in high-salinity conditions. Overall, our results suggest that clams experiencing higher salinities have a higher metabolic demand to support osmoregulation and compensate by increasing their filter-feeding rate.

Wednesday, September 29, 2010: Room 311-313 Food Webs (II) - Order: 6

SPATIAL AND TEMPORAL VARIATION IN SELENIUM CONCENTRATIONS IN THE INVASIVE CLAM CORBULA AMURENSIS IN THE SAN FRANCISCO BAY ESTUARY FROM 1995 TO 2010

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Selenium (Se), a naturally occurring trace element, can be mobilized by human activities in sufficient quantities that may threaten fish and wildlife. Efforts to differentiate contributions of local estuarine inputs relative to riverine inputs of Se in the San Francisco Bay and Delta are ongoing. Changing water management strategies and climate change, could alter Se sources and increase Se delivery to the Bay potentially endangering species of concern. Identifying Se sources has been confounded by limited bioaccumulation data in target species that span a range of hydrodynamic and estuarine conditions and models that relate bioaccumulation data to dynamic estuarine processes. As part of the CASCaDE (Computational Assessments of Scenarios of Change for the Delta Ecosystem) and USGS funded projects we are collecting baseline-monitoring data that is being used to develop models that integrate biodynamic and estuarine processes controlling the fate and effects of Se in food webs and in species of concern. Here we present bioaccumulation data for the models under development including fourteen years of Se concentrations in the invasive clam *Corbula amurensis* collected monthly at Carquinez Strait, in Suisun Bay and at the convergence of the Sacramento and San Joaquin Rivers. Selenium concentrations in the clams over the period of study ranged from a low of 8.5 to a high of 21.7 $\mu\text{g/g}$ and showed strong spatial and seasonal variation. Significant variation in Se concentrations was also observed among years where values declined from 1997 through 2005 and then increased to near 1997 levels in 2008. We present several hypotheses to explain variation in bioaccumulation data relative to biology and changing estuarine conditions.

Wednesday, September 29, 2010: Room 311-313 Food Webs (II) - Order: 7

GRAZING IMPACT OF THE OVERBITE CLAM ON THE MICROZOOPLANKTON ASSEMBLAGE OF THE SAN FRANCISCO ESTUARY

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The overbite clam *Corbula amurensis* has altered the San Francisco Estuary (SFE) since its introduction in 1986, and its feeding is believed to be the cause of a substantial decline in phytoplankton biomass and in abundance of some zooplankton species. Previous studies have demonstrated high feeding rates of *C. amurensis* on phytoplankton, bacteria, and copepod nauplii; however, no information is available about grazing on other microzooplankton. Microzooplankton are defined as heterotrophic eukaryotes 20 - 200 μm , which includes copepod nauplii, rotifers, naked ciliates, and tintinnid ciliates. Microzooplankton provide a key link in pelagic foodwebs by consuming phytoplankton and bacteria, and in turn being eaten by mesozooplankton. The primary objectives of this study were to (1) monitor the current abundance of microzooplankton in the Low Salinity Zone of the SFE (salinity < 6) in 2008 and (2) measure consumption rates of *C. amurensis* on microzooplankton, particularly ciliates. Feeding experiments revealed that the clams cleared 0.5 L ind⁻¹ h⁻¹ of microzooplankton, compared to a clearance rate of 0.2 L ind⁻¹ h⁻¹ of chlorophyll. When extrapolated to field populations of clams, these clearance rates exceed the growth capacity of ciliates. A lack of comparable data from before clams arrived precludes assessment of population changes in the microzooplankton, but at present they must be heavily subsidized from other parts of the estuary. Clams obtained much more of their food from phytoplankton than from the less abundant microzooplankton. This study complements other studies to show that all planktonic functional groups are consumed at high rates by *C. amurensis* in the SFE.

Wednesday, September 29, 2010: Room 311-313 Food Webs (II) - Order: 8

BIOMASS TRENDS IN A BIVALVE AT A DWR LONG TERM MONITORING SITE IN THE SACRAMENTO-SAN JOAQUIN DELTA

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The Department of Water Resources (DWR) conducts a benthic monitoring program and has been doing so for several decades. The monitoring has, historically only yielded abundance and species data. Beginning in January of 2007, an extra benthic sample has been collected during each sampling event. All live clams are removed, measured, weighed and an ash free dry mass was calculated. Regression equations from these samples have been used to predict the biomass for preserved historic samples for the invasive freshwater clam *Corbicula fluminea* at one of our long-term monthly monitoring sites, D28A (Old River near the mouth of Rock Slough). We have conducted analysis for trends over time and believe that future investigations invasive bivalve population size structure and biomass will yield information about the influence of local habitat characteristics on population density, biomass and grazing potential. This research could also be essential for managers of restoration programs in the Delta by assessing potential constituents that could affect food web mechanics in aquatic habitats.

Wednesday, September 29, 2010: Room 311-313 Food Webs (II) - Order: 9

CLAMS, FISH, SHRIMP, BIRDS, AND PHYTOPLANKTON: CAUSES AND EFFECTS OF SEASONAL AND INTERANNUAL VARIABILITY IN CLAM BIOMASS AND GRAZING IN THE NORTHERN SAN FRANCISCO ESTUARY

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Bivalves in the San Francisco Estuary are important as (1) prey for birds, demersal fish and invertebrates; (2) consumers of phytoplankton, microzooplankton, bacteria, and zooplankton; and (3) as vectors of contaminants. These multiple bivalve connections to the ecosystem mean it is important to understand what drives the seasonal and inter-annual variability in bivalve abundance and biomass in the estuary. We have used bay-specific conceptual models of bivalve recruitment, growth and mortality to understand and demonstrate the two major time scales of variability. Time series of bivalve biomass and abundance data were examined in conjunction with time series of environmental data and abundance of bivalve predators to determine the primary causes of the bivalve fluctuations. Seasonal variability in most of the northern estuary can be accounted for by a combination of physiological stresses due to long duration low salinity periods, natural mortality due to old age, and predation by birds. Interannual variability is driven by extremely high freshwater flow events and interannual variability of specific predators in the different embayments of the estuary. The San Francisco Bay Study (CDFG) trawl time series has allowed us to examine the close timing between bivalve recruitment, high demersal fish, shrimp and crab abundance, and the subsequent demise of the bivalve population in San Pablo Bay during good recruitment years of those predators. The result of this variability is that bivalve grazing in the years of high predation is very low thereby reducing grazing pressure on the phytoplankton during the summer and fall periods. We hypothesize that when large populations of demersal fish and invertebrates preyed on smaller juvenile clams, the adult bivalves that are prey for migrating ducks have greatly declined. Suisun Bay bivalve populations have fluctuated interannually but there is less evidence of changes in predator abundance driving the variability in this embayment.

