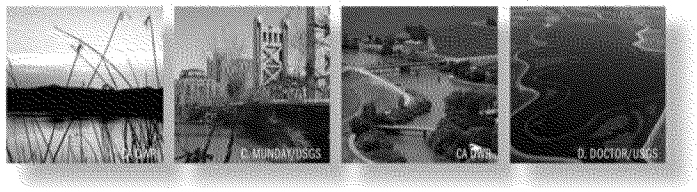
7th Biennial Bay–Delta Science Conference
Ecosystem Reconciliation:
Realities Facing the San Francisco Estuary

October 16–18, 2012 Sacramento Convention Center, Sacramento, California



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Money, Water, and Fish: Economics of Reconciliation

Ellen Hanak, Senior Policy Fellow, Public Policy Institute of California, hanak@ppic.org

Healthy watersheds are an important resource for the modern California economy, part of what makes the state a desirable place to live and work. Societal demand for these amenities is reflected in the adoption since the late 1960s of numerous state and federal environmental laws and regulations, over $34 billion in voter-approved state bonds supporting clean water and healthy watersheds, and numerous local investments devoted to environmental water efforts. Yet despite these endeavors, California has been fighting a losing battle to reverse declines in native aquatic ecosystems: the share of native fish species in reasonably secure condition fell from 38 to 19 percent between 1989 and 2010, and further deterioration is likely with climate change. Ecosystem reconciliation offers a hopeful alternative, because it shifts the focus from piecemeal regulation to improving overall ecosystem function. Reconciliation is also consistent with economic principles. At present, environmental management is often "siloed," with each agency and each project addressing particular issues in particular locations without an integrated vision of how these actions might contribute to overall improvement of ecological conditions. Coordinated approaches would be much more effective in protecting native species and would enable us to spend our dollars (and environmental water) more wisely.

Plenary Speaker Biography: Ellen Hanak is an economist and senior policy fellow at the Public Policy Institute of California (PPIC). Her career has focused on the economics of natural resource management and agricultural development. Since joining PPIC in 2001, she has built an influential, multi-disciplinary water policy research program involving scholars from across California. She has also held research positions with the French agricultural research system, the U.S. President's Council of Economic Advisors, the World Bank, and the Brookings Institution.

Tuesday, October 16, 2012: Room 308-313, Plenary Session – 9:10 AM

ED_000733_DD_NSF_00015174-00004

River Deltas: From Local Challenges to Global Syndrome

Charles J. Vörösmarty, Director, CUNY Environmental Crossroads Initiative

The world's coastlines are highly dynamic landforms, host to both terrestrial and aquatic lifeforms and distinctive ecosystems. Within the coastal zone, river deltas are among the most consequential of landforms and have played an essential role in human history, serving as cradles of civilization, testing grounds for early agriculture, and birthplace of hydraulic engineering. Today, deltas are home to a half-billion or more people. More than 200 million people are crowded into the Ganges, Nile, and Mekong deltas alone, and many of Asia's current or emerging megacities are located within deltas. As low-lying and low-relief plains, deltas are highly sensitive to even small changes in sea level and thus rightfully claim ground in the greenhouse warming debate. But the fragility of deltas is not solely a consequence of rising ocean waters. Many local human actions as well as upstream drainage basin management of landscapes and river systems are today defining the nature of river deltas. This presentation will offer evidence of an emerging global pattern of threat to the world's river delta systems, and explore the sources of this global syndrome. While threats to each delta are a unique combination of climate forcings; riverflow, sediment source and ocean energy regimes; biological communities; and, human engineering, there are certain commonalities. The ability to detect and act upon these threats remains a young science. The talk will conclude with a description of the intent and scope of a major new initiative on deltas—the International Year of Deltas (2013).

Plenary Speaker Biography: Charles J. Vörösmarty is a professor of civil engineering, a Distinguished Scientist with NOAA-Cooperative Remote Sensing Science and Technology Center and director of The City University of New York's Environmental Crossroads Initiative at The City College of New York. His research focuses on the development of computer models and geospatial data sets used in synthesis studies of the interactions among the water cycle, climate, biogeochemistry and anthropogenic activities. His studies are built around local, regional and continental to global-scale modeling of water balance, discharge, constituent fluxes in river systems and the analysis of the impacts of large-scale water engineering on the terrestrial water cycle.

Before he came to The City College of New York, he was a research full professor at the Institute for the Study of Earth, Oceans and Space at the University of New Hampshire, where he was founder and director of its Water Systems Analysis Group (http://www.wsag.unh.edu).

Tuesday, October 16, 2012: Room 308-313, Plenary Session – 9:40 AM

ED_000733_DD_NSF_00015174-00005

Present and Future Challenges for Estuaries: Towards Solutions

Marcia McNutt, Director, U.S. Geological Survey

Estuarine ecosystems across the Nation face many challenges to their environmental integrity. Estuaries such as the Chesapeake Bay, San Francisco Bay, and the Gulf of Mexico are each vastly changed and continue to change as the result of human actions — such as population growth; building levees, seawalls, and dams; land-based sources of pollution — and natural events like hurricanes and floods. In addition, these ecosystems face other human-induced natural challenges like climate change, sea level rise, and competition with non-native species. Improved understanding of the function and processes of estuarine natural systems helps inform decisions for adapting to sea level rise and preparing for increased storm events. The growing realization of the need to reconcile conflicting goals of human use while maintaining natural functioning of ecosystems has led to development of decision support tools that can help decision makers assess the trade-offs they must consider between natural ecosystems and how humans use them. The integrity of estuaries and the multiple challenges they face in three roughly analogous areas of the U.S. will be discussed with a final focus on the Bay-Delta area.

Plenary Speaker Biography: Marcia McNutt grew up in Minneapolis, Minnesota. She received a bachelor's in Physics from Colorado College, Phi Beta Kappa, Summa Cum Laude, and a doctorate in Earth Sciences from Scripps Institution of Oceanography. Dr. McNutt previously served as professor of Geophysics at Massachusetts Institute of Technology and as President and Chief Executive Officer of the Monterey Bay Aquarium Research Institute (MBARI), in Moss Landing, CA. Dr. McNutt has sailed as chief scientist on numerous oceanographic research voyages and published more than 100 peer-reviewed scientific articles. Her research has primarily focused on processes that lead to volcanic eruptions and formation of mountain belts far from the edges of the tectonic plates, and therefore are not explained by the plate tectonic paradigm. In 2009 she became director of the United States Geological Survey, where her responsibilities include leading the Nation's largest water, Earth, biological science and civilian mapping agency in its mission to provide the scientific data that enable decision makers to create sound policies for resource management and reducing vulnerability to natural hazards. She is a member of the National Academy of Sciences, the American Philosophical Society, and the American Academy of Arts and Sciences. The American Geophysical Union awarded her the Macelwane Medal in 1988 for research accomplishments by a young scientist and the Maurice Ewing Medal in 2007 for her significant contributions to deep-sea exploration. The Coast Guard awarded her their Meritorious Service Medal, the second highest honor open to civilians, for her efforts during the Deepwater Horizon oil spill. She holds honorary degrees from Colorado College, the University of Minnesota, Monmouth University, and the Colorado School of Mines. Her husband, Ian Young, is a sea captain. She has three daughters: Meredith and Dana work for a high tech company in Silicon Valley, and Ashley is in law school.

Tuesday, October 16, 2012: Room 308-313, Plenary Session – 10:50 AM

ED_000733_DD_NSF_00015174-00006

Scientific Discovery and the Co-Equal Goals of Water Reliability and Ecosystem Recovery

Peter Goodwin, Lead Scientist, Delta Science Program, peter.goodwin@deltacouncil.ca.gov

Knowledge discovery is occurring at an ever-increasing rate and the smartest generation in history is in the process of graduating from college. Another rapidly expanding trend is the deluge of data that has been well documented in the past five years. There are numerous challenges associated with our inability to adequately store or analyze data streams from different sources. But the potential benefits from mining diverse data, the ability of multi-disciplinary modeling to unravel complexity and conducting syntheses to improve holistic understanding are huge. Some lessons learned from 'Big' Science where diverse groups of scientists have clustered around vexing problems will be described from the perspective of how this could help build the science community working on developing an understanding of the Bay-Delta system from the tributary watersheds to the ocean. What scientific infrastructure could we begin to put in place today that will help the next generation of scientists address the challenges surrounding the co-equal goals of water resource reliability and protecting, restoring and enhancing the Delta ecosystem?

Plenary Speaker Biography: As Lead Scientist, Dr. Peter Goodwin works with the Delta Science Program staff, the Delta Independent Science board, agency scientists, and the scientific community at large to promote and coordinate the use of peer-reviewed science throughout the Delta Stewardship Council. Peter is the DeVlieg Presidential Professor in Ecohydraulics and professor of civil engineering at the University of Idaho and is the founding director of the Center for Ecohydraulics Research. His research includes modeling flows, sediment transport, and river channel evolution, quantifying the effects of restoration and understanding fish behavior in response to managed flows. He is a former CALFED Independent Science Board member and also serves as the scientific advisor for several government agencies addressing river and wetland management issues. He is also the director of Idaho's Experimental Program to Stimulate Competitive Research (EPSCoR), a federal-state partnership intended to build research infrastructure and encourage collaboration in states historically having received a low amount of federal research funding. He earned his Ph.D. from UC Berkeley in 1986.

Tuesday, October 16, 2012: Room 308-313, Plenary Session – 11:20 AM

ED_000733_DD_NSF_00015174-00007

Urban Pesticide Runoff from Neighborhoods in Northern California and their Contribution to Pesticide Contamination in Urban Creeks

Michael Ensminger, Cal EPA, Department of Pesticide Regulation, mensminger@cdpr.ca.gov
Kevin Kelley, Cal EPA, Department of Pesticide Regulation, kkelley@cdpr.ca.gov
Sheryl Gill, Cal EPA, Department of Pesticide Regulation, sgill@cdpr.ca.gov
Kean Goh, Cal EPA, Department of Pesticide Regulation, kgoh@cdpr.ca.gov

Since 2008 the California Department of Pesticide Regulation has conducted monitoring studies to determine the pesticide content in urban runoff. Water samples were collected from 13 storm drain outfalls and from seven urban creeks in the Sacramento and San Francisco Bay areas during rainstorm events and during California's dry season. Among both areas, 26 different herbicides and insecticides or their degradates were detected. Bifenthrin was the most commonly detected insecticide in all areas and site types. Fipronil (plus its degradates) was the second most frequently detected insecticide in the Sacramento area, but in the San Francisco Bay area, carbaryl and OP insecticides were detected about as frequently as fipronil. Imidacloprid was also detected, although this analysis was added later in the study and only in the Sacramento area. Synthetic auxin herbicides (2,4-D, dicamba, MCPA, triclopyr) and diuron were the most frequently detected herbicides in all areas and site types. However, diuron was detected less frequently in storm drain outfalls in the Sacramento area. Overall, there were no significant differences in the number of pesticides detected per sample from the two areas, although the Sacramento area had significantly more pesticides per sample during the dry season than did the San Francisco Bay area (median, 2 and 1, respectively; p=0.002). In both areas more pesticides were detected per sample during rainstorm events than during dry season monitoring (median, 6 and 1, respectively; p=0.00). Comparing site type (urban creek or storm drain outfall), the Sacramento area had significantly more pesticides in samples collected from storm drain outfalls whereas in the San Francisco area there were no significant differences between site type. Bifenthrin, fipronil, and malathion most frequently exceeded aquatic life benchmarks or water quality criteria.

Keywords: Pesticide urban monitoring, aquatic benchmark, bifenthrin, fipronil, malathion

Tuesday, October 16, 2012: Room 306, Organic Contaminants (I) – Order 1

ED_000733_DD_NSF_00015174-00008

Current Use Pesticides Detected in the San Francisco Bay-Delta during Spring 2011 and 2012

James Orlando, U.S. Geological Survey, jorlando@usgs.gov
Michelle Hladik, U.S. Geological Survey, mhladik@usgs.gov
Kathryn Kuivila, U.S. Geological Survey, kkuivila@usgs.gov

Current-use pesticides pose a threat to aquatic organisms in the San Francisco Bay-Delta estuary. Pesticide use is constantly changing, presenting a challenge for resource managers and policy makers trying to understand the fate and effects of these contaminants. The U.S. Geological Survey Pesticide Fate Research Group routinely updates analytical methods to adapt to changing pesticide use. Our gas chromatography/mass spectrometry and liquid chromatography/mass spectrometry methods were designed and modified to analyze over 100 pesticides and pesticide degradates in water, including several newer use rice herbicides, six neonicotinoid insecticides, and 35 fungicides, many of which are rarely included in monitoring studies. As part of a collaborative study working to understand the occurrence of current-use pesticides and other contaminants in the San Francisco Bay-Delta estuary and their potential effects on phytoplankton, our updated methods were used to analyze water samples collected during the spring of 2011 and 2012. During each year, water samples were collected weekly for ten consecutive weeks (March-May) from three sites in the San Francisco Bay-Delta. In 2011, 18 pesticides of varying type and use, were detected including the herbicide diuron and its degradates 3,4-DCA and DCPMU, several fungicides, and clomazone, a rice herbicide. Maximum pesticide concentrations were generally less than 100 ng/L, with the exceptions of clomazone, and the fungicide tetraconazole, (535 and 511 ng/L, respectively). All concentrations were below U.S. Environmental Protection Agency aquatic life benchmarks, with the exception of one detection of the pyrethroid bifenthrin (4.1 ng/L) which exceeded the chronic invertebrate toxicity benchmark of 1.3 ng/L. Pesticide concentration results from the spring 2012 sampling will be compared with those from 2011 to gauge the types and concentrations of pesticides that occur in the San Francisco Bay-Delta, providing valuable data to scientists and resource managers working to understand the role of contaminants in the region.

Keywords: Pesticides, contaminants, phytoplankton

Tuesday, October 16, 2012: Room 306, Organic Contaminants (I) – Order 2

ED_000733_DD_NSF_00015174-00009

Pyrethroid Concentrations in the American River: Historical Assessment and Impact of Proposed Regulatory Controls

Brant Jorgenson, Robertson-Bryan Inc., brant@robertson-bryan.com
Thomas Young, University of California, Davis, tyoung@ucdavis.edu

A watershed pyrethroid insecticide exposure model was developed for the lower American River watershed located in California, USA. The model incorporated empirically derived washoff functions based on previously run small scale rainfall simulations, along with actual pyrethroid insecticide use and watershed properties for Sacramento County, California. The model was calibrated to in-stream monitoring data and utilized to predict daily river pyrethroid concentration for a period spanning 1995 through 2010. Based on model predictions, a marked increase in pyrethroid toxic units is observed starting in the calendar year 2000, coincident with a watershed-wide increase in pyrethroid use. Approximately 80% of the predicted toxic unit exposure in the watershed was associated with the pyrethroids bifenthrin, cyfluthrin, and cypermethrin. Pyrethroid applications for above-ground structural pest control purposes utilizing suspension concentrate categorized product formulations accounted for greater than 93% of the total toxic unit exposure for all modeled years except 1995. Application of mitigation strategies, such as curtailment of structural perimeter band and barrier treatments as proposed by the California Department of Pesticide Regulation, yielded an approximate 80% reduction in predicted total toxic unit exposure in all modeled years. The model also predicted that similar mitigation gains could be achieved through a switch from suspension concentrate categorized products to emulsifiable concentrate categorized products. Even with these mitigation gains, the predicted concentration of some pyrethroids would continue to exceed chronic aquatic life criteria for pyrethroids on a frequent basis, illustrating the recalcitrant nature of the pyrethroid problem.