Wednesday, September 29, 2010: Room 311-313 Food Webs (II) - Order: 10

APPLICATION OF A WINTER RUN CHINOOK LIFE-CYCLE MODEL TO EVALUATE CONSERVATION MEASURES AND PROPOSED WATER PROJECT OPERATIONS

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Following the listing of a majority of salmon and steelhead populations on the U.S. Pacific Coast under the Endangered Species Act (ESA), debate began over the type and magnitude of actions needed to recover listed populations. The CALFED Science Independent Review of the analytical framework for assessing water project operations recommended the development of an integrative life-cycle, spatially explicit population model. We developed such a life-cycle model (operating on a daily time step) and used it to evaluate the influence of alternative water project operations (flows, temperatures, exports, floodplain inundation, Delta routing) and the effectiveness of conservation measures (habitat enhancements, predator reductions, harvest management, non-physical barriers) on winter run Chinook abundance and productivity. Model functions and parameters were derived from existing monitoring studies, especially mark-recapture data from acoustic and coded wire tag studies. Results indicate that water temperatures for egg incubation, predation mortality in the Sacramento River and Delta, and ocean harvest are major drivers of winter run Chinook abundance trends. Increased Yolo Bypass flooding and reduced South Delta exports yielded smaller benefits. Our life-cycle modeling proved to be a useful approach for distinguishing potential benefits of various recovery actions, framing expectations for population growth, and identifying critical data needs to support future management.

Wednesday, September 29, 2010: Room 311-313 SC-Species and Communities (I) - Order: 1

DEVELOPMENT OF FLOW AND THERMAL REGIMES FOR SPRING-RUN CHINOOK SALMON IN CLEAR CREEK

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Instream flow and water temperature in Clear Creek, a tributary to the Upper Sacramento River, have changed significantly since the construction of Whiskeytown Dam. Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in Clear Creek were extirpated for 30 years until they reappeared in 1999. Although the abundance of spring-run Chinook salmon has been increasing over the last decade, the population is still vulnerable to extirpation from demographic stochasticity. The objective of this study is to develop a flow regime, which integrates the characteristics of stream hydrology and water temperature requirements, to best promote recovery and enhancement of spring-run Chinook salmon populations in Clear Creek. The analysis of pre- and post-dam streamflow data in Clear Creek using the IHA method provided a basis for assessing hydrologic alterations of flow quantity, frequency, timing, and duration. Based on the data analysis, a “natural” flow regime in Clear Creek should include monthly low flows, high-flow pulses, and small floods. The development of a flow regime must also consider the thermal regime, especially during the summer when high water temperatures can be lethal to fish. A regression model was developed to estimate the reservoir release necessary to meet downstream water temperature requirements for spring-run salmon. The final instream flows recommended for Clear Creek considered both flow and thermal regimes. In addition, an adaptive management strategy for implementing the recommended instream flows and assessing the performance of the implementation will be discussed.

Wednesday, September 29, 2010: Room 311-313 SC-Species and Communities (I) - Order: 2

BIOLOGICAL COMMUNITIES IN SAN FRANCISCO BAY TRACK A NORTH PACIFIC CLIMATE SHIFT

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Oceanic populations are known to fluctuate in synchrony with large-scale climate patterns, but similar evidence has been lacking for estuaries because of shorter observational records; the dominant driver of estuarine ecosystem variability is often assumed to be river flow. In the San Francisco Bay, fish and invertebrates have been sampled systematically since 1980, and that data series shows large and unexplained changes in populations. Our analysis shows that several demersal populations of fish, crabs, and shrimp covary with two basin-scale modes of North Pacific climate, namely the Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NPGO). We present models that show these two modes account for large proportions of variance in these species, even in the presence of local outflow measurements. These findings demonstrate that forecasts of estuarine response to climate change must take into consideration how altered patterns influence coastal oceanography as well as watershed hydrology.

Wednesday, September 29, 2010: Room 311-313 SC-Species and Communities (I) - Order: 3

EVALUATING THE EFFECTS OF PROJECTED SEA-LEVEL RISE ON ENDEMIC TIDAL MARSH SPECIES IN SAN FRANCISCO BAY ESTUARY; AN INTERDISCIPLINARY APPROACH

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Coastal salt marshes and estuaries are projected to be disproportionately impacted by climate change and sea level rise, according to projections by the Intergovernmental Panel on Climate Change. Over 80% of wetlands in San Francisco Bay estuary have been lost to urban development and landscape modification. The San Francisco Bay estuary, though severely fragmented and modified, represents the largest remaining habitat for federally and state listed species. Projected sea-level rise could pose synergistic effects. Maintenance of habitat is crucial to the success of endangered species, but it remains unknown how sea level rise may impact the amount and quality of habitat for these species. Our goal in this ongoing research is to provide information to resource and land managers charged with the protection of endangered species and their habitats that are in need of regional and site-specific data to anticipated climate change impacts to their lands. A total of 13 San Francisco Bay salt marsh sites are included in this study. Changing sediment loads, extreme tide and storm events, salinities, and sea level rise will affect tidal marshes by altering the plant community composition and structure that provide the critical habitat for these endemic species. Our on going interdisciplinary study objectives are to: (1) develop high resolution elevation models using a RTK GPS of the tidal salt marshes and project effects of sea level rise and identify potential critical thresholds for vertebrate species; (2) model sediment geomorphic characteristics to evaluate marsh persistence through time; and (3) downscale tidal cycles to assess site-specific inundation patterns in the local marshes. We will be presenting our USGS National Climate Change Wildlife Science Center ongoing funded work in San Francisco Bay.

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LIFE HISTORY DIVERSITY WITHIN SPRING-RUN CHINOOK SALMON POPULATIONS

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Degradation and removal of habitat often impacts population and life-history diversity non-randomly. For instance, the Sacramento River has experienced a non-random loss of Chinook salmon populations' run timing and rearing strategies due to damming of upstream spawning grounds. In particular, spring-run populations that historically exhibited both a short (3-6 months; ocean-type) and long (10-15 months; stream-type) juvenile freshwater rearing strategy have been either extirpated or are federally listed as threatened under the ESA. Here we examine life-history diversity (i.e. freshwater rearing duration) in the three remaining independent spring-run populations (Mill, Deer, and Butte Creeks) and a fourth population, Clear Creek, which has recently been colonized following removal of a dam. To achieve this we have utilized otolith microchemical methods, specifically Sr isotopes, applied to adult spawners to retrospectively measure temporal and spatial patterns of freshwater residence during the juvenile life stage. We analyzed over 100 otoliths from 2007 spawning adults collected from our four study populations. Residence time in natal streams after first feeding ranged from <2 to 8 months, with most leaving either before 100 days or after 180. Juveniles spent very little time in the Delta (<45 days), even though this is often assumed to be an important rearing habitat. Total time to ocean entry ranged from 2 to 11 months, however >70% of individuals spent 6 months or less in the freshwater system. The current dominant populations in the Sacramento are fall run which only rarely exhibit stream-type behavior. This represents a shift from historical conditions; stream-type populations (i.e., spring and winter run) were prevalent in the Sacramento system before dams removed much of the headwaters habitat. As dams are removed and new habitat is made available, plasticity of these populations and life-histories will determine necessity and degree of management intervention to ensure colonization success.

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THE HISTORY OF NATIVE OYSTERS IN SAN FRANCISCO BAY: IMPLICATIONS FOR RESTORATION

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Federal- and state-funded efforts to restore native oysters (*Ostrea lurida*) in San Francisco Bay started in 1999, and plans and goals are now being developed for the large-scale creation of oyster beds in the Bay. These efforts are predicated on the well-known and oft-repeated history of the native oyster: it was hugely abundant in the Bay at the time of European contact, providing an important food source for the region's Native American inhabitants as shown by the accumulation of oyster shells in the Bay's shell mounds; it declined rapidly during the early colonial period due to a combination of overharvesting, pollution, and smothering by hydraulic mining sediment; and then it was apparently absent for decades until its rediscovery in the late 1990s, which initiated the current restoration efforts. However, a review of the historical, archaeological and geological evidence calls this common understanding of the history of the native oyster into question: virtually everything in this history is unsupported by the available physical and historical data. Restoration efforts have been successful when there is good evidence of the level of past abundance, a clear understanding of what anthropogenic stressors have reduced that past abundance, and a sufficient capacity to end or undo the effects of those stressors. All of this appears to be lacking in the case of the Bay's native oysters, which suggests that the existing restoration projects and the plans and goals being developed should be reconsidered.

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GOING WITH THE FLOW OR STAYING CLOSE TO HOME? POPULATION CONNECTIVITY, FRESHWATER FLOW, AND NATIVE OYSTER RESTORATION IN SAN FRANCISCO BAY

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A key missing piece of information for managers working to restore populations of the native oyster, *Ostrea conchaphila*, in San Francisco Bay is a clear picture of the links between populations in different parts of the Bay. Knowledge of population connectivity also will greatly improve our understanding of the causes and consequences of fluctuations in abundance and geographic distribution, as well as responses to floods, droughts, and many other disturbances. Do populations in some areas act as sources of larvae that maintain populations in other parts of the Bay? Are some apparently thriving oyster populations only able to keep up appearances due to constant inflow of larvae from source populations elsewhere? Do connectivity patterns change with altered freshwater outflow levels entering the Bay? We investigated oyster population dynamics and larval dispersal patterns in San Francisco Bay using a combination of population surveys, recruitment monitoring, and trace elemental fingerprinting methods. We examined oyster populations during the low flow season at the end of a three-year drought (Fall 2009) and during higher flow conditions (Spring 2010). In the fall of 2009, oyster abundance and size distributions differed significantly along the salinity gradient from upstream sites toward the mouth of the Golden Gate, with a maximum density of over 300 oysters / m² occurring in brackish waters near China Camp State Park. Significant regional variation in temperature and salinity conditions appear to be correlated with differences in timing of spawning and settlement throughout the year. Juvenile recruitment varied significantly around the Bay, with greatest settlement in moderately-to-high salinity areas, especially during warmer periods. Oyster larvae from different sites around the Bay contained sufficiently distinct trace elemental fingerprints to be discriminated from each other at fairly small spatial scales. Natal origins of collected juveniles are currently being investigated and will be presented.

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MIGRATION TIMING, ABUNDANCE AND DISTRIBUTION OF SANDHILL CRANES IN THE SACRAMENTO-SAN JOAQUIN DELTA OF CALIFORNIA

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The Sacramento-San Joaquin Delta is an important wintering area for two subspecies of Sandhill crane (*Grus canadensis*), including the threatened greater sandhill crane (*G. c. tabida*). Effective crane conservation and management requires an understanding of migration chronology, winter abundance and distribution, subspecies composition, and significance of the Delta landscape. We conducted surveys during 2007-08 and 2008-09 to document crane migration chronology, winter abundance and distribution. We counted cranes from the ground bi-weekly at roost sites and during the morning foraging periods at several major use areas in the Delta. We also conducted three aerial surveys on randomly-selected transects in 2007-08. Cranes first arrived in the Delta in early September with arrivals peaking in early October and departures peaking in late February. The last cranes departed in mid-March. Our sandhill crane population estimates from roost counts ranged from 6,421 to 27,213, averaging 15,037 during the winter season. Estimates from aerial surveys (conducted in January and February only) ranged from 9,028 to 21,225 and averaged 16,445. Fluctuations in population estimates over time were primarily due to movements of lesser sandhill cranes (*G. c. canadensis*) in and out of the Delta. We estimated that at least 2,750 of the state-Threatened greater sandhill cranes wintered in the Delta. We combined a variety of survey data and radio-telemetry locations to map crane distribution in the Delta. This information has implications for focusing management and conservation and future mitigation efforts on the most important regions of the Delta as well as timing of management of roost sites and foraging landscapes for greater sandhill cranes.

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WINTERING SHOREBIRDS IN THE SAN FRANCISCO BAY ESTUARY: POPULATION CHANGE AND FUTURE MONITORING

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The San Francisco Bay estuary (SF Bay) provides habitat for more migrating and wintering shorebirds than any other coastal wetland on the US Pacific coast south of Alaska and has been designated as a site of hemispheric importance by the Western Hemisphere Shorebird Reserve Network. Currently there is no annual effort to monitor shorebirds using SF Bay despite ongoing habitat changes in the estuary. Designing an efficient and robust annual shorebird monitoring program for SF Bay is an essential step towards the long-term conservation and management of shorebirds in the Western Hemisphere. As part of a larger project to develop a monitoring program for wintering shorebirds in all of California, we employed data from comprehensive November censuses of SF Bay (1990 – 1992 and 2006 – 2008) to quantify spatial and temporal changes in shorebird populations between time periods and to conduct spatial sampling simulations. We assessed the efficacy of reduced effort surveys (e.g. 50% of comprehensive survey) and several sampling frameworks (e.g. stratified random sampling) to identify changes in shorebird populations in SF Bay that were observed in the high-effort, comprehensive censuses. Our data suggest that, overall, populations of the majority of shorebird species in SF Bay were similar between 1990 – 1992 and 2006 – 2008 with the mean total number of shorebirds counted annually in the two time periods being 342,991 and 344,954, respectively. Our simulations suggested that a 75% reduction in survey effort could provide estimates of population change within 20% of the true change using an appropriately weighted stratified sampling design. Based on this analysis, we propose a statistically robust, logistically feasible, long-term monitoring program for wintering shorebirds in SF Bay to track spatial and temporal population trends and the impact of changing climate and habitat conditions.