Keywords: Insecticide, stormwater, toxicity, modeling, water quality, bifenthrin, pyrethroid, pesticide regulation

Tuesday, October 16, 2012: Room 306, Organic Contaminants (I) – Order 3

ED_000733_DD_NSF_00015174-00010

Distribution of the Pyrethroid Insecticide Concentration between Freely Dissolved and Particle-Bound Forms in Sacramento Wastewater Effluent

Emily Parry*, University of California, Davis, eparry@ucdavis.edu
Thomas Young, University of California, Davis, tyoung@ucdavis.edu

Pyrethroid insecticides are a major current use insecticide class in the US. Whole water concentrations of pyrethroids have been reported in the dechlorinated final effluent (DFE) of Sacramento Wastewater Treatment Plant (SWTP). Tests with 100% effluent reported toxicity to aquatic arthropods, however, upon 50-50 dilution with river water no toxicity was observed. Research has shown that the form of the pyrethroid, freely dissolved, complexed with organic matter, or adsorbed to sub-micron particles, can affect its toxicity to aquatic organisms and have implications for fate and transport. Effluent from the SWTP was sampled six times in the course of a yearlong study. The DFE was fractionated by laboratory centrifugation to different particle size cuts. The pyrethroid concentration associated with each fraction was quantified to determine if there was a particular size fraction that treatment operations could focus on to maximize pyrethroid removal. Solid phase microextraction (SPME) was used with pyrethroid serial additions to measure an organic carbon normalized distribution coefficient (K_{oc}) between pyrethroids and the suspended wastewater particulate matter. Values for log K_{oc} ranged between 6.5-7.4 depending on sampling date and chemical. Calculation with the measured K_{oc} and whole water pyrethroid concentration predicts that < 5% of the pyrethroid is in the freely dissolved phase. The SWTP effluent discharge represents 1-2% of the Sacramento River volume. The form of pyrethroids in effluent has implications for their transport down the river and their effect on organisms that reside downstream in the Sacramento - San Joaquin River Delta.

Keywords: pyrethroids, sorption, partition coefficient, wastewater, effluent

Tuesday, October 16, 2012: Room 306, Organic Contaminants (I) – Order 4

ED_000733_DD_NSF_00015174-00011

Asking the Fish: Using Tissue Concentrations to Understand Pesticide Exposure

Kelly Smalling, US Geological Survey, ksmall@usgs.gov
Kathryn Kuivila, US Geological Survey, kkuivila@usgs.gov

Current-use pesticides are of concern in the Sacramento-San Joaquin Delta (Delta) and are considered a possible contributor to the Pelagic Organism Decline (POD). Hundreds of pesticides are applied annually within the Delta watershed in agricultural and urban areas and are transported into surface waters throughout most of the year. Interactions between life histories of the fishes and the temporal and spatial variability of pesticides in the environment make understanding routes of potential exposure difficult. A different approach is to "ask the fish". Most current-use pesticides are only moderately lipophilic and will not biomagnify but have the potential to accumulate in organisms. Other advantages of measuring fish tissue concentrations rather than environmental concentrations are implicit bioavailability and inclusion of all exposure pathways.

A new robust and sensitive method was developed to extract pesticides from specific organs or whole bodies using solvent extraction at high temperature and pressure followed by cleanup using size exclusion chromatography and Florisil. As fish are typically exposed to complex mixtures of pesticides, the tissue extracts are analyzed for over 100 pesticides using gas chromatography/mass spectrometry. Three fish species from three central California coastal estuaries with intense-agricultural watersheds were analyzed for pesticides. Five insecticides (3 organophosphate and 2 pyrethroid insecticides) and five fungicides were detected in the tissue. Pesticide residues in fish tissues demonstrate exposure and tissue concentrations may serve as a metric that can be linked to biological endpoints. The next steps are to characterize tissue concentrations in species of concern and link back to potential effects. This information is critical for resource managers and biologists to assess the potential risks of multiple stressors as well as long-term contaminant exposure to aquatic organisms.

Keywords: Current-use Pesticides, Tissue, Accumulation, Fish

Tuesday, October 16, 2012: Room 306, Organic Contaminants (I) – Order 5

ED_000733_DD_NSF_00015174-00012

Effect of Diuron and Imazapyr Herbicides on Phytoplankton in the San Francisco Estuary in an Experimental Study

Sarah Blaser, Romberg Tiburon Center, SFSU, sarahblaser@gmail.com
Frances Wilkerson, Romberg Tiburon Center, SFSU, fwilkers@sfsu.edu
Alexander Parker, Romberg Tiburon Center, SFSU, aeparker@sfsu.edu

Herbicides may be used widely within estuarine watersheds and have the potential to negatively affect estuarine organisms living downstream of the site of their application. Diuron is one herbicide of concern in the northern San Francisco Estuary (SFE) because it is used extensively and persists for long periods in the environment. Despite measured concentrations in the SFE, little is known about the potential impact of diuron on phytoplankton communities. A second herbicide in use in the SFE is imazapyr, which is applied to marsh habitat adjacent to the SFE to control invasive plants. This study investigated the impact of additions of diuron and imazapyr on carbon assimilation, nitrogen uptake and community composition of natural phytoplankton assemblages collected in the SFE. Results show that diuron reduced carbon assimilation number at concentrations as low as 1 $\mu g\ L^{-1}$ during both acute (t=0 hr) and chronic (t=48 hr) exposure treatments. This concentration is within the range of diuron concentrations previously reported for the northern SFE. Imazapyr exposure did not negatively affect carbon assimilation number during acute exposure, but carbon assimilation number decreased with the addition ofimazapyr (mg L^{-1}) in chronic exposure experiments. Phytoplankton biomass and abundance was lower in treatments with diuron and imazapyr, and the phytoplankton community composition shifted with the addition of diuron and imazapyr. These data have important implications for management, especially if they are used for invasive plant removal.

Keywords: herbicide, phytoplankton, carbon assimilation, nitrogen uptake, community composition, contaminants

Tuesday, October 16, 2012: Room 306, Organic Contaminants (II) – Order 6

ED_000733_DD_NSF_00015174-00013

Effects of Pesticides to Critical Zooplankton Species of the San Francisco Estuary

Sarah Lesmeister*, UC Davis, salesmeister@ucdavis.edu
Swee Teh, UC Davis, sjteh@ucdavis.edu

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 meso-zooplankton play an important role as food sources to larval fish and pelagic organisms, factors affecting their changes in abundance in recent years warrants an investigation. Insecticide exposure from nearby agricultural and urban run-off may be one of several factors acting to lower pelagic productivity in the estuary. The goal of this study is to estimate mean lethal concentrations (96-hr-LC50s) of five pesticides (Bifenthrin, Permethrin, Lambda-cyhalothrin, Chlorpyrifos and Fipronil) and to assess if ambient field water samples from critical spawning and nursery habitat are affecting the survival of *E. affinis* and *P. forbesi*. The 96-hr-LC 50 values of five pesticides investigated are near environmentally relevant concentrations. Of the five pesticides studied the most toxic to least toxic are Bifenthrin, Lambda-cyhalothrin, Permethrin, Fipronil with96-hour LC 50 values ranging from 10 to 1000 ng/L. Chemical analyses of these pesticides are currently under investigation. Ambient water testing is a work in progress, where pilot studies indicate acute toxicity of ambient water of critical habitats to copepods. Findings from this study may lead to changes in types of pesticides used and timing of pesticide applications in the SFE. Changes in pesticide regulation may lead to a more sustainable ecosystem by decreasing the population level effects of pesticides on zooplankton, resulting in an increase of food supply to higher trophic level organisms.

Keywords: acute toxicity, *Eurytemora affinis*, pesticides, *Pseudodiaptomus forbesi*,

Tuesday, October 16, 2012: Room 306, Organic Contaminants (II) – Order 7

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Assessment of the Effects of Tertiary Pesticide Mixtures upon Aquatic Invertebrates

Simone Hasenbein*, Dept. of Anatomy, UC Davis, shasenbein@ucdavis.edu
Sharon P. Lawler, Dept. of Entomology, UC Davis, splawler@ucdavis.edu
Juergen P. Geist, Technische Universitaet Muenchen, Germany, geist@wzw.tum.de
Inge Werner, Swiss Centre for Applied Ecotoxicology, Eawag/EPFL, Duebendorf, Switzerland, Inge.Werner@oekotoxzentrum.ch
A. Keith Miles, USGS, WERC, Davis Field Station, UC Davis, akmiles@ucdavis.edu
Richard E. Connon, Dept of Anatomy/Physiology/Cell Biology, UC Davis, reconnon@ucdavis.edu

Aquatic communities in California are often adjacent to areas of intense pesticide use that discharge complex mixtures of contaminants into surface waters. The objective of this study was to address the effects of mixtures of pesticides commonly used in agriculture and urban pest control on aquatic invertebrates.

We focused on the effects of type-I (permethrin) and type-II (lambda-cyhalothrin) pyrethroid pesticides, along with chlorpyrifos (organophosphate) on two aquatic invertebrates, the midge *Chironomus tentans,* and the amphipod *Hyalella azteca*. Both organisms represent important and potentially vulnerable components of the food web in the Sacramento-San Joaquin Delta.

By using the toxic unit approach based on the median lethal concentrations (LC50) for each compound, we compared the effects of pesticide mixtures and their respective individual concentrations on survival, growth, and swimming performance following 10d-exposures.

Exposure to pesticide mixtures resulted in additive responses on survival and synergistic responses on growth in *C. tentans.* Swimming velocity was diminished at concentrations close to the LC25 of permethrin and chlorpyrifos when compared to lambda-cyhalothrin. There was no significant difference in swimming velocity at LC25 of the respective mixtures indicating an antagonistic response, whereas at LC50 the response was additive.

The concentrations of lambda-cyhalothrin to which *H. azteca* were exposed did not result in significant mortality, however there was a significant decrease in growth following exposure. Conversely, organisms exposed singly to permethrin and chlorpyrifos resulted in an increase in growth. Using pesticide mixtures, the response on growth was antagonistic, whereas the response on swimming velocity was additive.

This study highlights the importance of using a number of different endpoints to adequately assess the effects of contaminants, both single and in mixture. We conclude that mortality alone is not an informative endpoint, especially since environmentally relevant concentrations do not generally occur at levels that result in direct mortality.

Keywords: pesticide mixtures, pyrethroids, sublethal effects, effect assessment, invertebrates

Tuesday, October 16, 2012: Room 306, Organic Contaminants (II) – Order 8

ED_000733_DD_NSF_00015174-00015

Variation in Pyrethroid Sensitivity among *Hyalella azteca* from Different Sources

Donald Weston, University of California, dweston@berkeley.edu
Helen Poynton, University of Massachusetts, Boston, Helen.Poynton@umb.edu
Gary Wellborn, University of Oklahoma, gwellborn@ou.edu
Michael Lydy, Southern Illinois University, mlydy@siu.edu

There have been reports of water or sediment samples causing toxicity when tested in the laboratory with *Hyalella azteca*, yet the same waterbodies contain thriving populations of the same species. To further explore these reports, the sensitivity of ten populations of *H. azteca* to pyrethroid insecticides was determined. Three populations were from established laboratory cultures, and seven were from wild collections. The three lab cultures, and some of the wild populations, shared comparable sensitivity to pyrethroids, with LC50s within a factor of three of another. Yet some field populations had LC50s two orders-of-magnitude greater. The relative sensitivity to pyrethroids did not appear to be a function of the extent of prior pyrethroid exposure within the habitat from which they were collected. However, pyrethroid sensitivity was related to the degree of genetic similarity among the populations. DNA sequencing supported previous findings that *H. azteca* represents not a single species, but a species complex. Based on the genetic data, four members of this complex appeared to be represented within the ten populations we examined, and one member in particular was extraordinarily tolerant of pyrethroids. These findings have substantial ramifications to use of *H. azteca* for environmental monitoring in the Bay-Delta related to the source of the animals used, and how cultures are maintained.

Keywords: Pyrethroids, *Hyalella azteca*, Toxicity testing

Tuesday, October 16, 2012: Room 306, Organic Contaminants (II) – Order 9

ED_000733_DD_NSF_00015174-00016

Effects of Endocrine Disrupting Chemicals on *Menidia beryllina*, a Resident Fish in the Sacramento-San Joaquin Delta

Bryan Cole, University of California, Davis, bjcole@ucdavis.edu
Susanne Brander, University of North Carolina, Wilmington, smbrander@ucdavis.edu
Richard Connon, University of California, Davis, reconnon@ucdavis.edu
Gary Cherr, University of California, Davis, gncherr@ucdavis.edu

A diverse and growing number of endocrine disrupting chemicals (EDCs) are known to be present in the waters of the Sacramento-San Joaquin (SSJ) Delta. These EDCs can come from natural sources or from a range of anthropogenic sources including agricultural and urban runoff, as well as in treated wastewater effluent. We have developed *Menidia beryllina*, the Inland Silverside, as a model resident species for studying effects of EDCs on fish, and ultimately on fish populations, in the SSJ Delta and other impacted waterways in the United States. Currently there is only a limited understanding of the impacts of exposure to combinations of EDCs, particularly when estrogenic and androgenic EDCs are mixed. As such this study focused on the biological response of *Menidia* to natural SSJ Delta waters throughout the seasons. We have quantified the expression of a suite of endocrine-related response genes and of choriogenin protein levels, using a *Menidia*-specific antibody to choriogenin, in wild populations around the Delta. Similar assays have also been performed on naïve juvenile fish exposed to SSJ Delta water in one-week long flow-through exposures at two sites spread throughout the seasons. These latter experiments will enable direct comparison of the endocrine response in exposed fish to that in controls which have only experienced EDC-free water. This study will provide time-integrated mechanistic data on the effects of EDCs on fish throughout the SSJ Delta, and should ultimately be able to inform the extent to which EDCs are responsible for the pelagic organism decline in the SSJ Delta.

Keywords: Endocrine disrupting chemicals, fish, SSJ Delta

Tuesday, October 16, 2012: Room 306, Organic Contaminants (II) – Order 10

ED_000733_DD_NSF_00015174-00017

Can Rice and Tule Wetlands Help Manage a Changing Delta?

Amy Merrill, Stillwater Sciences, amy@stillwatersci.com
Phil Bachand, TetraTech, Philip.Bachand@tetratech.com
Stuart Siegel, Wetlands and Water Resources, Inc., stuart@swampthing.org
William Horwath, U.C. Davis, wrhorwath@ucdavis.edu
Bees Butler, U.C. Davis, butler@primal.ucdavis.edu

The Sacramento-San Joaquin Delta plays a critical role in conveying water to 3 million agricultural acres and over 25 million drinking water users. Conveyance faces ever-increasing challenges: sea level rise, land subsidence, increasing flood risk - particularly along the urbanized fringe, and failing fisheries. Coupled with these enormous challenges is a regional desire to maintain the local agricultural-based economy, recreation, and rural nature of a 700,000-acre open space located within an hour of several major metropolitan areas. Our team is examining the efficacy of shifting agricultural land uses towards a critical mass of rice and wetlands in the Delta to mitigate or reverse subsidence and greenhouse gas emissions and reduce hydrostatic pressures on levees, thereby reducing risk to water conveyance while supporting the Delta ecosystem and local agronomic economy. We compare three 'book-end' scenarios to help articulate the potential benefits, risks, and complexities associated with expanding rice agriculture and managed carbon sequestration wetlands in the Delta: (1) Business as Usual Delta (BAU), (2) Conveyance Delta (minimizing conveyance risk), (3) Agrarian Delta (where/how can rice and wetlands improve conditions for local producers). An important fourth scenario, Ecosystem Delta (where/how can rice and wetland distribution maximize ecological function and wildlife habitat), will be considered in the next phase of this project. Based on existing and new information gathered on GHG emissions from Delta BAU, rice, and carbon sequestration wetlands , economic impacts, and levee failure risk, we present Delta-wide maps identifying three tiers of potential strategic locations of rice and wetland land use (recommended, neutral, discouraged) for each scenario. Using findings on surface and groundwater flow models, soil carbon and subsidence, and an analysis of farm-scale management options and constraints from Twitchell and Bouldin Islands, we present island-scale best management strategies for developing rice and wetlands in the central-western subsided Delta.

Keywords: Carbon sequestration, wetlands, rice, agriculture, regional and island scales, GHGs

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Counting Carbon: Methane and Carbon Dioxide Emissions from Agricultural and Restored Delta Peatlands

Jaclyn Hatala*, University of California - Berkeley, jhatala@berkeley.edu
Dennis Baldocchi, University of California - Berkeley, baldocchi@berkeley.edu
Sara Knox, University of California - Berkeley, saraknox@berkeley.edu
Joseph Verfaillie, University of California - Berkeley, jverfail@berkeley.edu

Over the past century, the practice of drained agriculture has resulted in extreme peat subsidence and sustained emissions of carbon dioxide from Delta islands. Reverting lands back to flooded conditions is an attractive intervention to abate further subsidence and improve ecosystem carbon storage in the Delta, since flooding inhibits peat oxidation to carbon dioxide. However, inundation also creates ideal conditions for the production of methane, a potent greenhouse gas and additional pathway of carbon loss. Quantification of the trade-offs between carbon dioxide and methane emissions from different Delta land uses is the first step towards understanding whether flooded landscapes can sustainably reverse the trend of chronic carbon loss in terrestrial Delta ecosystems.

In this study, we measured continuous carbon dioxide and methane fluxes at the landscape scale at four Delta sites with varying degrees of inundation: a drained pepperweed pasture (2007-2012) and a restored wetland (2010-2012) on Sherman Island, and a drained corn field (2012) and a rice paddy (2009-2012) on Twitchell Island. The sites experienced the same weather and climate due to their close proximity, so inundation was the strongest environmental contrast. The pasture and corn field were net carbon dioxide sources to the atmosphere in all years measured, and the pasture periodically emitted large amounts of methane from drainage ditches surrounding the field. The rice paddy was a slight sink for carbon dioxide and emitted relatively low amounts of methane in all years. The restored wetland was a net sink for carbon dioxide, although it was the largest emitter of methane of the four sites. Overall, flooded landscapes experienced less peat subsidence and carbon loss compared with the drained landscapes.

Keywords: carbon flux, land use dynamics, subsidence, methane emissions

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Greenhouse Gas Emission from Rice: A Crop to Address Water and Subsidence Issues in the Delta

William Horwath, University of California Davis, wrhorwath@ucdavis.edu
Yacov Assa, University of California Davis, yassa@ucdavis.edu
Jennifer Morris, University of California Davis, jmorris@ucdavis.edu
Timothy Doane, University of California Davis, tadoane@ucdavis.edu

Greenhouse Gas Emissions (GHG) from corn and rice on Twitchell Island are currently being monitored. The objective is to determine the value of rice as an alternative crop to address water and subsidence issuesin the Delta. GHG are being monitored every one to three weeks. Overall, rice CH_4 emissions averaged 184 and 26 kg CH_4-C/ha for the 2010 and 2011 rice growing seasons, respectively. During 2011 most of the $CH_4$was emitted during the winter. Total CO_2 emission from bare soil was slightly higher in rice than corn during 2011 (11,200kg CO_2-Cand 9600kg CO_2-C/ha, respectively). During spring-fall 2010 period, corn averaged slightly higher than rice (6600kg CO_2-C and 7450kg CO_2-C/ha, respectively). The most significant difference between the crops was the emission of 184 and 411kg CH_4-C/ha from rice during 2010 vs. 2011 rice seasons, respectively. Total estimated residue carbon input from both crops was similar in 2011 (about 5 metric tons C/ha) but much higher for the corn in 2010 (5 and 9 metric tons C /ha in the rice and corn, respectively). The current practice in the corn system of residue removal for cattle feed by the local farmer would bring the estimated corn residue C input in 2011 to less than 1 metric tons/ha. The data presented here suggests that both systems have a net loss of C and that more than 90% of the GHG emissions in rice occur during winter when rice is not flooded. More than 90% of the N_2O and 40% of the CO_2 is emitted during the fallow period in the corn system. Since winter/spring is the highest emission period for both crops, alternative managements should be studied to reduce GHG emissions during this period.

Keywords: methane, nitrous oxide, soil organic carbon, rice, corn, subsidence reversal

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The Economics of Establishing Rice-Based Cropping Systems in the Delta

Leslie Butler, University of California-Davis, ljbutler@ucdavis.edu
Tianxia Zhou, University of California-Davis, tianxiazhou@gmail.com

Farming practices in the Delta over the last century have resulted in substantial subsidence of the islands, increasing levee fragility, risks to water conveyance, GHG emissions from oxidized soils, and decreasing water quality. Our goal is to demonstrate that the establishment of rice-based cropping systems is one agricultural solution for the Delta. Rice is expected to result in important environmental benefits: concurrently mitigating GHG emissions, soil loss, and subsidence while also reducing risks to California's water supply, protecting water quality and enhancing the ecosystem and agriculture. This paper explores the economics associated with converting traditional Delta grown crops, to rice.

We have estimated current and future costs and benefits of converting about 14 of the most commonly grown crops in the Delta to rice production and analyzed: 1) the net present value of converting each crop to rice over time, 2) issues associated with the conversion (changes in cultural practices, capital requirements, etc.), and, 3) projections of yields, prices and costs of production for each crop.

Taking into account the risks and uncertainties associated with rice conversion in the Delta, we have found that rice is a feasible replacement for many of the crops grown in the Delta. For crops that are not feasibly replaced by rice, we have found a number of potential strategies and alternatives.

While it is too early to come to a definitive conclusion about widespread rice production in the Delta, our current results indicate that rice can be a feasible replacement for many traditional crops currently grown in the Delta. However, there are a number of other variables that may potentially enhance, or in contrast, may have negative impacts, on the overall feasibility of establishing rice-based cropping systems in the Delta. These will form the main basis of discussion.

Keywords: Rice-based Cropping Systems, Economics, Cost and benefits, agriculture, ecosystem

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Ongoing Efforts to Develop Pilot Projects and Protocols for Verification of GHG Reductions in the Delta

Campbell Ingram, Delta Conservancy, cingram@deltaconservancy.ca.gov
Belinda Morris, American Carbon Registry, bmorris@winrock.org

With more than 250,000 acres of deeply subsided (up to 25 feet) peat soils currently in agriculture, can managed carbon wetlands and rice cultivation in the Delta be implemented at scale to realize carbon sequestration and subsidence reversal benefits? For over 15 years a team of academics and agencies have been studying two 7 acre plots of managed wetlands planted in tule. Additional research has analyzed the economic viability of managed wetlands as compared to agriculture commodities in the Delta. These efforts indicate that conversion to managed wetlands reduces subsidence and greenhouse gas emissions associated with agriculture production practices. Carbon sequestration rates are high, variability of trace gas emissions is potentially high and requires more research, and economic viability will depend on the future of the carbon market and the development of protocols for verification of GHG reductions in the Delta. Based on these results a team of agencies, academics and nonprofit organizations is seeking to implement farm scale pilot projects at several locations in the Delta, and develop a protocol for adoption by voluntary carbon registries and for consideration in California's cap and trade program. In this session we will present the results of an economic analysis of the potential for conversion to carbon farming in the Delta. We will discuss the ongoing efforts to fund and develop pilot projects and outline the different elements required for carbon trading to take place, including science and modeling needs, greenhouse gas accounting protocols, verification requirements, and carbon pricing, and we will discuss carbon trading in voluntary and compliance markets.

Keywords: carbon sequestration, subsidence reversal, managed wetlands for carbon, GHG protocols

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Findings from the 2012 NRC West Coast Sea Level Rise Report

Dan Cayan, Scripps Institution of Oceanography, U.C. San Diego and U. S. Geological Survey, dcayan@ucsd.edu

This talk will review findings recently released in a National Research Council (NRC) report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. The report summarizes the IPCC (2007) findings on global sea-level change and published research results on the processes that contribute to sea-level change in the region and also presents the NRC Committee's analysis of relevant data and model results. For the California coast south of Cape Mendocino, the NRC Committee projection is that sea level will rise 4 to 30 cm by 2030 relative to 2000, 12 to 61 cm by 2050, and 42 to 167 cm by 2100. For the Washington, Oregon, and California coasts north of Cape Mendocino, the NRC Committee projection is between –4 cm (sea-level fall) and +23 cm by 2030, –3 cm and +48 cm by 2050, and 10 to 143 cm by 2100. Major sources of uncertainty in the regional projections are related to assumptions about future ice losses and a constant rate of vertical land motion over the projection period. Most of the damage along the California, Oregon, and Washington coasts is caused by storms—particularly the confluence of large waves, storm surges, and high astronomical tides during a strong El Niño. To date, there is a lack of consensus among climate model simulations about whether the number and severity of storms will change in the northeast Pacific.

Keywords: Sea Level Rise

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Delta Conservancy Climate Change Policy

Kristal Davis–Fadtke, Delta Conservancy, kmdavis@deltaconservancy.ca.gov

The Sacramento-San Joaquin Delta could undergo many changes due to climate change and sea-level rise in the decades ahead. The potential affects to this region include an increased risk of levee failure, loss of agricultural land and productivity, loss of wetlands, reduced water quality, contamination of groundwater supplies, more water dedicated to meeting water quality standards, biodiversity shifts, increased vulnerability to invasive species, and changes to State Water Project and Central Valley Project operations. As a primary state agency to implement ecosystem restoration in the Delta, the Delta Conservancy seeks to understand and addresses potential climate change impacts, and developed a climate change policy to assist in determining what could increase the Delta's resiliency to the effects of climate change. The Delta Conservancy believes the regional economic and environmental health are linked to the Delta's vulnerability to potential climate change impacts listed above, and that strengthening the Delta region's economy will help the Delta adapt to potential future conditions resulting from climate change. To further this goal, the Delta Conservancy identified in its climate change policy a suite of carbon management and adaptation strategies, as well as guidelines on assessing risk from sea-level rise.

Keywords: Climate Change

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Sea-Level Rise and Coastal Inundation during the Near-Term

Jeanine Jones, California Department of Water Resources, jeanine@water.ca.gov

What does projected sea-level rise mean for coastal inundation now and in the next few decades? The majority of California's open coast is physically protected from inundation (but not necessarily from erosion) by sea cliffs or dune backed beaches; vulnerability to inundation is a localized condition. Although many planning scenarios focus on the large end-of-century projections of global mean SLR, mid-century projections are only in the ballpark of one foot; near-term effects will be experienced as inundation during winter storm events, especially events occurring during stronger El Niño conditions when sea levels can be higher than average. During these events, storm surge and high tides can temporarily increase sea levels to amounts not otherwise expected until the century's end, as was experienced during the

1982–83 El Niño when some of the Central Coast's worst historical erosion damage was observed. Coastal inundation can stem from multiple sources: seawater (storm surge, storm events during high tides), riverine (overbank flow from freshwater drainages), or local stormwater system overflows. This latter condition was observed during 2010 atmospheric river storm events in Southern California, when high-intensity precipitation overwhelmed local stormwater drainage systems and caused urban flooding. Tools for responding to inundation during winter storms events include improved research observations of offshore meteorological and wave conditions, and improved observations and forecasting for extreme precipitation events, such as atmospheric rivers.

Keywords: Sea-Level Rise

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San Francisco Bay Area Sustainable Communities Strategy

Will Travis, Bay Area Joint Policy Committee, travis@bayareajpc.net

In the decades ahead, predicted acceleration of sea-level rise from global climate change threatens over 330 square miles of low-lying shoreline property and over $60 billion worth of public and private development around San Francisco Bay. To deal with this challenge, the San Francisco Bay Conservation and Development Commission recently adopted new regulations that require sea level rise to be addressed when planning shoreline projects. At the same time, the Metropolitan Transportation Commission and the Association of Bay Area Governments are formulating a Sustainable Communities Strategy, which is aimed at reducing driving—the region's largest source of greenhouse gas emissions—by encouraging local governments to plan more compact, mixed-use development near transit corridors within the urbanized core of the region. However, much of the existing development and many transportation corridors are in low-lying areas around the bay that are vulnerable to sea-level rise, and living and working near highways exposes the public to higher levels of air pollutants. To meet these challenges in a manner that will advance economic prosperity in the Bay Area, these three regional agencies, along with the Bay Area Air Quality Management District, are working together under the overview of a Joint Policy Committee to formulate a comprehensive regional strategy that will advance the economy, increase social equity, and protect environmental quality by integrating greenhouse gas mitigation and climate change adaptation into the region's Sustainability Communities Strategy.

Keywords: Climate Change

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Implications of Sea Level Rise and Climate Change for the Coastal and Interior Waters of California: Panel Discussion

Amber Mace, UC Davis, ajmace@ucdavis.edu
John Andrew, California Department of Water Resources, jandrew@water.ca.gov

The National Research Council's report, "Sea Level Rise in California, Oregon, and Washington," is soon to be released in June 2012. The report evaluates of each of the major contributors to global and local sea level rise and gives the associated range of values for the western U.S. for 2030, 2050, and 2100. This special session is convened to present and discuss the report's findings on sea level rise and climate change that affect the coastal and interior waters of California, as interpreted by well-known, local climate experts of California. The session's chair, John Andrew (DWR), convened the speakers, who will evaluate and present what is known about (a) climate-induced increases in storm frequency and magnitude; (b) related changes to regional and local sea level rise estimations; and (c) the efficacy of coastal habitats and coastal restoration (e.g. watershed restoration) in increasing the resilience of communities and ecosystems along the West Coast of California. Amber Mace (UC Davis) will moderate the panel, and begin with Daniel Cayan (Scripps Institution of Oceanography), a member of the NRC committee, who will briefly describe the report findings. The discussion will then move from science to planning and policy, with three speakers discussing implications for California's Coast (Jeanine Jones, DWR), San Francisco Bay (Will Travis, Bay Area Joint Policy Committee), and Sacramento–San Joaquin Delta (Kristal Davis–Fadtke, Delta Conservancy). (If time permits, an additional speaker from the Ocean Protection Council or State Coastal Conservancy may provide update of the state's coastal adaptation strategy.) Panelists will further the discussion by asking "what's next?" Amber Mace will close the panel discussion, summarizing the speaker's main points and giving her interpretations of the general direction of public policy-making regarding to sea level rise and climate change at local and national levels. John Andrew will provide the session's epilogue, thanking all speakers, and bringing audience awareness to recent humanitarian efforts in the face of global climate change by introducing the trailer for the conference's featured documentary, "Someplace With a Mountain."