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HABITAT SUSTAINABILITY FOR AN ENDANGERED SONGBIRD: A CASE STUDY ON THE SACRAMENTO RIVER

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The California-listed endangered songbird, the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), has fewer than 300 individuals remaining statewide according to the most recent census published in 2000. The largest population (about 100 individuals) was found in the riparian forests on the Sacramento River. Large patches of Fremont cottonwood (*Populus fremontii*) and willow (numerous *Salix* spp.) are known to be the reproductive and feeding habitat of cuckoos on the river. The reproduction and growth of these plant species are dependent on flooding cycles and new geomorphic substrates created from channel meander processes (erosion and deposition). The vegetation patches have been found to persist in the floodplain between 10-60 years. To better understand the temporal dynamics of the cuckoo's habitat, a 132 km (80 river miles) study reach on the meandering sector of the Sacramento River was studied to document spatial shifts in cuckoo habitat patches due to hydro-geomorphic processes, vegetation recruitment, and succession over a 35 year period (1952-1987). The co-occurrence of natural vegetation and floodplain age were used to model patches of the cottonwood-willow plant association. Of the 1,664 ha of habitat patches in 1952 only 247 ha (15%) were coincident with 1987. Of the 62 patches delineated for 1987, 17 (27%) emerged anew and independently of the 1952 patches and the remaining 83% formed from shifting adjacent to the patches from 1952. The degree to which the surrogate variable "floodplain age" could predict the presence or absence of cuckoos was tested using four years of observation data (1987-1990); it was found that 75% of patches were correctly predicted for cuckoo presence or absence. The commission error and the omission error were each 12.5%. These findings suggest that long-term sustainability of yellow-billed cuckoo habitat requires on-going river channel meander dynamics to maintain regeneration of large patches of cottonwood-willow plant communities.

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REBUILDING DELTA SOILS: THE BALANCE OF GREENHOUSE GASES

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Efforts to restore and convert wetlands on deeply subsided Delta peat islands hold many environmental benefits such as subsidence reversal, soil carbon storage, and atmospheric carbon sequestration. Although these ecosystems can store carbon dioxide (CO₂) or limit the oxidation of existing peats, the anaerobic conditions created by permanent and semi-permanent flooding can result in the release of methane (CH₄), a more potent greenhouse gas. The USGS Carbon Group, Sacramento and UC Berkeley Biometeorology group are conducting studies to measure CO₂ and CH₄ emissions from two types of wetland restoration management strategies to rebuild soils on existing agricultural peatlands: (1), conversion to rice cultivation, and (2), conversion to a continuously inundated wetland. Quasi-continuous measurements utilizing eddy covariance for CO₂ and CH₄ were conducted on Twitchell Island above rice cultivation plots in 2009 and above a restored wetland marsh in 2010. Preliminary results suggest that rice cultivation can be a strong sink for CO₂, due to high rates of photosynthesis during the day and the inhibition of CO₂ released at night as respiration is limited by the flooded conditions. CH₄ emissions were lower than expected, but still about two times the amount compared to the CH₄ measurements collected from a pasture located on Sherman Island. The lower than expected CH₄ emissions may be due to the fact that 2009 was the first year of cultivation and there is a lack of an established methanogenic bacteria community and/or a suitable substrate of labile carbon. Initial results from the restored wetland are similar to the rice cultivation plots and have the potential to be a strong sink for CO₂. However, CH₄ fluxes are expected to be higher as conditions for methanogenesis most likely exist after ten years of vegetative growth since the wetland was established.

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CARBON STORAGE, GAS FLUXES, AND POTENTIAL GREENHOUSE GAS EFFECTS OF RE-ESTABLISHING WETLANDS ON ORGANIC SOILS IN THE SACRAMENTO-SAN JOAQUIN DELTA

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Draining wetlands in the Sacramento-San Joaquin Delta has caused oxidation and subsidence of the underlying organic soils. Following wetland re-establishment to two different water depths in 1997 (continuously flooded to ~25 cm and ~55 cm), we measured morning to midday gaseous carbon (C) fluxes, approximately monthly, by using vented chambers, for 6 years; and, estimated annual C storage for over a decade. Carbon dioxide (CO₂) losses from the organic soil decreased as much as 10-fold shortly following flooding. Results from ¹⁴C isotope analysis showed that CO₂ emitted from a neighboring agricultural field contained significant 'old' carbon, while wetland CO₂ emissions were of a more modern origin. The shallower wetland showed more CO₂ uptake and respiration than the more deeply flooded wetland; but, the deeper marsh emitted more methane (CH₄). Thus, the shallower wetland had greater potential estimated greenhouse gas reduction benefits than the deeper wetland, despite similar estimates of annual carbon storage in areas with emergent marsh in both wetlands. Overall, CO₂ uptake was enough greater than CH₄ release in areas of emergent marsh that not only does re-establishing marshes in the Delta restore a strong carbon sink to the region, but greenhouse gas balance estimates demonstrated potential for significantly reduced radiative forcing. Furthermore, spatial variability in wetland environmental conditions appeared to affect decomposition dynamics and consequent CH₄ losses, suggesting that wetland management can be used to minimize the greenhouse gas effects of re-established marshes in the Delta. In contrast, areas without emergent vegetation showed little carbon storage, and much lower uptake of CO₂ compared to CH₄ losses, such that the increased radiative forcing from these areas may not be counterbalanced by the benefits of mitigating the oxidative loss of organic soils with flooding.

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TRIALS AND TRIBULATIONS ON MEASURING GREENHOUSE GAS (CARBON DIOXIDE, METHANE AND WATER VAPOR) FLUXES OVER A PEATLAND PASTURE AND RICE PADDY IN THE SACRAMENTO-SAN JOAQUIN DELTA

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New advances in laser spectrometers are enabling us to measure greenhouse gas (methane, carbon dioxide, water vapor) fluxes directly and quasi-continuously with the eddy covariance technique. We have been measuring methane, carbon dioxide and water vapor fluxes for the past 3 years over a degraded peatland pasture on Sherman Island and over a rice paddy on Twitchell Island the past year. These measurements are enabling us to deduce rates of net and gross greenhouse gas exchange that is occurring over drained and flooded peatlands in the Delta. However, to avoid potential artifacts due to advection from upwind wetlands, ditches and/or cows, we conducted a set of ancillary studies that help us interpret our flux measurements. In this talk we report on our flux measurements. In summary we find that the drained pasture is a small source of methane ($< 10 \text{ nmol m}^{-2} \text{ s}^{-1}$), a moderate source of carbon dioxide and a steady source of water vapor ($> 700 \text{ mm/y}$). The episodic occurrence of cows in the flux footprint yields methane fluxes that exceed $100 \text{ nmol m}^{-2} \text{ s}^{-1}$. In comparison, the rice paddy is a small source of methane ($5\text{-}15 \text{ nmol m}^{-2} \text{ s}^{-1}$), a net sink for CO_2 from the atmosphere (about $200 \text{ gC m}^{-2} \text{ y}^{-1}$) and an strong source of water vapor ($> 1000 \text{ mm/y}$).