Keywords: Climate Change

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Benthic Nutrient Fluxes in the San Francisco Bay Delta: Nutrient Stoichiometry, Dentrification and Effects of Benthic Microgal Photosynthesis

Jeffrey Cornwell, UMCES Horn Point Laboratory, cornwell@umces.edu
Michael Owens, UMCES Horn Point Laboratory, owens@umces.edu
Patricia Glibert, UMCES Horn Point Laboratory, glibert@umces.edu
Jeffrey Alexander, UMCES Horn Point Laboratory, jalex@umces.edu

The nutrient mass balance of estuaries includes major inputs from terrestrial, atmospheric and coastal sources; in shallow water ecosystems, sediment nutrient recycling, burial and transformation can also be important. While benthic nutrient fluxes have been assessed at several sites in northern San Francisco Bay, such data across a Delta-Bay transect have not been developed. In September 2011 and March 2012, we measured benthic processes across a gradient from the Delta to Suisun Bay. Dark and illuminated core incubation techniques were used to measure rates of denitrification, nutrient fluxes (phosphate, ammonium, nitrate), and oxygen fluxes including benthic photosynthesis.
Overall rates of oxygen-based metabolism were modest, with shallow water sediments showing substantial photosynthesis by benthic microalgae. Photosynthesis generally attenuates the efflux of N and P in costal sediments, but several sites showed an enhancement of nitrification under illumination, as well as an enhancement of fluxes of soluble reactive phosphorus (SRP). The fluxes of SRP in Honker Bay, Franks Tract, Big Break and Sherman Island were directed into the sediment, likely a result of efficient scavenging by surficial sediment iron oxides. When SRP fluxes were compared to total dissolved inorganic nitrogen (DIN) fluxes for all sites, most of the data approximated Redfield proportions. However, three Bay sites had significant P retention relative to DIN, while all the Delta sites from the light experiments had excess P release relative to N. Coupled nitrification-denitrification was the dominant denitrification pathway, with ~30% of remineralized N denitrified. Our spring 2012 data shows decreased nutrient fluxes and oxygen uptake driven at least in part by cooler water temperatures compared to fall 2011.
Rates of denitrification, benthic photosynthesis, and N/P nutrient net fluxes in these shallow sediments are important to regional nutrient balance, with return fluxes of nutrients supporting phytoplankton production.

Keywords: sediment-water exchange, denitrification, benthic microalgae, sediment oxygen demand, phosphorus, nitrogen

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New and Regenerated Productivity: an Oceanographic Concept Applied to the San Francisco Bay Delta to Understand Phytoplankton Response to Improved Irradiance and Nitrate versus Ammonium Supply

Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Alex Parker, Romberg Tiburon Center, San Francisco State University, aeparker@sfsu.edu

New and regenerated primary production is a basic concept of marine biogeochemistry/marine ecology, introduced by Dugdale and Goering (1967). In the ocean, nitrate occurs in deep water and when advected to the euphotic zone is considered "new" nutrient. Ammonium is supplied to the euphotic zone and to phytoplankton by grazing or bacterial degradation of organic matter. New production sets the upper limit for yield from the ecosystem, e.g. for fish. Multiple sources of both nitrate and ammonium to the San Francisco Bay Delta makes it inappropriate to apply the new production concept directly to the estuary. However, our studies have shown that phytoplankton biomass is accumulated (forms blooms) and most carbon uptake occurs when nitrate is the nitrogen source. Evaluation of nutrient uptake and chlorophyll accumulation in enclosure experiments made at a series of irradiances (and some with nutrient additions), revealed two groups of responses, those with >10% surface irradiance and those with <10%, effectively dividing the euphotic zone into 2 layers. In the upper zone, sufficient light exists for ammonium uptake that reduce the ambient ammonium concentration to levels allowing nitrate uptake to occur. In the lower zone, with light < 10%, phytoplankton production is based only on ammonium uptake at a slow rate likely balancing in situ regeneration of nitrogen from organic N. Consequently, primary production in the upper zone may be designated "new production" and that in the lower zone," regenerated production. Understanding these functional components of the water column helps explain the interactions of changing transparency and relative nutrient loading in estuarine production and bloom initiation in San Francisco Bay Delta.

Keywords: nitrate ammonium new production euphotic zone primary production phytoplankton bloom

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Experimental Manipulations Confirm the Role of Ammonium as a Stress to Phytoplankton in the Bay Delta

Patricia Glibert, University of Maryland Center for Environmental Science, Horn Point Laboratory, PO Box 775, Cambridge, MD 21613, glibert@umces.edu
Richard Dugdale, San Francisco State University, Romberg Tiburon Center, 3152 Paradise Dr., Tiburon, CA 94920, rdugdale@sfsu.edu
Frances Wilkerson, San Francisco State University, Romberg Tiburon Center, 3152 Paradise Dr., Tiburon, CA 94920, fwilkers@sfsu.edu
Alex Parker, San Francisco State University, Romberg Tiburon Center, 3152 Paradise Dr., Tiburon, CA 94920, aeparker@sfsu.edu

There has been considerable debate as to the effects of elevated levels of ammonium on the food web of the Bay Delta. While the effects of nutrient quantity are reasonably well understood in terms of eutrophication, the effects of high nutrient loads on algal physiology are far less understood. It is well known that different forms of nitrogen are used at different rates by phytoplankton. Shifts in nitrogen (N) form from nitrate to ammonium generally lead to community shifts away from plankton communities dominated by diatoms to those dominated by flagellates, cyanobacteria, and eubacteria, in turn, resulting in a shift in composition of higher food webs. Here we report on a series of experimental manipulations in which both form of N and light availability were varied and the phytoplankton physiological and community response monitored on time scales ranging from hours to days. Samples were collected in the Sacramento River during fall 2011, 2012, and spring 2011. Site, seasonal, and time scale differences were observed. Overall, these experiments confirm that 1) nitrate uptake is inhibited by ammonium and the degree of inhibition increases with ammonium concentration; 2) the decrease in nitrate uptake is not compensated for by increases in ammonium uptake resulting in depression in total nitrogen uptake; and 3) biomass accumulation (growth) is depressed when total nitrogen uptake is inhibited. These data underscore the importance of elevated ammonium loads as a major stressor of the Bay Delta.

Keywords: ammonium, diatoms, inhibition, physiological response, community composition

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Inside and Outside Forces Change the San Francisco Bay Phytoplankton Community

Tara Schraga, U.S. Geological Survey, tschraga@usgs.gov
James Cloern, U.S. Geological Survey, jecloern@usgs.gov

Our 18-year (1993-2011) record of phytoplankton species abundance and biomass in San Francisco Bay reveals striking changes in synchrony with two events: a 1999 shift in climate forcing across the Pacific Ocean, and landscape modification of the Bay.

The 1999 climate shift was associated with cooling of the coastal ocean, intensification of upwelling, and record-high abundances of marine shrimp and juvenile flatfish and crabs. Coincident changes were detected in phytoplankton biomass, including increasing baseline levels and the appearance of autumn blooms. Formerly common species, such as the diatom *Coscinodiscus marginatus* and dinoflagellate *Oxytoxum milneri*, disappeared while others, including the diatom *Thalassiosira nodulolineata* and dinoflagellate *Polykrikos schwartzii*, appeared for the first time after 1999 and have persisted in the Bay. A shift of the dominant species from *Thalassiosira rotula* to *Thalassiosira punctigera* has potential implications for higher trophic levels since *T. rotula* produces biochemicals that can block reproduction of invertebrates such as copepods.

Since 2004, the South Bay Salt Pond Restoration Program has opened numerous decommissioned salt ponds to exchange with the Bay. These connected ponds function as incubators for phytoplankton, including species harmful to invertebrates, fish, mammals, and birds. Following the ponds openings, four previously undetected toxic algal species have been detected in the South Bay (Karenia, Karlodinium, Heterosigma, and Chattonella), with three species persisting in high abundances.

Therefore, shifts in phytoplankton community composition have occurred in synchrony with local and ocean-basin scale environmental changes, but mechanisms of these shifts are not apparent. We have begun a pilot monitoring program to measure phytoplankton functional groups with diagnostic pigments and to measure algal toxins to determine if the new occurrences of toxin-producing species are a potential risk to Bay and human health. In this era when support for monitoring programs is diminishing globally, the imperative for monitoring has never been greater.

Keywords: phytoplankton, phytoplankton taxonomy, longterm data, monitoring

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Are Shallower, Slower Habitats Necessarily "greener"? How Clams Upend Conceptual Models Guiding Ecosystem Management in the Delta

Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov
Janet Thompson, U.S. Geological Survey, jthompso@usgs.gov
James Cloern, U.S. Geological Survey, jecloern@usgs.gov

As "food for the fish-food", phytoplankton is the dominant energy source to the pelagic food web of the Sacramento-San Joaquin Delta. However, Delta phytoplankton biomass is low and its long-term downward trend has been paralleled by declines in fish and zooplankton (fish-food). Low phytoplankton biomass and productivity are therefore implicated as factors contributing to the multi-decadal declines in fish species. For that reason, plans for managing the future Delta include actions aimed at enhancing phytoplankton productivity. Two common conceptual models shape those plans and expectations of the ultimate outcomes. The first holds that shallower aquatic habitats promote higher phytoplankton biomass and productivity than deeper habitats because they provide more sunlight energy for phytoplankton photosynthesis (the "Shallower is greener" model). The second holds that more slowly moving water is associated with higher phytoplankton biomass and productivity because longer retention time can allow for greater phytoplankton biomass accumulation (the "Slower is greener" model).

Although these conceptual models seem intuitive and reasonable, they aren't always correct. Using mathematical models and field observations, we show that where bivalve grazing is significant (as in much of the Delta), shallower and slower habitats: 1) are not necessarily characterized by higher phytoplankton biomass or productivity; 2) may be characterized by *lower* phytoplankton biomass and productivity than deeper, faster habitats; and 3) are associated with much greater uncertainty regarding ultimate algal biomass and productivity than deeper, faster habitats. These lessons all suggest that habitat depth and transport time should not be used as indicators of phytoplankton biomass and production. Further, phytoplankton growth and loss (e.g. grazing) rates must be considered together in estimates and expectations of algal biomass or production. Consideration of only one part of the mass balance can lead to substantial error. Practical implications of these lessons for management of the Delta will be discussed.

Keywords: Delta phytoplankton clam bivalve grazing transport model restoration habitat

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Spatial, Temporal, and Tidal Effects on the Distribution of Zooplankton in the Deep Water Ship Channel of the San Joaquin River, CA

Mark Brunell, Department of Biological Sciences, University of the Pacific, mbrunell@pacific.edu
Gary Litton, Department of Civil Engineering, University of the Pacific, glitton@pacific.edu
William Stringfellow, Ecological Engineering Research Program, University of the Pacific, wstringfellow@pacific.edu

As part of a larger study investigating dissolved oxygen dynamics in the tidally-influenced San Joaquin River (SJR) of the Sacramento –San Joaquin Delta Estuary, algal and zooplankton distributions were analyzed for the enhancement of a water quality model necessary to adaptively manage watershed use. The study reach consisted of a 10-mile segment of the Deep Water Ship Channel (DWSC) within the SJR below the Port of Stockton, including the Turning Basin. Monitoring was performed during summer and fall of 2011 and summer of 2012. Three studies were performed: spatial distribution, evaluation of the effect of the Turning Basin on zooplankton abundance in the DWSC, and zooplankton grazing rate quantification. Lateral and vertical distributions at fixed stations, under differing tidal conditions, were highly variable. In the SJR longitudinal monitoring, zooplankton concentrations increase with distance downstream from the Port of Stockton. However, the highest zooplankton concentrations were found in the tributary Turning Basin of the DWSC. These data suggest that the Turning Basin serves as an incubating reservoir of zooplankton that exchange with tidal circulation. Additional studies were conducted in 2012 to verify these observations under lower net flow conditions and directly measure grazing rates with microcosms to incorporate zooplankton in the water quality model.

Keywords: zooplankton, Deep Water Ship Channel, San Joaquin River, grazing

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Invasive Zooplankton Alter Nutritional Prey Quality for Fish in San Francisco Estuary

Pavel Kratina, Watershed Sciences Center, University of California Davis, pkratina@ucdavis.edu
Monika Winder, Watershed Sciences Center, University of California Davis, mwinder@ucdavis.edu

Degradation of carrying capacity and consequent food limitation has been proposed as one of the key factors driving the recent decline of pelagic fishes in the upper San Francisco Estuary. Recent dramatic drop in fish biomass, however, was not accompanied by equivalent decrease in zooplankton carbon, the key food source for threatened and endangered fish species. We tested whether essential nutrient concentrations of zooplankton community changed with the establishment of invasive species. Fatty acid (FA) associated food quality is a critical factor that regulates the energy transfer between primary producers and consumers, and plays an important role in growth, development and reproduction success in heterotrophs. We compared the fatty acid profiles of dominant native and invasive zooplankton species collected in the Estuary. Lower concentrations of essential FAs in invasive species would suggest negative changes in the food quality for fish. Our analyses show substantial differences in long-chain polyunsaturated FAs (PUFAs) across zooplankton taxa. The invasive cyclopoid *Limnoithona* that currently dominates plankton communities had the lowest concentration of eicosapentaenoic acid (EPA). We also detected substantially lower accumulation of monounsaturated fatty acids (MUFAs) by *Limnoithona*, potentially associated with their carnivorous diet. Higher accumulation of EPA but no accumulation of docosahexaenoic acid (DHA) in cladocerans was confirmed in our analysis of *Daphnia*. These taxonomical differences in the FA composition altered nutritional quality of the whole community, because native cladocerans significantly declined while invasive *Limnoithona* increased after their introduction in the early 1990s. Observed shifts in the essential FAs of the whole zooplankton community likely modified growth and survival of secondary consumers. On the basis of these results, plankton biomass and the available zooplankton composition data from long-term monitoring program, a food quality index for pelagic fishes can be developed and used to optimize the management decisions.

Keywords: Fatty acids, food quality, food quantity, invasive species, fish, zooplankton

Tuesday, October 16, 2012: Room 308-310, Food Webs and Lower Trophic Dynamics (II)–Order 7

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The Other Fish Food: A Preliminary Look at Spatial and Temporal Trends in Amphipod Abundances in the Upper Sacramento-San Joaquin Estuary

Heather Fuller, California Department of Water Resources, hlfuller@water.ca.gov
Janet Thompson, United States Geological Survey, jthompso@usgs.gov
Wayne Fields, Hydrozoology, wcf1940@sbcglobal.net

Dietary studies have shown that amphipods are important components of the diets of many native and non-native fishes in the San Francisco Estuary (estuary); however, spatial and temporal trends in amphipod abundances in the estuary are not well studied. The Department of Water Resources' multi-year spatially extensive benthic special study provides an opportunity to examine the trends in abundance of several species of amphipods in the Delta and the low salinity zone (LSZ) of the estuary. We selected sampling locations distributed throughout the Delta and LSZ using a Generalized Random Tessellation Stratified (GRTS) design, a spatially balanced method of randomly selecting sites. Site selection was weighted towards non-bay water bodies (e.g., sloughs, flooded islands, and rivers), as previous studies have shown little site to site variation in benthic communities in the bays compared to other areas of the estuary. We analyzed samples from 48 sites in May and October of 2007-2011. Although 13 species of amphipods were collected, four represented 97% of total amphipods collected: *Gammarus daiberi* (31%), *Americorophium spinicorne* (27%), *Americorophium stimpsoni* (21%), and *Hyalella* sp. (18%; requires submerged aquatic vegetation). Total amphipod abundance was highest in May 2008 and lowest in May 2011. The highest abundances of amphipods were consistently found at the two sites in Sherman Lake, while the lowest abundances were found at sites in the main channel in Suisun Bay. The amphipod community at the majority of sites was made up of at least two or three species; few sites had only one species present. Our results suggest that the quantity and species composition of amphipods in the food web will vary both regionally and by microhabitat. Future analyses of the over 600 other sites sampled during GRTS will help us further understand this variation, as well as seasonal and yearly variation in amphipod abundances.

Keywords: Amphipods Benthic community Food web

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Influence of Biotic Interactions on the Distribution of the Copepod *Pseudodiaptomus forbesi* in the Upper San Francisco Estuary

Karen Kayfetz*, Romberg Tiburon Center, San Francisco State University, kkayfetz@mail.sfsu.edu
Wim Kimmerer, Romberg Tiburon Center, San Francisco State University, kimmerer@sfsu.edu

Distributions of estuarine organisms are dictated in part by physiological tolerances to salinity, but salinity is not the only factor that determines where species are found. This study examines how biological interactions may influence the distribution of the copepod *Pseudodiaptomus forbesi* in the upper San Francisco Estuary (SFE). Two lines of evidence suggest that biotic interactions, not physiology, limit the range of *P. forbesi in* the SFE. First, historical records show that *P. forbesi* was abundant across a broader range of salinity before than after 1993, when two copepods were introduced to the estuary that may compete with or prey upon *P. forbes*i. Second, laboratory experiments on the salinity tolerance of this species show that it is physiologically capable of tolerating a wider range of salinity than it currently inhabits in the SFE. Feeding experiments show that while *P. forbesi* exploits some food sources that are not used by the other species there is also some overlap, indicating potential for competition. Predation on *P. forbesi* by one of the introduced copepods was also examined in laboratory experiments and may have some effect on its population.

Copepods are an important food source for many fish species and *P. forbesi* in particular can constitute a large fraction of the diet of the endangered delta smelt. Understanding the ecology and distribution of this species provides insight into the productivity of the system and the resources available to higher trophic levels.

Keywords: copepod, feeding, FlowCAM, diatom, flagellate, ciliate, prey, diet, delta smelt

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Evidence of Food Web and Biogeochemical Changes in the San Francisco Estuary as Indicated by Stable Isotope Analysis of Historical Zooplankton Samples

Julien Moderan, Romberg Tiburon Center - San Francisco State University, jmoderan@gmail.com
Robin Stewart, US Geological Survey, Water Resources Division, arstewar@usgs.gov
Wim Kimmerer, Romberg Tiburon Center - San Francisco State University, kimmerer@sfsu.edu

In recent years, numerous species introduction and alterations of freshwater flow have resulted in a strong decline of phytoplankton biomass and subsequent impacts in both zooplankton and pelagic fish communities of the San Francisco Estuary (SFE). Here we use carbon and nitrogen stable isotopes of zooplankton, a key component in estuarine systems and a major food source for many important and endangered fish species, as a bioindicator to document foodweb and biogeochemical changes in the SFE over the past decades. This retrospective analysis based on long-term series of zooplankton samples collected from 1976 through 2010 should provide insights into the relative contribution of local phytoplankton and terrestrially-derived organic matter sources to the plankton-based foodweb, trophic levels of the dominant species, trophic interactions, and how they have changed related to primary environmental modifications. We present preliminary results from an experiment aimed at validating the use of archived samples. We measured the impact of common preservation methods (freezing *versus* formalin), and duration of preservation on the stable isotope composition of six copepods and one mysid species. Initial results indicate a limited impact of formalin preservation on stable carbon isotopic composition (<1‰), which occurred rapidly after preservation and remained rather constant over time (thus predictable). Preservation effects were more variable and species-dependant for stable nitrogen isotopes (from <1‰ for *Acartiella sinensis* and *Hyperacanthomysis longirostris* to unexpectedly high for *Pseudodiaptomus forbesi*) but remained for most species smaller than the expected trophic enrichment and should still allow the calculation of correction factors, as they were stable over time. Preliminary results based on historical samples collected in the San Joaquin river at Buckley Cover will also be presented. These results will be valuable in improving our understanding of the upper SFE and of the possible mechanisms contributing to the Pelagic Organism Decline.

Keywords: Zooplankton, Stable Isotope, Foodweb, Organic Matter, Low Salinity Zone

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Principles and Recommendations for Life Cycle Models

James Anderson, University of Washington, jjand@uw.edu

Fish life cycle models are playing significant roles in the BDCP and the restoration of endangered species. Existing models present compelling, but different, explanations for the declines of Central Valley salmon and Delta smelt. However, the limited theory/data underling these models and the lack of a clear of evaluation process make it difficult to select between them. With the looming of model wars, a collaborative model development process is needed that encourages consensus and understanding. Drawing on experiences of veterans of review panels (NRC 2010, 2012; Rose, Anderson, McClure & Ruggerone 2011) I summarize issues and suggestions for the process of model development.

Philosophy–Life cycle models have varying degrees of mechanistic and statistical complexity which are ultimately determined by expert opinion. However, experience shows that neither expert opinion nor ability to fit data guarantees a model is correct or addresses relevant questions. To limit the modeling of myth alternative models should be developed and judged on their statistical and mechanistic aspects. Level of complexity should depend on the target audience: simple models inform the public on how the system works, forecast models assist managers and predictive models assist planners in designing futures.

Communication–A model is a logical structure combining ideas and data. Maintain a glossary of terms and concepts and a repository of data. Standardize documentation and public presentations. Publish the models in journals (SFWES).

Process–Modelers follow a process, which includes: identifying questions, reviewing existing models, synthesizing and summarizing data, formulating the structure and processes, coding, documentation, calibration, validation, sensitivity analysis and scenario evaluation. Each of these steps should be done in a collaborative and open manner. Models developed in isolation and reviewed in workshops and panels can lead to counterproductive model wars.

Ownership–Ultimately ownership belongs to the responsible agency but versions should be available to the target audiences: public, managers, planners.

Keywords: life cycle models, modeling process and evaluation

Tuesday, October 16, 2012: Room 311-313, Existing and Emerging Life Cycle Models (I)–Order 1

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Application of a Winter Run Chinook Salmon Life Cycle Model to Evaluating Conservation and Management Actions

Steven Zeug, Cramer Fish Sciences, stevez@fishsciences.net
Paul Bergman, Cramer Fish Sciences, pbergman@fishsciences.net
Bradley Cavallo, Cramer Fish Sciences, cavallo@fishsciences.net
Kristopher Jones, Cramer Fish Sciences, kjones@fishsciences.net

Resource managers in the Central Valley are challenged to maintain stable or increasing populations of Chinook salmon in the face of increasing demand on the water resources and habitats that salmon depend on to complete their life cycle. Alternative management plans are often selected using professional opinion or piecemeal observations in place of integrated quantitative information that could reduce uncertainty in the effects of management plans on population dynamics. We developed a stochastic life cycle simulation model for winter run Chinook salmon in the Sacramento River with the goal of providing managers a tool for more effective decision making and demonstrating the utility of life cycle models for resource management. Sensitivity analysis revealed that the input parameters that influenced variation in salmon escapement were dependent on which age class was examined and their interactions with other inputs (egg mortality, Delta survival, ocean survival). Certain parameters (e.g. river migration survival, harvest) hypothesized to be important drivers of population dynamics were not identified in sensitivity analysis; however, there was a large amount of uncertainty in the value of these inputs and their error distributions. Thus, the model also was useful in identifying future research directions. Use of IOS for evaluating the BDCP has focused on entering modeled flow and temperature data for different scenarios and examining model output. However, this strategy does not take full advantage of model capabilities. Models like IOS can and should be used develop management scenarios by gaming different strategies. For example, the benefit of reducing harvest could be pitted against a reduction in exports or increases in river flow. To date, all scenarios have focused on early life stages of salmon and haven't addressed other life stage despite having management control over sources of adult mortality (harvest). The model presented provides an effective tool for decision making.

Keywords: Salmon

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Using OBAN and Decision Theory to Evaluate BDCP Alternatives

Noble Hendrix, QEDA Consulting, LLC, Affiliate Faculty University of Washington, noblehendrix@gmail.com
Ray Hilborn, School of Aquatic and Fisheries Sciences, University of Washington, rayh@u.washington.edu
Curry Cunningham, School of Aquatic & Fishery Sciences, University of Washington, curryc2@uw.edu
Robert Lessard, Columbia River Inter-Tribal Fish Commission, lesr@critfc.org

Multiple anthropogenic and natural factors affect the population vital rates of Chinook salmon (*O. tshawytscha*). We developed a statistical framework entitled Oncorhynchus Bayesian Analysis (OBAN) to evaluate factors hypothesized to affect Chinook populations. To date we have applied this framework to winter and spring-run Chinook in the Sacramento River, CA. The OBAN framework is a state-space, stage-structured model that estimates the impact of hypothesized factors on the survival rates between stages. The impacts of factors are described by posterior probability distributions that characterize the uncertainty in the relationships between factors and stage-specific survival. The output of the OBAN model is a set of posterior probability distributions that can be used to forecast future abundances of Chinook as a function of hypothetical future factor levels (e.g., harvest rates, Yolo flooding, exports, etc.). The OBAN models have been used to evaluate Bay-Delta Conservation Plan (BDCP) alternatives in this context, producing probability of abundance and probability of quasi-extinction under different alternatives.

The OBAN framework can potentially be limiting, however, because forecasts of future abundances cannot easily accommodate hypothetical alterations to the ecosystem, such as the proposed North Delta diversions. Yet, there is the potential to use decision theory alongside Bayesian analyses (Berger, J. 1991, Statistical Decision Theory and Bayesian Analysis, Springer) as a coherent framework for incorporating subjective probability distributions of future interventions in the forecasted system. Importantly, the objective shifts from forecasting realistic distributions of abundances to developing robust decisions. We describe how we have coupled the OBAN models and the decision framework to provide evaluations of BDCP alternatives under hypothetical alterations to the Bay-Delta ecosystem.

Relevance: We combine a retrospective statistical model (OBAN) with a decision theory framework to facilitate decision-making under hypothetical alterations to the ecosystem as part of the BDCP process.

Keywords: Bayesian analysis, OBAN, Chinook, decision analysis, BDCP

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A Flexible, Multi-Input Life Cycle Model for Chinook Salmon in the Central Valley of California

Candan Soykan, SWFSC, candan.soykan@noaa.gov
Tim Beechie, NWFSC, tim.beechie@noaa.gov
Correigh Greene, NWFSC, correigh.greene@noaa.gov
Noble Hendrix, R2 Resource Consultants, nhendrix@r2usa.com
Steve Lindley, SWFSC, steve.lindley@noaa.gov
Leora Nanus, SWFSC, leora.nanus@noaa.gov
Russell Perry, USGS, rperry@usgs.gov

Recognizing that multiple factors affect survival and capacity across a gradient of habitat types and for a variety of life stages, we are developing a flexible life cycle model for Chinook salmon in the Central Valley of California. The model combines empirical data relating water temperature and flow levels to survival, with capacity estimates based on channel roughness, water depth, and velocity. These inputs are used to estimate life-stage- and river-reach-specific survival and capacity in the Species Life-cycle Analysis Module (SLAM) modeling framework. The initial versions of the model will focus on comparing salmon population dynamics given current, historical, and future scenarios (assuming BDCP-based changes in habitat and hydrology). Present limitations of the model are due, in large part, to a lack of empirical data on survival and/or capacity for various life-stage/habitat-type combinations. We are presently working on alternate methods to estimate these parameters, particularly fry survival in the Delta using modifications to the Particle Tracking Module of DSM-II. The flexible framework developed for this model means that new data (e.g., turbidity) and/or factors (e.g., hatchery fish) can be easily assimilated, and that diverse scenarios can be explored within a single modeling framework. However, even in its present form, the model provides a means to compare Chinook population dynamics under alternate scenarios and evaluate effects of specific management actions.

Keywords: Chinook Salmon, Life Cycle Model, Survival, Capacity, HEC-RAS

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Sacramento River Chinook: Modeling the Influence of Environmental Variability in a Stock Complex

Curry Cunningham*, University of Washington, School of Aquatic and Fishery Sciences, curryc2@uw.edu
Noble Hendrix, R2 Resource Consultants, Inc.; Affiliate Faculty at University of Washington, nhendrix@r2usa.com
Robert Lessard, Columbia River Inter-Tribal Fish Commission, lesr@critfc.org
Ray Hilborn, University of Washington, School of Aquatic and Fishery Sciences, rayh@u.washington.edu

Chinooksalmon (*O. tshawytscha*) populations spawning in the Sacramento River (CA) and its tributaries have demonstrated high variability, and in some cases significant declines in spawning abundance, during the past 40 years despite restrictions to commercial and recreational fishing activities. Concern over the sustainability of Sacramento River Chinook populations has driven our inquiry into the environmental drivers of survival during specific life-stages and competition amongst stocks at likely points of interaction. We are in the process of developing a stage-structured population dynamics model that will permit hypotheses to be tested regarding the impact of environmental factors on productivity and capacity in various life-stages, the influence of hatchery production on the survival of natural stocks, and competition amongst co-migrating and co-rearing natural and hatchery-produced groups. Environmental factors under investigation may be broadly categorized as: 1) the result of natural changes in marine productivity, or 2) arising from anthropogenic influences in the system including changes to water flow and temperature, access to rearing habitat, and water exports or diversions for agriculture and urban use. We estimate the direction and magnitude of influence from the suite of environmental factors by fitting models to historical time series of abundance and environmental data (~1970+). Competition is evaluated between Spring, Winter and Fall-run Chinook from the Sacramento mainstem, as well as naturally reared and hatchery produced stocks from tributaries throughout the watershed.

The purpose of this research is to provide a quantitative framework for assessing the influence of both environmental and anthropogenic factors on the survival of threatened and endanger Chinook salmon populations in the Sacramento River, California, and a means for estimating future changes in abundance under alternative ecological and water use policy scenarios.

Keywords: life-cycle, modeling, Chinook, Sacramento, productivity, capacity, hatchery

Tuesday, October 16, 2012: Room 311-313, Existing and Emerging Life Cycle Models (I) – Order 5

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Hierarchical Spatial-temporal Modeling of Delta Smelt Population Dynamics

Ken Newman, USFWS, ken_newman@fws.gov
Wim Kimmerer, Romburg Tiburon Center, San Francisco State University, kimmerer@sfsu.edu
Pete Smith, USGS, retired, pesmith07@comcast.net
Randy Baxter, California Department of Fish and Game, rbaxter@dfg.ca.gov
Emilio Laca, UC Davis, ealaca@ucdavis.edu
Bill Bennett, UC Davis, wabennett@ucdavis.edu
Wendy Meiring, UC Santa Barbara, meiring@pstat.ucsb.edu
Fred Feyrer, US Bureau of Reclamation, ffeyrer@mp.usbr.gov

A spatially explicit, hierarchical state space model has been formulated and fit to predict delta smelt population dynamics. Delta smelt are a species listed as threatened under the Federal Endangered Species Act and listed as endangered under the California Endangered Species Act. This model was developed primarily to provide resource managers a tool for assessing and predicting the effects of various management actions, particularly actions aimed at restoring the population, on the population dynamics. We are using fish, other biota, and physical data from multiple sources in an integrated manner to estimate the parameters of the model. Management actions can be translated into changes in model input variables or covariates, which in turn affect model processes such as survival. Alternatively, management actions can be translated more directly as changes in a model process, e.g., survival is adjusted up or down by some specified amount. We show how this structure and fitting procedure yields model outputs of direct interest to managers, such as population viability or recovery analyses. This tool is of direct relevance for quantitatively evaluating how different actions might affect the survival of delta smelt and potential for recovery.