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RECENT ADVANCES IN SUBSIDENCE MEASUREMENT AND MITIGATION

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Subsidence of Delta organic soils and levees is a primary landscaping altering process affecting ecosystem sustainability. Key consequences include increased volume below sea level, drainage loads of water quality constituents of concern, seepage onto islands and decreased arability and levee stability. To estimate and understand recent subsidence, we collected elevation and soils data on Bacon and Sherman islands at locations of previous elevation measurements. Measured subsidence rates on Sherman Island from 1988 to 2006 averaged 1.23 cm yr^{-1} (0.5 in yr^{-1}) and ranged from 0.7 to 1.7 cm year^{-1} . Subsidence rates on Bacon Island from 1978 to 2006 averaged 2.2 cm year^{-1} and ranged from 1.5 to 3.7 cm year^{-1} . Changing land-management practices and decreasing soil organic matter content have resulted in decreasing subsidence rates since the early and mid 1900's. Since 2009, we have experimented with acquiring monthly airborne synthetic aperture radar interferometry (UAVSAR) to measure sub centimeter changes in Delta land surface elevations at $10 \text{ m X } 10 \text{ m}$ surface area resolution. We are using repeat pass interferograms to assess short-term changes in the Delta and applying permanent scatterers InSAR (PInSAR) technique to image longer-term motion of individual targets from multiple look directions on single flight lines. This is providing robust information about subsidence in agricultural areas. Preliminary flight data shows widespread coherence and reasonable agreement with ground truth measurements. To help understand causes and estimate future subsidence, we developed a model that effectively simulates subsidence and carbon loss from organic soils. We predict that elevation decreases from 2007 to 2050 will range from a few cm to over 1.3 m. During the next 40 years, we estimated the increase in volume of the land surface that is below sea level to be 346,956,000 million m^3 (281,300 ac-ft). Recent data indicate that rice cultivation will arrest subsidence.

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SEDIMENT ACCRETION AND CARBON SEQUESTRATION IN SAN FRANCISCO BAY SALT AND BRACKISH TIDAL WETLANDS

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We are measuring rates of sediment accretion and carbon sequestration in eight natural salt and brackish tidal wetlands in the San Francisco Bay Estuary. This research is motivated by the need to understand long-term stability of tidal wetlands in the face of sea-level rise and to provide background data to predict long-term rates of carbon sequestration in restored wetlands within the Estuary, as California is currently evaluating the possibility of assigning carbon trading credits for wetland restoration. Our sites cover South SF Bay (three sites), North SF Bay (three sites) and Suisun Bay (two sites), representing the geographical range of the Estuary as well as serving as analogs for long-term carbon sequestration in restored wetlands across the Estuary. We are collecting six cores at each site (two transects with three stations each). This approach is designed to allow us to identify spatial variation both within and among wetlands in the Estuary. Cores are being dated using ^{137}Cs and ^{210}Pb profiles. Long-term sediment accretion rates from the South Bay sites have ranged primarily from 0.3 to 0.9 cm/yr, while North Bay sites are closer to 0.1 to 0.3 cm/yr, leaving most sites close to or slightly above current rates of sea-level rise. However, many sites could experience increased rates of inundation under predicted rates of future sea-level rise, potentially leading to long-term conversion of wetlands to open-water or mudflats. Carbon sequestration rates have averaged approximately 50 g/m²/yr over the 100 year time span of ^{210}Pb and are slightly higher for ^{137}Cs -based dates. One South SF Bay site has accumulated over 100 g/m²/yr C; however, most of the high rates of sequestration are based on ^{137}Cs dating.

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NUTRIENT LOADING AND BENTHIC NATIVE-INVASIVE SPECIES DYNAMICS

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The effects of nutrient loading on the success of biological invasions is best understood in terrestrial systems, where studies have generally shown that increased nutrients facilitate the spread of invasive plants. To date, these relationships have remained largely unexamined in marine systems and at higher trophic levels. We conducted studies to examine the effects of interactions between nutrient loading and invasion by the invasive mud snail, *Ilyanassa obsoleta*, on the native snail *Cerithidea californica*, in San Francisco Bay. We experimentally manipulated densities of *Cerithidea* and *Ilyanassa* as well as nutrient levels at two tidal elevations to investigate the role of nutrients in invasion success in this system. Results indicate that nutrient additions increased microalgal (diatom) biomass at both tidal elevations. The native snail grew significantly more than the invasive snail on the higher, vegetated marsh, where it is generally found. Similarly, the invader grew significantly more than the native on the lower, unvegetated mudflat, where its densities are generally higher. Nutrients increased growth in both species but did not alter this “home team” habitat advantage. However, nutrients did significantly increase growth of the native on the marsh compared with the mudflat. Without nutrients, *Cerithidea* growth on the marsh was not significantly greater than on the mudflat, suggesting that nutrients provide a refuge for the native in this habitat. While nutrients consistently benefited *Cerithidea* with regard to growth, they harmed *Ilyanassa* with regard to mortality. Overall, nutrients significantly increased mortality of the invader but did not affect native mortality. In summary, these results indicate that nutrients in soft sediment benthic systems can play an important quantitative role in determining invasion success at higher trophic levels by affecting competitive dynamics between native and invasive species but their qualitative impact is context-dependent. Nutrient control should be a critical element of Bay-Delta management efforts.

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PHYSICAL INTERACTIONS BETWEEN FLOATING MACROPHYTES AND ENVIRONMENTAL FLOWS: IMPLICATIONS FOR INVASIVE PLANT MANAGEMENT IN THE DELTA

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Invasive floating macrophytes are aquatic weeds that exert strong negative influences on an ecosystem owing to characteristics such as high growth rates aided by asexual reproduction, formation of dense floating mats that out-compete other plant species, and unanchored root systems that allow dispersal by passive drifting by on environmental flows. Water hyacinth (*Eichhornia crassipes*) is one such weed that has invaded freshwater systems worldwide, including the Sacramento-San Joaquin Delta (Delta). Water hyacinth causes significant problems in the Delta and is costly to control. Improved control strategies of water hyacinth are needed; this research examines physical interactions between plants and surrounding flows to better understand transport mechanisms that govern regional dispersal. Experiments in an open channel flume and a wind tunnel were conducted using live water hyacinth plants to observe flow-induced forces and surrounding flow fields for different mat configurations. Forces were measured directly using a strain gauge and velocities were measured using an acoustic Doppler velocimeter (water) and a sonic anemometer (air). Over similar Reynolds number regimes, water drag forces exceed air drag forces for a given mat and water drag coefficients are greater than wind drag coefficients. Drag coefficients for water and air decrease with increasing mat Reynolds number, although water drag coefficients have a steeper decrease. Mean drag coefficient increases as mat length to height ratio (L/D) increases, suggesting frictional drag is important. The presence of water hyacinth mats in a channel causes deflection of air and water flows around the mat structure and increases turbulence in both fluids. These results suggest that water-driven transport, when present, is the dominant mechanism for water hyacinth dispersal, although ambient flow conditions at source locations must also be considered. This research forms the basis for future development of a predictive model for floating macrophyte dispersal based on physical processes.

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EVALUATING THE POTENTIAL FOR SPREAD OF AN INVASIVE FORB, LIMONIUM RAMOSISSIMUM, IN SAN FRANCISCO BAY SALT MARSHES

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Because invasive plants threaten San Francisco Bay's restored and historic salt marsh communities, identifying the extent of new invasions and how the potential for additional spread is affected by physical factors will help managers prioritize invasive species for control. In 2007, *Limonium ramosissimum* ssp *provinciale* populations were discovered in South S.F. Bay marshes. While invasive in southern California marshes, the extent of the invasion in S.F. Bay marshes, and how salinity and inundation stress at the marsh and estuary scale affects the plant's dispersal, establishment, growth and reproduction, is unknown. To determine invasion extent, marshes were searched and *Limonium* was mapped with GPS. To test dispersal potential, *Limonium* seeds were floated in aquaria of different salinities for up to 14 days and then germinated in fresh water. To test how salinity affects establishment, seeds of *Limonium* and 3 common marsh species were germinated in salinities from 0 to 45. To test how common stressors effect growth and reproduction, *Limonium* plants were grown from seeds to flowering under crossed inundation and salinity treatments in a greenhouse experiment. Results indicate *Limonium* has established in at least 15 marshes in S. SF Bay, covering approximately 3 acres. *Limonium* seeds can float in 15 and 30 salinity aquaria for at least two weeks, and then germinate in fresh water (~86%) regardless of salinity or time floating. When tested under saline conditions, *Limonium* seeds germinated at rates equal to common native marsh species at 0, 15, 30 and 45 salinity. When *Limonium* was grown under crossed salinity/inundation treatments, both factors independently affected growth and flowering. Taken together, these results suggest *Limonium* is capable of long distance dispersal events, can establish as readily as common native halophytes, and invasions rates will accelerate if populations spread to low salinity marshes. *Limonium*'s invasion potential warrants early removal.

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QUAGGA AND ZEBRA MUSSELS IN THE WESTERN U.S.: INVASION AND RESPONSE 2007-2010

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Quagga and zebra mussels, native to Europe, were discovered in the Great Lakes in the 1980s, with zebra mussels subsequently spreading widely in eastern North America. Impacts on the lower Great Lakes and other water bodies have been large and various, including alterations of food webs, light penetration and water chemistry, with associated reductions in the populations of native bivalves, benthic amphipods and fish. Economic impacts are typically estimated in the hundreds of millions to billions of dollars, and include impacts on water supplies, commercial and recreational fishing, other water-based recreation, navigation, and property values. Both mussels were discovered in the western U.S. in 2007/08. This presentation will describe the mussels' current western distribution; the potential for environmental factors, especially calcium concentrations, to limit their distribution in the Delta watershed; monitoring efforts; the controversy over reports of larval detection (by microscopy and molecular genetic assays) in Western water bodies, including the likelihood that at least some of the reported detections are false positives; interception, containment and eradication efforts; and will present a protective strategy that focuses on more effective containment.

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INVASIVE SPECIES RISK ASSESSMENT AND PLANNING – A TOOL TO REDUCE THE RISK OF SPREADING INVASIVE SPECIES IN NATURAL RESOURCE MANAGEMENT ACTIVITIES

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Invasive species are a known threat to species diversity, water movement, infrastructure maintenance, and human health. A regional overview of invasive species, potential pathways for moving invasive species and the process that can reduce this risk will be introduced as part of an overview of the US Fish and Wildlife Service's new Invasive Species and Risk Assessment and Planning tool or ISRAP. The ISRAP tool is a science-based approach for limiting the unintentional spread of invasive species. Natural resource management activities such as animal and plant surveys and movements, restoration construction, environmental monitoring and others can provide a pathway for the spread invasive species. These non-targets species, both plants and animals, can be transferred on clothing, sampling equipment, vehicles, or gear during these activities. ISRAP provides a solution by assessing the risk of an activity for moving invasive species from one location to another and identifying methods or procedures that can be used to reduce this risk of spread. ISRAP is an updated version of Hazard Analysis and Critical Control Point or HACCP planning.

Wednesday, September 29, 2010: Room 314 Invasives - Order: 5

AN EVALUATION OF THE HYDRODYNAMIC AND SALINITY IMPACTS RESULTING FROM THE DEEPENING OF THE SACRAMENTO DEEP WATER SHIP CHANNEL

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The U.S. Army Corps of Engineers is conducting a reevaluation study for deepening the Sacramento River navigation channel. The Sacramento project is a Limited Reevaluation Study which includes the evaluation of the hydrodynamic and salinity impacts of the proposed deepening of the Sacramento DWSC. Given concerns about increased salt intrusion into the Sacramento-San Joaquin Delta which may result from this deepening project, a three-dimensional hydrodynamic and salinity model was used to simulate salt intrusion under currently maintained conditions and under the proposed channel deepening alternatives under both existing and future conditions. The UnTRIM Bay-Delta model was used to simulate salt intrusion under the currently maintained DWSC configuration and under the project alternative that entails the deepening of the Sacramento DWSC. In this analysis the Sacramento DWSC extending from Mile 0 near Collinsville to Mile 35 is deepened from 30 feet MLLW to 35 feet MLLW. Since the upstream reach from Mile 35 to the Port of Sacramento has already been deepened to a depth of 35 feet MLLW, no additional deepening of this reach was applied in this scenario. The predicted impact of the deepening of the Sacramento DWSC on stage, flow, and salinity in the Sacramento-San Joaquin Delta will be presented. The results show that the deepening of the Sacramento DWSC does not have an impact on salinity in the Sacramento-San Joaquin Delta during periods when X2 is less than 75 km. During late summer and fall conditions the Sacramento DWSC Deepening scenario results in increased salt intrusion along the Sacramento River between Collinsville and Rio Vista. The predicted impact of the deepening of the Sacramento DWSC deepening on X2 and the D-1641 water quality standards will be discussed.