Keywords: delta smelt, Interagency Ecological Program, hierarchical model, Bayesian, MCMC

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Bay Delta Ecosystem Diagnosis and Treatment

Jesse Schwartz, ICF International, Jesse.Schwartz@icfi.com

Numerous stressors on the Bay Delta ecosystem have resulted in an impaired presentation in numerous dimensions. Ecosystem-based management of the Bay Delta, though well supported in the policy arena and thoroughly discussed in the scientific literature, seems complicated by the diverse and sometimes competing requirements of threatened and managed species that make use of these commons. The initiative to compoundly optimize the system for water exports and aquatic ecology has resulted in a sophisticated suite of models and management tools for seasonal and water-year based resource allocation. More recent planning efforts have included habitat restoration efforts aimed to relax limiting factors affecting delta smelt (*Hypomesus transpacificus*) and other species. There remains, however, some distance between the prescriptions of management and the prognosis of existing and new treatment plans that are operating on numerous and sometimes disparate scales. I describe an application of the medical model to the Bay Delta Ecosystem aimed to support long-term (20 year) diagnosis and treatment through integrated plans, actions, and outcomes. Bay Delta Ecosystem Diagnosis & Treatment (BDEDT) builds upon implementations of the medical model in the tributaries to the Bay Delta, and leverages the comparison between patient (i.e. current) and template (i.e. system potential) presentations of the system as these would be perceived through the eyes of delta smelt. I describe the benchmark performance of a Lefkovitch stage based model for delta smelt, spatio-temporal aspects of various life-history trajectories through the delta, species-habitat relationships, and the potential sensitivities to limiting factors based on existing published literature. I present these modeling elements within the Ecosystem Diagnosis & Treatment analytical framework with an emphasis on its application to habitat restoration and management.

Keywords: Fish

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Models as Tools for Learning: Room for Many in the Sandbox

Steven Culberson, U.S. Fish and Wildlife Service, Bay-Delta Fish and Wildlife Office, steven_culberson@fws.gov

Predicting population trajectories of endangered species is difficult. We used a systems modeling approach to simulate the delta smelt lifecycle to explore smelt population behavior. Several smelt life stage attributes and environmental co-variates are included in the model. We used several model versions in comparison as a logical, learning-by-doing exercise for evaluating potential steps for recovery. We suggest agencies place increased emphasis on quantitative and semi-quantitative systems modeling and learning. We encourage simple systems simulation as supplement to consultant- or investigator-driven model building and "problem solving." The use of models as learning tools stems from the idea that models are disposable, quick, cheap, and useful for only a short period of time and for a limited set of questions.

Keywords: Systems Modeling, smelt, population, simulation

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A Lower Trophic Level Food Web Model for Simulating Dynamics in the Low Salinity Zone (LSZ) of the San Francisco Estuary

Shaye Sable, Dynamic Solutions, LLC, ssable@dsllc.com
Kenneth Rose, Louisiana State University, karose@lsu.edu
Wim Kimmerer, San Francisco State University, kimmerer@sfsu.edu
Steve Bartell, Cardno ENTRIX, smbartell@aol.com
Eugene Maak, U.S. Army Corps of Engineers, eugene.c.maak@usace.army.mil

A version of the comprehensive aquatic systems model (CASM) was developed to simulate daily growth processes and food web interactions over one year among important lower trophic level (LTL) populations in the low salinity zone (LSZ) of the San Francisco Estuary. The LTL food web is comprised of two phytoplankton populations and nine consumer groups that include multiple populations of particle-feeding zooplankton, a predatory copepod, *Corbula* clams, mysids, and a pelagic fish group. Daily population growth is determined by bioenergetics-based equations, and daily inputs for light, temperature, depth, nutrients, suspended sediments, and particulate organic matter differentially modify maximum photosynthesis and consumption of the populations. Field data and outputs generated for 2004 by EFDC hydrodynamic and water quality models were used as model inputs, and daily predicted biomasses for the populations were calibrated to biomass data collected by the Interagency Ecological Program using an automated program called PEST. PEST adjusted the bioenergetic parameters of the populations to best fit the predicted and the observed biomasses. The PEST-calibrated parameters were then manually fine-tuned to produce a realistic set of values that provided reasonable diet composition and degrees of coupling among the populations within the food web. The calibrated LTL food web showed that phytoplankton growth was severely light-limited in 2004 and had to be subsidized from outside the LSZ in order to support the food web. The calibrated model was used to evaluate changes in energy cycling and food web responses, as well as potential changes in food supply (particle-feeding and predatory zooplankton) for delta smelt, due to bottom-up changes in primary production and top-down effects from clam grazing. The CASM can evaluate a variety of bottom-up effects of water quality and restoration measures on production and distribution of the LTL populations in the San Francisco Estuary.

Keywords: lower trophic level food web, low salinity zone, model

Tuesday, October 16, 2012: Room 311-313, Existing and Emerging Life Cycle Models (II)–Order 9

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Historical Ecology and Landscape Scale Restoration: Application to the McCormack-Williamson Tract

Julie Beagle, San Francisco Estuary Institute, julieb@sfei.org
Robin Grossinger, San Francisco Estuary Institute, robin@sfei.org
Alison Whipple, San Francisco Estuary Institute, Alison@sfei.org

Historical ecology encourages a landscape-level perspective for restoration through improved understanding of how historical patterns and processes shaped habitat in the recent past. This conceptual understanding of landscapes can be used to evaluate current conditions and develop future scenarios. We used the recently-completed picture of the historical Delta landscape to explore opportunities for the McCormack-Williamson Tract (MWT), a 1600-acre tract along the Mokelumne River. This site provides an example of balancing contemporary constraints to restoration (including existing infrastructure and flood protection concerns) with the goals of landscape-scale restoration.

We placed the site within the larger pattern of historical Delta landscapes and related local habitat patterns to the controlling physical gradients using historical data and conceptual models. This aided interpretation of the contemporary physical landscape and identified opportunities and constraints to landscape-scale restoration. The historical record revealed features such as lakes, natural levees, and tidal channels that could be strategically incorporated into the restoration vision. This perspective helped focus restoration options, including the relative proportion and placement of different habitats and physical features within project design constraints, maximizing the site's potential. The approach also identified opportunities to improve ecological connectivity and long-term adaptability to sea level rise and other environmental changes. A central component of translating the historical landscape perspective to site-scale design was envisioning a process that spanned a short-term vision of restoration possible within the site's bounds, within in the context of a longer-term vision for the Delta.

The project should increase the likelihood of successful restoration design for the MWT and provide a strong rationale for expected ecological functions. From a regional perspective, this local-scale/landscape-scale approach illustrates the value of understanding different landscapes of the historical Delta and connects restoration at MWT to restoration principles and strategies being developed for the Delta regionally.

Keywords: landscape-scale, restoration, historical ecology, ecological functions

Tuesday, October 16, 2012: Room 314, Issues and Challenges in Landscape-Scale Restoration (I) – Order 1

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Suisun Marsh Historical Ecology: Notoriously Swampy and Overflowed Lands

Amber Manfree*, UC Davis, admanfree@ucdavis.edu

I have been assessing the deep and recent history of Suisun Marsh as a contribution to a book on the future of the Marsh. Synthesis of information from historic maps, early explorers' accounts, and other sources reveals that, for the past 6,000 years, it has been a place of constant – and relatively rapid – geomorphic and ecological change. In addition to the natural variability of a large marsh situated in the estuarine transition zone, human- and animal-landscape interactions prior to European contact were ecologically significant. Shifts in human and animal populations during the Spanish and Mexican eras, followed by agricultural development and duck club management, have kept the marsh landscape continually in flux. The rate and quality of change has intensified since European contact in 1769 and even more since the Gold Rush. Management agreements in the past 40 years have been based on relatively recent conditions, and do not address the immense variability and complexity inherent in the region, or the increasing importance of the Marsh for protecting native plants and animals in the San Francisco Estuary. Understanding both the deep and recent history of the Marsh provides insights which inform management approaches, point to potential restoration and rehabilitation targets, and alter attitudes about appropriate human-landscape interactions.

Keywords: Suisun, marsh, environmental, landscape, ecology, history

Tuesday, October 16, 2012: Room 314, Issues and Challenges in Landscape-Scale Restoration (I) – Order 2

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Management Considerations Associated with Large-Scale Ecosystem Restoration

Curt Schmutte, State Federal Contractors Water Agency, CSchmutte@mwdh2o.com
Byron Buck, State Federal Contractors Water Agency,

Restoration actions contemplated for the Sacramento-San Joaquin Delta must occur at the landscape scale to achieve replication of historic habitat functions and meet the key restoration requirements established by the Bay Delta Conservation Plan, regulatory biological opinions and the Suisun Marsh Plan. The number and pace of acres that would need to be restored is unprecedented. There are inherent challenges in such an massive undertaking, not the least of which is land acquisition and overcoming land speculation that threatens to complicate the assemblage of necessary lands. This presentation will examine key constraints, opportunities and challenges associated with large-scale land acquisition and habitat restoration.

Water agencies may develop habitat by securing lands suitable for habitat restoration through traditional direct fee/easement purchase and development, joint public-private partnerships or competitively priced, completed restoration. Public agencies are bound by appraised fair market land prices and the wise expenditure of public funds to maximize the restoration benefits. The State Federal Contractors Water Agency has determined that development of habitat projects on a large scale is far more cost-effective and biologically prudent than acquisition of random, small "postage-stamp" parcels. Accordingly, the implementing agencies are coordinating efforts to act in unison and are not proposing to entertain purchase of expensive habitat credits from mitigation banks as a mechanism to advance habitat restoration. However, if privately developed, fully functioning habitat can be provided at equal or greater habitat value and at a cost less than comparable agency-developed projects, it would be considered. Therefore, it is in the public's interest to clarify acquisition efforts, create competitive opportunities for privately developed efficiencies and dampen harmful unrealistic expectations.

Keywords: Landscape-Scale Restoration

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Delta Working Landscapes

Michael Machado, Delta Protection Commission, marc.ceccarelli@delta.ca.gov

The Delta Protection Commission's Delta Working Landscapes program encourages farmland to be utilized as valuable habitat by providing opportunities for private landowners to incorporate wildlife friendly farming with current agricultural practices. Currently, attention and effort is being focused on restoring the natural habitats of the Sacramento-San Joaquin Delta to support aquatic and terrestrial wildlife that may have negative impacts to the Delta's economy and culture. Working Landscapes projects provide benefits over traditional ecological restoration projects as the land remains in agricultural production, thus continuing to contribute to the overall economic sustainability of the Delta while encouraging local citizens to serve as environmental stewards of the landscape.

Approach

Delta Working Landscapes approaches these problems through a variety of methods. Planting vegetative buffers along irrigation ditch banks and hedgerow plantings improve water quality by reducing runoff of pesticides and sediment. Farm cultural practices which can benefit for wildlife friendly agriculture, such as rice, corn and wheat fields have been identified and have implemented seasonal flooding and restoration to increase winter wildlife habitats. These projects have additionally supported water quality improvement, salinity control, subsidence reversal, and weed control.

Results

The Delta Working Landscapes projects improve the environmental quality of existing landscapes in the Delta; coordinate programs with local farmers to understand the social, economical, environmental and governmental policy hurdles and incentives to perform conservation practices; and communicate to farmers the advantages of implementing wildlife friendly agricultural practices.

Conclusions / Relevance

- Partnerships between public and private efforts are possible
- Delta farmers have a strong interest in agricultural and wildlife conservation
- Delta farmers understand the importance of improving the existing quality for future generations
- Working Landscape Projects can be the key for a sustainable Delta

Keywords: Delta, Working, Landscapes, Protection, Commission

Tuesday, October 16, 2012: Room 314, Issues and Challenges in Landscape-Scale Restoration (I) – Order 4

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South Bay Salt Pond Restoration Project: Overview and Updates

John Bourgeois, California Coastal Conservnacy, jbourgeois@scc.ca.gov
Laura Valoppi, USGS, laura_valoppi@usgs.gov
Cheryl Strong, USFWS, Cheryl_Strong@fws.gov

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 restoration actions completed to date in Phase 1. At the completion of Phase 1 actions, there will be 1600 acres of tidal marsh restoration, 1440 acres of muted tidal restoration, 710 acres of reconfigured ponds, and 7 miles of new trails. The presentation will also set the stage for the series of technical talks addressing specific key uncertainties in the talks to follow.

Keywords: wetland restoration; adaptive management

Tuesday, October 16, 2012: Room 314, Issues and Challenges in Landscape-Scale Restoration (I) – Order 5

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Implementing the Habitat Restoration Requirements of the Biological Opinions: DWR/DFG Fish Restoration Program Agreement Implementation Strategy

Dennis McEwan, CA Department of Water Resources, dmcewan@water.ca.gov
Dan Riordan, CA Department of Water Resources, driordan@water.ca.gov
Gina Benigno, CA Department of Water Resources, gbenigno@water.ca.gov
Ling-ru Chu, CA Department of Water Resources, lchu@water.ca.gov
Pam Lindholm, CA Department of Water Resources, plindhol@water.ca.gov

In response to population declines of endangered native fish, management directives require the restoration of many thousands of acres of tidal wetland habitat in the Delta. DWR and DFG have entered into a cooperative program called the Fish Restoration Program Agreement (FRPA) to actively address this need. In its first year, the FRPA Program has completed an Implementation Strategy for the habitat restoration requirements called for in the NMFS salmon Biological Opinion, FWS delta smelt Biological Opinion, and DFG longfin smelt Incidental Take Permit. The FRPA Implementation Strategy outlines our approach to implementing habitat restoration actions, highlights some early implementation projects that have already been identified, and provides guidelines for finding future restoration sites to fulfill restoration requirements. The scientific principals underlying the development of project design alternatives will be discussed. Additionally, all FRPA restoration projects will have an associated monitoring and adaptive management plan, to ensure proper ecosystem functioning. To ensure consistency and comparability of monitoring data between projects, we are in the process of developing a delta-wide tidal habitat restoration monitoring plan, which will include the opportunity to conduct special studies to help address key uncertainties associated with habitat restoration in the delta. We highlight some early implementation projects, which primarily occur in the Cache Slough region of the northern delta. Projects including Calhoun Cut, Yolo Ranch, and Prospect Island are currently in various stages of the planning process. As technical activities develop, FRPA is actively seeking open and transparent opportunities to discuss progress with stakeholders. While there will be challenges and impediments to restoration as projects progress, FRPA is making progress toward fulfilling the tidal wetland habitat restoration requirements aimed at restoring native fish populations.