Wednesday, September 29, 2010: Room 314 Human Modified Systems - Order: 1

TRANSPORT MECHANISMS IN THE STOCKTON DEEP WATER SHIP CHANNEL: A THREE-DIMENSIONAL TRACER AND MODELING STUDY

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Since the 1960s, the Stockton Deep Water Ship Channel (DWSC), part of the freshwater tidal reaches of the San Joaquin River, has been periodically subject to critically low concentrations of dissolved oxygen. The problem has been well studied, and researchers agree that there are a number of factors interacting to contribute to the problem, including a change in bathymetry of the system due to the development of the area as a Port, decreased velocity (increased residence time) through the reach, and an increase in oxygen demanding substances from upstream sources. In order to gain a better understanding of the transport processes at work, a sulfur hexafluoride (SF₆) tracer study (Schmeider 2008) was conducted during August 2005. The results of the tracer study were incorporated in the calibration of a three-dimensional hydrodynamic and water quality model, SI3DWQ (Doyle 2010), to produce a model capable of exploring how changes in management decisions for the system would impact transport through the channel, and therefore dissolved oxygen concentrations. One of the major findings of the tracer study that was accurately represented in the calibrated model was the tidal trapping of material in the turning basin portion of the DWSC. The tidal trapping allows the turning basin to be an ongoing source of tracer to the rest of the channel. The scenarios investigated helped to alleviate the tidal trapping and decrease the total residence time in the DWSC, which should also alleviate the dissolved oxygen problems.

Wednesday, September 29, 2010: Room 314 Human Modified Systems - Order: 2

A COMPARISON BETWEEN THE SACRAMENTO AND MISSISSIPPI DELTA LEVEE SYSTEMS

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Abstract: The presentation will address the similarities and differences between two major US Delta Levee systems: the Sacramento-San Joaquin River Delta System in Northern California and the Mississippi River Delta Levee System in Louisiana. As a Water Resources Engineer for the Delta Levees and Environmental Engineering office at DWR, I have firsthand experience with the Sacramento system as a result of participating in various Delta infrastructure projects and field visits. A recent volunteering trip to assist with cleanup of the oil spill in the Gulf has given me the opportunity to also experience the Mississippi system on a personal basis. Several photographs that I have taken of each system will be shown in this presentation, and topics discussed will be sustainability, environmental impacts, subsidence, and local issues.

Wednesday, September 29, 2010: Room 314 Human Modified Systems - Order: 3

WATER RESOURCES SENSITIVITY TO CLIMATE CHANGE, LAND USE CHANGE, AND POPULATION GROWTH IN THE STANISLAUS, TUOLUMNE AND MERCED BASINS

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Studies of climate change impacts on hydrology and water operations have become increasingly popular over the past decade, and have yielded insights into system sensitivity to climate-impacted hydrologic regimes. The goal of this study is to integrate projections of such climate change impacts with other anthropogenic changes that will occur in parallel, in particular urbanization and population growth. We built an integrated hydrology and water operations model of the Stanislaus, Tuolumne, and Merced River Basins using the WEAP platform. We ran the model using an ensemble of 12 downscaled GCM scenarios, and spatially explicit projections of urbanization and population growth through the year 2099. Results are described separately and in combination. Consistent with other studies, climate change alone results in increasing water demands and decreasing water supply reliability by mid-century. Adding population growth and urbanization results in decreasing demands, as agricultural land is taken out of production and replaced with low-density residential uses. In this rapidly urbanizing agricultural area, the combined effect is a decrease in total water demands, and concomitant increase in water supply reliability under climate change with population growth. The results suggest that multiple anthropogenic stressors will act in concert to produce impacts on water systems different from individual stressors considered alone. The results highlight the importance of considering land use, in particular when invoking population growth as a driver of change. The study also suggests that a spatially explicit approach to such projections is important, and that the choice of case studies can influence outcomes. While this study focuses on water supply, we acknowledge that anthropogenic changes of the projected magnitude will have substantial impacts on other aspects of the water and ecological system, and discuss other limitations of the modeling approach.

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ANTHROPOGENIC INFLUENCES ON RECENT BATHYMETRIC CHANGE IN WEST-CENTRAL SAN FRANCISCO BAY AND IMPLICATIONS FOR BEACH SUSTAINABILITY

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From 1997 to 2008, west-central San Francisco Bay lost over 14 million cubic meters of sediment, the majority of which was located within aggregate mining lease sites. The rate of sediment loss is nearly three times the rate determined from bathymetric surveys spanning 1947 to 1979, indicating a rapid acceleration of sediment loss from the region during the last decade. As only 10% of the mapped substrate is dominated by mud, and only 5% of the measured sediment loss is from mud-dominated substrates, the majority of the sediment lost from west-central San Francisco Bay was coarse sediment, material that would otherwise have been available for transport to eroding, open-coast beaches. While it is difficult to establish the precise contribution of the various potential anthropogenic influences to the observed sediment loss from 1997 to 2008 in west-central San Francisco Bay, the timing, spatial distribution, and magnitude of sediment loss suggests a strong correlation with sediment removal by aggregate mining activities. Sediment loss in the entire San Francisco Bay Coastal System during the last half-century is estimated at 240 million cubic meters, and most of this is believed to be coarse sediment (i.e., sand and gravel) from Central Bay and the San Francisco Bar, which is likely to limit the sand supply to adjacent, open-coast beaches. This hypothesis is supported by a calibrated numerical model that indicates that there is a potential net export of sand-sized sediment across the Golden Gate, suggesting that a reduction in the supply of sand-sized sediment within west-central San Francisco Bay will limit transport to the outer coast. The massive loss of sediment from the system, as a whole, is due to a combination of factors that include delta management practices, in-bay dredging, and aggregate mining.

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SURVIVAL OF JUVENILE LATE-FALL CHINOOK SALMON USING DIFFERENT MIGRATION ROUTES TO NEGOTIATE THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

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We developed a multistate mark-recapture model to estimate 1) survival of juvenile salmon using different migration routes to negotiate the Sacramento-San Joaquin River Delta, and 2) the probability of fish using each route. Since these parameters determine population-level survival, simultaneous estimation of both allowed us to quantify the relative contribution of each migration route to population-level survival. We applied this model to three years of acoustic telemetry data (2007-2009) with releases made when the Delta Cross Channel gates were both open and closed. We identified consistent patterns in survival among migration routes, but substantial variation in survival among releases and years. Specifically, releases in 2008 exhibited lower survival than other years. Despite considerable variation among releases, survival for routes leading to the interior Delta was always lower than for Sacramento River. Fish that migrated through Sutter and Steamboat sloughs had survival probabilities that ranged between that of the Sacramento River and the interior Delta. Because of route-specific differences in survival, the fraction of fish using each migration route will affect population-level survival. The fraction of fish entering each route was generally related to the fraction of discharge, but large deviations from this expected relation suggested other factors also influenced migration routing. We discuss how survival within migration routes interacts with movement among routes to influence population survival. Such insights are critical for quantifying the effect of water management actions on endangered juvenile salmonids.

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JUVENILE SALMONID HABITAT USE OF STREAM CHANNEL RESTORATION IN CLEAR CREEK: LONGER-TERM OBSERVATIONS RELATED TO SUSTAINABILITY

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The CALFED and CVPIA funded Lower Clear Creek Floodway Rehabilitation Project is a multi-phase project, designed to restore 2.5 miles of stream channel and floodplain habitat. While the project met its adult habitat goals, we evaluated the secondary, juvenile-habitat goal of the project. Clear Creek is a high priority watershed for CALFED, which has funded similar large-scale restoration projects in other watersheds. Direct measurement of juvenile densities has rarely been performed in these other projects. We evaluated two objectives: 1) attain average juvenile densities equal to or greater than control reaches, and 2) retain juvenile habitats for at least 5 years, with juvenile densities twice those in the control reaches. We conducted habitat use surveys in the spring of 2003, 2005, 2008 and 2010 to evaluate the affect of the project on juvenile Chinook densities. Our study focused on Phases 3A and 3B, which were completed in 2002 and 2007 respectively. The survey area included two restoration phases and two control reaches. We estimated Chinook numbers from underwater snorkel observations. We compared fish densities by reach, restored versus unrestored, incorporated habitat features and presence of adjacent riparian vegetation, using ANOVA and pairwise comparisons. Overall, juvenile densities were lower in restoration areas than in controls. While high juvenile densities were sustained in Phase 3A, Phase 3B would benefit from additional instream work. Phase 3B had significantly lower juvenile densities than other reaches in part because performance of revetment rootwads in 3B declined. We examined how differences in design, implementation or evolution of the rootwads may result in differences in habitat structure, complexity, water velocity and sustainability. The 3B rootwads and poor quality habitats would be improved by adding suitable substrate, submerged shoreline vegetation, and additional woody debris. This monitoring will be useful in adapting this and future projects.

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WINTER OBAN: A STATISTICAL LIFE-CYCLE MODEL FOR WINTER-RUN CHINOOK

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Salmonid research in the Bay – Delta has tended to be focused on the controllable freshwater factors that affect salmon run variability, such as flows and diversions, but there has been less emphasis on other sources of variability such as the ocean. We constructed a life-cycle model of winter-run Chinook that accounts for mortality during all phases of the life-history, that estimates model coefficients in a statistical framework, evaluates covariates that may explain dynamic vital rates, and incorporates uncertainty in the model structure and model coefficients (through Bayesian estimation). The model is entitled Oncohychnus Bayesian Analysis (OBAN). Evaluation of multiple anthropogenic and environmental driver variables indicated that temperature in the spawning reaches, minimum flows in the fry rearing reaches, access to Yolo bypass and water exports in the Delta, upwelling dynamics in the Gulf of Farallones, and ocean harvest were able to explain variability in the winter-run Chinook population dynamics. Evaluation of the impact of the effects indicated that the winter-run abundance is most sensitive to temperatures in the spawning reaches and flows in the fry rearing stage. The sensitivity of the model is somewhat dependent upon the abundance data to which the model was statistically fit. Thus, adult escapement and juvenile counts at Red Bluff Diversion Dam (RBDD) can be used to evaluate the upstream portion of the life-history, whereas the impact of factors occurring after RBDD are less easily identified due to correlation of survival rates in the Delta, Gulf of Farallones, and ocean stages. Such life history models are critical for understanding the factors that have been associated with changes in population abundance historically, and thus form a short list of actions that may lead to population recovery of listed species, such as winter-run Chinook in the Sacramento River.

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QUANTIFYING FLOW AND TEMPERATURE EFFECTS ON PRODUCTION OF CENTRAL VALLEY STEELHEAD

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Central Valley steelhead are an ESA listed species playing an increasingly pivotal role in reservoir and Delta water management. The influence of resident rainbow trout on production of anadromous steelhead has been repeatedly identified as a critical uncertainty during evaluations of threatened and endangered steelhead (*Oncorhynchus mykiss*) populations. The freshwater resident form of *O. mykiss* (rainbow trout) is not currently listed under the ESA, but two expert panels of independent scientists have concluded that population viability analyses for *O. mykiss* should account for the interdependence of both the resident and anadromous forms where they coexist. Given the importance of Central Valley *O. mykiss* to water project management and deliveries, and pervasive misconceptions about the interplay between resident and anadromous rainbow trout, we propose to use successful programs originally developed in Washington (see <http://www.fishsciences.net/projects/yakima/>) as a steppingstone for development of a steelhead modeling framework for the California Central Valley. Modeling conducted in watersheds in Washington and Oregon indicate that flow and temperature conditions may strongly influence predominance of resident or anadromous life-histories, suggesting that trends in abundance of resident rainbow trout and steelhead can be predicted under a variety of flow management regimes. Furthermore, production of steelhead in regulated river systems was shown to be inextricably linked to abundance of resident rainbow trout, and anadromous juvenile production from resident spawners appears to be an important driver of steelhead persistence during periods of low marine survival.

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ADVANCES IN SALMONID MONITORING: THE CALIFORNIA COASTAL SALMONID POPULATION MONITORING PLAN AND THE SALMON MONITORING ADVISOR

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Without salmon monitoring, we can not know what condition salmon populations are in and whether our actions are helping or harming these populations. This talk describes two recent advances in salmonid monitoring: The California Coastal Salmonid Population Monitoring Plan and The Salmon Monitoring Advisor website. The California Coastal Salmonid Monitoring Plan has been developed to gauge the condition and recovery of coastal salmonids and uses the Viable Salmonid Population concept; abundance, productivity, spatial structure, and diversity; as a framework. It divides California into Northern and Southern areas with a boundary north of the Pajaro River. In the Northern Area, adult numbers will be estimated mostly through expanded redd survey selected in a random, spatially balanced way, and in the Southern Area, adults will be counted at fixed stations due to different species composition and extreme low abundance. Spatial structure will be monitored using juvenile summer-fall snorkel surveys. Diversity traits are locally different, and will need to be examined using local diversity monitoring plans. A second project is the web-accessible knowledge base called the “Salmon Monitoring Advisor”. The site is accessible in a hierarchical manner to reflect diverse audiences, including (1) scientists who design monitoring programs and/or analyze the resulting data, (2) technical staff who implement monitoring designs in the field, (3) people involved in providing funding for monitoring programs, and (4) managers and decision makers. It provides advice and guidelines of how to work through the essential steps involved in designing monitoring programs to meet objectives. It provides pros and cons of different designs, rather than being prescriptive about which design best meets a particular monitoring objective. The web site uses seven sequential steps to guide monitoring design and implementation and provides extensive explanations and real-world examples for each step.

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