Keywords: restoration, tidal wetland, marsh, cache slough complex, smelt, salmon

Tuesday, October 16, 2012: Room 314, Issues and Challenges in Landscape-Scale Restoration (II) – Order 6

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Issues and Challenges to Restoration at the Landscape Scale – The Whole is More Than the Sum of its Parts

Michelle Orr, ESA PWA, morr@esassoc.com

Regional-scale restoration presents opportunities to restore significant ecosystem benefits. It also introduces complexities that don't typically come into play for smaller restorations. Because of this, successful restoration of larger areas requires more than extrapolating from the experience of smaller sites. This presentation draws primarily on wetland restoration examples from the San Francisco Bay-Delta, with select comparisons to other regional restoration efforts. Projects planned for the Bay-Delta total tens of thousands of acres and would approximately double the extent of tidal habitats. By virtue of their scale, larger restorations have the potential to affect regional processes such as estuarine sedimentation, tidal hydrodynamics, and salinity regime. Successful planning requires that these regional changes are considered in terms of how they affect offsite land uses and the restored areas themselves. Outside the restored areas, these changes can affect drainage and flooding, navigation, dredging, and wind-wave erosion of levees and existing habitat. Within the restored areas, these changes can affect the evolution of habitats and achievement of restoration goals. Adaptive management is generally recognized as an important component of managing uncertainty in large-scale restoration implementation. What is meant by adaptive management, however, varies greatly depending on who you ask. This presentation will compare and contrast adaptive management approaches in use in San Francisco Bay, the Delta, and coastal Louisiana.

Keywords: regional, wetland restoration, adaptive management

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Time Heals All: Reconciling Conflicting Restoration Goals

Christopher Enright, Delta Science Program, cenright@deltacouncil.ca.gov

Investigations of the historical landscape reveal the characteristic scale and repeating pattern of landscape elements like seasonal freshwater lakes and dendritic tidal creeks and their interaction with natural flows. Yet, applying this understanding to restoration strategies must confront the fact that we begin degraded: Today, Delta land is subsided and severely disconnected from the estuary. Restoration efforts will require decades to return some native landscape forms and functions, even as several native species are in peril. Restorations therefore must do it all: At once recover landscape features and elevation while functioning adequately for native species in the interim.

This talk attempts to reconcile these two ideas with a synthesis of estuarine landscape restoration understanding. First, restoration of native tidal marsh function depends on recovering characteristic forms including vegetated marsh plains elevated near the top of the tidal frame and incised by branching sloughs. This multi-decade process will require, at a minimum, restoration designs that import sediment while vegetation colonizes expanding edges where sediment can be trapped. The trajectory of this sedimentation-vegetation feedback should be a key restoration performance metric that, in turn, depends on properly scaling tide, river, and wind forcing to the dynamic impedance of projects. Second, in the interim decades, restorations must function adequately for native species even as the land water interface is dominated by deep intertidal and shallow subtidal forms. Many native nekton first seek suitable dynamic conditions like fluvial and tidal currents, temperature, and salinity. Once there, organisms use the available structural habitats to find food and refuge. Where dynamic habitats overlap reliably with diverse structural habitat options, native species production can be resilient, even on the interim landscape. Understanding and managing the dynamics of restoration projects will require far more focused and capable modeling, science and management structures than exist today.

Keywords: Restoration scale, reconciliation, land-water interface, natural flow, habitat structure

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Connecting Wetland Restoration and Subsidence Reversal to the Carbon Market

Stephen Crooks, ESA PWA, SCrooks@esassoc.com

The Delta is a highly fragile system, with rising sea level and ongoing land subsidence the risk of levee failure grows. A significant earthquake could potentially flood multiple islands, which if abandoned could permanently change the hydrology and ecology of, and drinking water supply from, the Delta. Restoration activities under BDCP are focused upon the Delta margins, ignoring the deeply subsided central region. Should the Central Delta fail the resiliency of these restoration activities will be questionable. Against this backdrop, some 5 x 10^6 tCO2 are released from Delta organic soils, contributing to California's GHG emissions.

Subsidence reversal, the rebuilding of organic soils through simple water management and tule growth, has been demonstrated to be achievable. If adopted on a large-scale, this activity has potential to reverse Delta fragility, reverse historic GHG emissions, and contribute to long-term ecosystem restoration. While challenges remain, significant hurdles are being overcome. By the time of this conference, the Verified Carbon Standards, a world-leading registry for land-based carbon projects is expected to be on the verge of adopting a change in their rules allowing for the submission of *wetland restoration and conservation* methodologies and projects. The next critical step, the drafting of a methodology setting monitoring and reporting requirements for carbon projects in the Delta, is in progress and may be available for deployment by the summer of 2013. The potential to connect Delta restoration to carbon financing is becoming a reality.

Over the past century we have dug ourselves into an ever deepening hole; literally 2.5 billion cubic meters in size. While not a panacea, by next year we may have an additional financing tool to dig ourselves out. Now is the time to integrate subsidence reversal and carbon sequestration into landscape level planning, identifying barriers to implementation and opportunities for landowners and managers.

Keywords: wetland blue carbon peat landscape planning climate change adaptation mitigation

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Solutions for Landscape-Scale Restoration Challenges

Eric Ginney, ESA PWA, eginney@esassoc.com

The preceding speakers in this session addressed a range challenges related to planning, designing and implementing landscape-scale restoration actions in the Sacramento-San Joaquin Delta and the adjacent lowland river systems. While many of the challenges are related to human-induced issues (i.e., property speculation) and are inherently difficult to address, some of the technical challenges would benefit from additional structure and focus upon the problems.

This presentation will summarize some of the key challenges presented by earlier presenters and will offer potential solutions, emphasizing two technical aspects. The first is the development and use of conceptual models to identify, understand, and quantify benefits for landscape-scale processes. An applied case study illustrates the need of such an effort and explores how such a tool illustrates benefits not visible with an approach that examines smaller-scale processes. The model and its use would greatly benefit regional planning within the estuary and would assist in relating different regions (and processes) and integrating restoration across regions to achieve landscape-scale results.

The second aspect addresses the development of a framework to support assessment and organization of hydrodynamic model results and their relation to restoration planning and estuary research. The framework, which uses the landscape-scale conceptual model as a foundation, would create a common place of understanding as restoration design (at a parcel and regional scale) begins to accelerate. The framework will help restoration designers to maintain a consistent understanding and vision for desirable hydrodynamic and geomorphic processes (at a landscape scale), and assist in establishing a common set of goals related to a desired threshold/magnitude and location of certain processes. Further, this framework will help all entities involved in restoration to understand how the estuary's "existing conditions" evolve through time as restoration advances by tracking process change through time and relating it to landscape function.

Keywords: conceptual model; restoration; landscape-scale; regional planning; design;

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A Two-Tiered Analytical Approach for Testing Contaminant Mixture Interactions

Krista Callinan*, University of California, Davis, cfcallinan@ucdavis.edu
Linda Deanovic, University of California, Davis, ladeanovic@ucdavis.edu
Stephanie Fong, Central Valley Regional Water Quality Control Board, SWFong@waterboards.ca.gov
Swee Teh, University of California, Davis, sjteh@ucdavis.edu

The study of contaminant effects in mixtures is a growing field of research, and the analytical approaches used are advancing with it. The two most commonly applied methods for mixture analysis either compare empirical toxicity data to theoretical models of additive response (Concentration Addition and Independent Action), or statistically analyze mixtures for interactions, using methods such as multiple logistic regression or generalized linear model analysis. Studies comparing additive models to empirical data are qualitatively useful, but they are not statistically substantiated. On the other hand, statistical approaches are analytically more robust, but they are only conclusive as to the significance of interactions, and do not confirm whether mixtures are additive and if so by which model. The current study employs a unique experimental design that allows for the use of both analytical approaches. Binary mixtures of multiple aquatic contaminants were tested for toxic effects and interactions on the epibenthic amphipod, *Hyalella azteca*. Concentration responses were tested concurrently in each experiment, along with six equipotent and six non-equipotent mixture treatments. Mortality, swimming behavior and growth were measured upon test termination after 10 days of exposure. Significant toxicant effects and interactions were tested by generalized linear model analysis, using the four by four factorial of mixture treatments incorporated into the experimental design. Empirical data were also compared to effects predicted by the two theoretical models of mixture response, made possible by the dose response curves generated within each experiment, and the multiple equipotent mixture concentrations tested. Results obtained both characterized and statistically quantified the interactions occurring among common aquatic contaminants. As such, these methods provide a robust and comprehensive analysis to define the toxicity of environmentally relevant mixtures in order to best predict the consequent effects on resident species.

Keywords: mixture toxicity, *Hyalella azteca*, pyrethroids ammonia copper model statistics

Wednesday, October 17, 2012: Room 306, Contaminants– Order 1

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Utilizing Molecular Biomarkers to Assess Urban Related Contaminant Effects in the Sacramento River

Erika Fritsch, UC Davis, ebholland@ucdavis.edu
Dan Riordan, California Dept. Water Resources, driordan@ca.water.gov
Linda Deanovic, UC Davis, ladeanovic@ucdavis.edu
Rich Breur, California Dept. of Water Resources, rich@water.ca.gov
Debra Denton, USPEA, Denton.Debra@epamail.epa.gov
Richard Connon, UC Davis, reconnon@ucdavis.edu

Approaches to measure the toxicity of chemicals to aquatic organisms typically rely on standardized laboratory toxicity tests, where effect thresholds are expressed as lethal concentrations. However, the toxic effects of contaminants are often subtle, and occur at exposure levels far below the concentrations that cause lethality. The vast urban area that expands the length of the Sacramento River has long been a source of contaminants leading to the presence of a diverse mixture of chemicals, all at sublethal concentrations. To help address potential impacts of the contaminants detected, standard toxicity tests were performed where larval fathead minnow (*Pimephalespromelas*) were exposed for 7days to water collected from the Sacramento River at Veterans Bridge, Garcia Bend, and at the Hood Field Station. In addition to chemical analyses and lethal impacts of collected samples, a suite of 48 genes were utilized to assess potential, sublethal, molecular impacts in exposed fish. Pharmaceuticals and personal care products were among the most commonly detected contaminants at all locations sampled displaying site and seasonal specific differences in chemical profiles. This included a number of antibiotics, the cholesterol drug gemfibrizol, the pain reliever ibuprofen, and the antibacterial agent triclosan. Interestingly, gene responses also displayed site and seasonal specific effects on either neuromuscular or endocrine related pathways, where there were stronger impacts observed in those fish exposed to water collected in the Spring, which contained increased levels of ibuprofen. This data suggests that transcription profiles may be utilized to discern the effect of environmentally relevant contaminant mixtures found in the Sacramento River. This is a highly sensitive approach, which could aid regulatory decisions when determining threats to resident fish populations in the aim of developing total maximum daily loads for water quality purposes in consistently impacted areas.

Keywords: Contaminants Sublthal Effects Pharmaceutical and Personal Care Products Molecular Biomarkers

Wednesday, October 17, 2012: Room 306, Contaminants– Order 2

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North San Francisco Bay Selenium Characterization Study

Tom Grieb, Tetra Tech, Inc., tom.grieb@tetratech.com
Greg Cutter, Old Dominion University, gcutter@odu.edu
Gary Wortham, Tetra Tech, Inc., gary.wortham@tetratech.com
Sujoy Roy, Tetra Tech, Inc., sujoy.roy@tetratech.com
Laura Richards, Old Dominion University, lcrichar@odu.edu
Limin Chen, Tetra Tech, Inc., limin.chen@tetratech.com
North San Francisco Bay Selenium Characterization Study

Thomas Grieb[1], Greg Cutter[2], Gary Wortham[1], Sujoy Roy[1], Laura Richards[2], and Limin Chen[1]

[1]Tetra Tech, Inc., Lafayette CA, 94549; [2]Old Dominion University, Norfolk, VA 23529

Selenium speciation data in the North San Francisco Bay (NSFB) and its major freshwater inflows have not been collected for more than a decade. New information, contributing to the understanding of the behavior of selenium in NSFB, is presented from a characterization study conducted through four sampling events, representing dry and wet-weather conditions between September 2010 and April 2012. Three types of samples were collected and analyzed: (1) Transect samples collected along a salinity gradient in the estuary, including locations in the Sacramento and San Joaquin Rivers, and offshore of the Golden Gate Bridge; (2) Refinery effluent receiving-water samples collected near the effluent outfall to characterize near-field selenium concentrations and speciation; and (3) Refinery effluent samples collected at a fully treated effluent discharge location. The data obtained in this work are compared directly with the prior sampling, and allow interpretation of changes over the preceding decade and are used as the basis for a major reevaluation of selenium speciation in the Bay after a gap of 10 years. New information is presented on the sources of selenium and the seasonally-influenced physical and chemical factors that affect the complex behavior of dissolved and particulate selenium, and the relative efficiency of food webs in concentrating selenium in the Bay-Delta Ecosystem. A revised conceptual selenium model is presented, and the use of these data in the application of a numerical model of selenium fate and transport in the North San Francisco Bay is described.

Keywords: Selenium, North San Francisco Bay, Conceptual Model

Wednesday, October 17, 2012: Room 306, Contaminants– Order 3

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Improved Monitoring of Water Quality and Pelagic Organism Decline in the Delta with Continuous In Situ Sensor Measurements

Brian Pellerin, US Geological Survey, bpeller@usgs.gov
Bryan Downing, US Geological Survey, bdowning@usgs.gov
Brian Bergamaschi, US Geological Survey, bbergama@usgs.gov
John Franco Saraceno, US Geological Survey, saraceno@usgs.gov

Characterizing Delta habitat quality and nutrient availability to Delta food webs is an essential first step to understanding and predicting the success of pelagic organisms. However, water quality and nutrient supply changes continuously as tidal and wind-driven currents move new water parcels into comparatively static geomorphic settings. Newly-developed, commercially-available sensor technology permits real-time collection of a broad suite of water quality data at intervals over which these hydrologic and chemical changes occur. Optical and wet chemistry sensors provide data on organic matter, sediment, nitrogen and phosphorus dynamics that may help identify ecosystem processes related to the health of pelagic food webs and the pelagic organic decline (POD) in the Sacramento – San Joaquin Delta. In particular, the simultaneous collection from multiple chemical sensors – along with the basic water quality variables currently measured such as temperature and salinity - will provide clearer evidence for linkages between physical and chemical drivers and ecosystem dynamics over short time scales, as well as show how short-term events are expressed in long term trends. In December 2011, we deployed a suite of optical and wet-chemical sensors for continuous (e.g. every 30 minutes) data collection from Liberty Island, an area which has received attention as important habitat for Delta smelt and other pelagic fish. Our results show that a variety of physical and biological processes ranging from episodic wind events to tidal dynamics and seasonal patterns affect nutrients, particles (inorganic and organic) and organic matter on time scales that range from minutes to weeks. We view such data as an important component of the long term monitoring program for the Delta, and as critical for evaluating long-term trends, assessing environmental health, and evaluating the effectiveness of habitat restoration and contaminant mitigation programs.

Keywords: Nutrients, organic matter, Delta, water quality, in situ, real time

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Suisun Bay Reserve Fleet - Metals Discharge to Suisun Bay

David Elias, San Francisco Bay Regional Water Board, delias@waterboards.ca.gov

The Maritime Administration's (Marad) Suisun Bay Reserve Fleet has been discharging metals-laden paint and stormwater to Suisun Bay for decades due to lack of fleet maintenance. Is this discharge significant and can it be abated? Subsequent to an enforcement action that resulted in a consent decree finalized in federal court between Marad, the San Francisco Bay Regional Water Board, ArcEcology, Natural Resources Defense Council, and Baykeeper, a team including the Regional Water Board, Tetra Tech, and Marad fleet managers worked together to collect the data needed to answer these questions. The data included laboratory analyses of paint and stormwater from dozens of vessels over a period of years. The results of the sampling effort and the analysis of the data trends over time have allowed the team to make the following findings: 1) vessels left with exfoliated paint on the decks and exfoliating paint on the vessel structure discharge significant concentrations and quantities of both total and soluble metals, including lead, copper, and zinc; 2) simple ship maintenance focused on avoiding stormwater contact with paint chips will significantly reduce the discharge of metals to surface water (140 tons of paint were removed from an initial sweeping of 20 vessels); 3) aerial deposition of background concentrations of both metals and petroleum from other sources must be quantified to assess the contribution to the discharge from the vessels; and 4) clean vessels continue to discharge metals to surface water at much lower concentrations. The results of the study show that the proper maintenance of vessel coatings and the proper disposal of exfoliated paint will result in a significant reduction in metals discharge to surface water. Therefore, efforts to require proper vessel maintenance should be supported by both the regulatory and the maritime communities.

Keywords: Stormwater, Suisun Bay, Maritime Administration,

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Particle Size Distributions of Suspended Sediment in the Sacramento-San Joaquin River Delta

Scott Wright, U.S. Geological Survey, sawright@usgs.gov
Daniel Whealdon-Haught, U.S. Geological Survey, dwhealdo@usgs.gov

Particle size distributions of suspended sediment in rivers and estuaries are of interest for a variety of reasons, such as their influence on erosion and deposition processes, their effect on light penetration and primary/secondary aquatic production, and their influence on contaminant adsorption processes. Also, particle size is known to affect the amount of light and sound that is scattered by suspended particles; thus, parameters that are typically used as surrogates for suspended-sediment concentration, such as turbidity and acoustic backscatter, are dependent on particle size distributions. Measurements of *in situ* particle size distributions were made at seven sites in the Sacramento-San Joaquin River Delta as well as along a longitudinal profile of the Sacramento River from Verona (upstream of tidal influence) to Rio Vista (mostly tidal). Size distributions were measured with a laser diffraction particle sizer. At the seven sites, measurements were made from an instrument package deployed on the channel bed. On the Sacramento River, vertical profiles were collected from a stationary boat. Preliminary data analyses indicate a consistent tri-modal size distribution in the Delta, with a narrow peak in the 3-7 micron range, a broad peak centered at 40-50 microns, and a narrow (smaller) peak in the 200-300 micron range. The relative contribution of the different modes varied by site and by position in the tidal cycle. Physical samples collected alongside the *in situ* data suggest that flocculation occurs at all sites; further analysis of samples is ongoing that will further quantify the degree of flocculation. The Sacramento River longitudinal profile documents the flocculation process occurring in the vicinity of the fluvial-tidal transition; as this transition is crossed, the measurements indicate transfer of sediment from the 3-7 micron mode primarily to the 40-50 micron mode. Understanding these flocculation processes is critical for robust numerical modeling of Delta sediment transport.

Keywords: suspended, sediment, particle size, Delta Sacramento River

Wednesday, October 17, 2012: Room 306, Sediment Data and Turbidity in the Bay-Delta System– Order 1

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Sacramento-San Joaquin Delta Sediment Budgets Including Regional Transport and Deposition Characteristics for Water Year 2011

Tara Morgan-King, U.S. Geological Survey, tamorgan@usgs.gov
Scott Wright, U.S. Geological Survey,
David Schoellhamer, U.S. Geological Survey,

Sediment is recognized as an integral component to the long term management of the highly stressed Sacramento-San Joaquin Delta. By understanding sediment loads, transport, and deposition, we can model contaminant transport, estimate habitat quality, and determine sediment available for wetland restoration in the presence of sea level rise and subsidence. Interest in Delta suspended-sediment transport processes has increased due to recent studies linking fish habitat and movement, particularly Delta smelt, to turbidity. In 2010, we added to an existing network of monitoring sites and began extensive sediment sampling. Our monitoring program is specifically designed to calculate suspended-sediment flux and support numerical modeling efforts. Water year 2011 was above average for both precipitation and flow, though Sacramento River sediment concentrations were low. From 1975 to 2010, suspended-sediment concentrations within the Delta have decreased by approximately 50% and preliminary results show that sediment load to the San Francisco Bay continues to decrease. Similar to previous findings during 1999-2002, in 2011 we found that roughly 75% of the suspended-sediment transported to the Delta by both the Sacramento and San Joaquin Rivers deposits, and the Sacramento River watershed is the primary source of this sediment. In 2011, about 50% of the total sediment deposited was in the central Delta (roughly 800 Kt) and close to 75% of this sediment came from the Sacramento River watershed. The North Delta was the least efficient at trapping sediment, and the Southern Delta was the most efficient at trapping sediment. Though the trap efficiencies for the North and South Delta differed (37% and 62% respectively), the quantity of sediment deposited was similar. Nearly 30% of the total sediment load was transported to the Delta from December 1 to mid-February; nearly 60% of the total load was transported from mid-February to mid-July.

Keywords: sediment flux, turbidity, sediment budget

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Hydraulic Geometry and Bed Material Characteristics of the Sacramento-San Joaquin River Delta

Mathieu Marineau, U.S. Geological Survey, mmarineau@usgs.gov
Scott Wright, U.S. Geological Survey, sawright@usgs.gov
Dan Whealdon-Haught, U.S. Geological Survey, dwhealdon@usgs.gov

Hydraulic geometry relations are often useful tools for studying erosion or aggradation processes in a fluvial system, yet are not well quantified in channels affected by both tidal flow and streamflow. In addition, using hydraulic geometry relations in the Sacramento-San Joaquin River Delta presents a particular challenge as the Delta consists of a complex network of channels in which sediment transport pathways may be influenced by the hydraulics at upstream channel bifurcations. Hydraulic geometry, stage and discharge records, and bed-material particle sizes were analyzed at 29 streamgaging stations currently operated in the Delta. The channels at these sites represent a range of widths (45-720 meters), depths (2.5 to 13 meters), median particle sizes (0.025 to 0.68 mm) and varying degrees of influence by tidal flow and streamflow. Characteristics of downstream hydraulic geometry (width, depth and cross-sectional area) were found to have a positive correlation to the magnitude of median streamflow discharge. Cross-sectional area was the characteristic with the highest correlation (Pearson's coefficient of linearity, r, of 0.87). Spatial analysis of median particle size revealed some channels contained bed material which was much different than nearby channels. Some of the variability in the particle size may be related to effects of channel dredging, Delta island flooding, and hydraulic mining. Hydraulic controls at upstream bifurcations may also contribute to some of the variability found between two downstream channels. Preliminary analysis of detailed bed material sampling, bathymetry and transects of streamflow velocity collected at two channel bifurcations in the Sacramento River will also be presented. An understanding of the hydraulics and sediment transport mechanisms in the Delta can be used in the development and support of on-going numerical modeling and provide insight into future effects on erosion and depositional processes in the Delta as a result of sea-level rise or Delta island flooding.

Keywords: bed material, hydraulic geometry, bifurcations

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Development of a Coupled Sediment Transport and Hydrologic (HSPF) Model of the Sacramento River Basin, CA, to Estimate Future Sediment Supply to the Bay-Delta System

Michelle Stern*, USGS, CAWSC, mstern@usgs.gov
Lorraine Flint, USGS, CAWSC, lflint@usgs.gov
Justin Minear, USGS, CAWSC, jminear@usgs.gov
Scott Wright, USGS, CAWSC, sawright@usgs.gov
Alan Flint, USGS, CAWSC, aflint@usgs.gov

The Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE II) project requires a better understanding of how potential future changes in the characteristics and climate of watersheds draining into the San Francisco Estuary-Watershed (SFEW) will affect water quality, ecosystem processes, and key species. As part of the cascading set of interconnected components and processes used in CASCaDE II, projections are necessary to estimate future sediment supply from the Sacramento River basin, the source of 80 percent of the sediment contributed to surface water in the SFEW. A sediment transport model using the Hydrological Simulation Program – Fortran (HSPF) is being developed to simulate daily streamflow and suspended-sediment concentrations (SSC) in the Sacramento River and tributaries below the major contributing dams. The HSPF model will provide a direct coupling of current and future climate with the watershed potential sediment sources to estimate sediment supply to the SFEW. Inputs into the HSPF model include precipitation, air temperature, dew point, solar radiation, and wind, as well as watershed parameters such as soil characteristics, land use, geology, channel characteristics, and topography. The HSPF model will be calibrated by using existing SSC and stream discharge data from numerous USGS gages along the Sacramento River and its contributing major tributaries. The HSPF model will initially be calibrated to replicate the declining sediment-supply trend over the past 50 years, and preliminary results will be presented. To predict sediment loads from the minor contributing rivers (San Joaquin, Cosumnes, Mokelumne), an empirical scaling approach will be used to estimate general trends based on model results for the Sacramento River. Results from the HSPF model will provide inputs to the turbidity and geomorphology model, the marsh sustainability model, and the native and alien fishes investigation of the CASCaDE II project.

Keywords: Hydrolologic Modeling, HSPF, Sediment supply, CASCaDE II, Climate Change, SFEW

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Suspended-Sediment Trapping and Pulse Attenuation in the Tidal Reach of Corte Madera Creek, a Tributary of San Francisco Bay

Maureen Downing-Kunz, U.S. Geological Survey, mokunz@usgs.gov
David Schoellhamer, U.S. Geological Survey, dschoell@usgs.gov

As sediment supply from the Central Valley to San Francisco Bay decreases, smaller, local tributaries may play increasing roles in sediment supply to this estuary. However, tidal interactions near tributary mouths can affect the magnitude and direction of sediment supply to the estuary. We investigated suspended-sediment dynamics in the tidal reach of Corte Madera Creek, an estuarine tributary of San Francisco Bay, using moored acoustic and optical instruments. Flux of both water and suspended-sediment were calculated from observed water velocity and turbidity for two periods in each of wet and dry seasons during 2010. During wet periods, net suspended-sediment flux was seaward, caused by higher suspended-sediment concentrations (SSC) on ebb tides; tidally-filtered flux was dominated by the advective component. However net seaward flux was only 40% of flux into the tidal reach from the watershed. In contrast, during dry periods, net flux was landward, caused by higher SSC on flood tides; tidally-filtered flux was dominated by the dispersive component. The mechanisms generating this landward flux varied; during summer we attributed wind-wave resuspension in the estuary and subsequent transport on flood tides, whereas during autumn we attributed increased spring tide flood velocity magnitude leading to local resuspension. A quadrant analysis was developed to summarize flux time series by quantifying the relative importance of sediment transport events. These events are categorized by the velocity direction (flood vs. ebb) and the magnitude of concentration relative to tidally-averaged conditions (relatively-turbid vs. relatively-clear). During wet periods, suspended-sediment flux was greatest in magnitude during relatively-turbid ebbs, whereas during dry periods it was greatest in magnitude during relatively-turbid floods. These results suggest that other San Francisco Bay tributaries may alternate seasonally as sediment sinks or sources, leading to the conclusion that previous calculations of sediment supply from local tributaries to the open waters of the estuary are likely overestimates.

Keywords: suspended-sediment transport, sediment supply, sediment flux, local tributary, seasonal variation

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San Francisco Bay Sediment Transport: Comparison of Sediment Supply to San Francisco Bay from Coastal and Sierra Nevada Watersheds

Lester McKee, San Francisco Estuary Institute, lester@sfei.org
Mik Lewicki, Entrix, Seattle, Washington, MLewicki@entrix.com
Neil Ganju, USGS, Woods Hole, MA, nganju@usgs.gov
David Schoellhamer, USGS, Sacramento, dschoell@usgs.gov

Information on suspended sediment loads is of paramount importance for managing the world's estuaries. To address this information need, a comprehensive analysis was completed for the San Francisco Bay system by combining a number of formerly disparate data sets. Suspended sediment and optical backscatter measurements near the head of the estuary were used to generate a continuous suspended sediment concentration record. In addition, periodic measurements of velocity and suspended sediment variation in the cross-section were used to validate the use of point samples collected on the edge of the channel for generating loads. Suspended sediment loads were determined by combining daily averaged suspended sediment concentrations with daily flow estimates adjusting for dispersive loads. Sediment loads from the many hundreds of small drainages around the Bay were determined using 235 station years of suspended sediment data covering 38 watershed locations, regression analysis, and simple modeling. Over 16 years, net annual load to the head of the estuary varied from 0.13-2.58 (mean = 0.89) million metric t, or 5.8t/km^2/yr. Small drainages in the nine-county Bay Area discharged between 0.090 and 4.44 (mean = 1.46) million metric t with an average yield of 179 metric t/km^2/yr. Our results indicate that external loads to the Bay are dominated by the many hundreds of urbanized and tectonically active tributaries that drain just 8,125 km^2 adjacent to the Bay and that during only 5 years did sediment loads from the Central Valley likely exceed loads from the sum of the local smaller drainages. If San Francisco Bay is typical of other estuaries in active tectonic or climatically variable coastal regimes, managers responsible for water quality, sediment accumulating in shipping channels, or restoring wetlands in the world's estuaries may need to more carefully account for proximal small urban drainages that may dominate allochthonous sediment supply.

Keywords: variability, suspended sediment, loads, management, central valley, San Francisco Bay

Wednesday, October 17, 2012: Room 306, Sediment Transport in the San Francisco Bay Coastal System– Order 1

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A Multi-Constituent Approach for Analyzing Sediment Transport in the San Francisco Bay Coastal System

Mary McGann, U.S. Geological Survey, mmcgann@usgs.gov
Li Erikson, U.S. Geological Survey, lerikson@usgs.gov
Elmira Wan, U.S. Geological Survey, ewan@usgs.gov
Charles Powell, II, U.S. Geological Survey, cpowell@usgs.gov
Rosalie F. Maddocks, University of Houston, Texas, RMaddocks@uh.edu

San Francisco Bay influences so many aspects of life in the area, including the region's financial health. A key factor in this process is maintaining the waterways that provide access to the estuary and this requires an understanding of the regional sediment dynamics. A multi-constituent approach provides a method by which to discern patterns of sediment transport and deposition in the San Francisco Bay coastal system. Analysis of the biological, anthropogenic, and volcanic constituents in >300 samples collected in the region from 1995 to 2010 identifies several patterns: 1) marine organisms (benthic and planktic foraminifera, ostracods, diatoms, and radiolarian) are found in the estuary at the southern end of south bay, commonly in the middle of San Pablo Bay, and occasionally as far east as Honker and Grizzly Bays; 2) estuarine ostracods and benthic foraminifera are present outside the bay on the San Francisco Bar and along the coast; 3) marsh benthic foraminifera and freshwater gastropods and ostracods are present in the middle of the subembayments of the estuary; 4) welding slag and glass microspheres are found far from their presumed origin of docks or roads; and 5) volcanic glass shards are transported from the Great Valley through the delta to all regions of the bay, including the extreme end of south bay and along the coast outside the bay south to Pedro Point. From these data, we can conclude that sediment is transported from the delta to all regions of the bay and out into the offshore realm. The channel in north, central, and south bays, and the Golden Gate, are conduits for sediment movement and sites where scouring occurs. The primary sites of deposition are situated in Honker, Grizzly, and Richardson Bays, along the margins of Suisun, San Pablo and south bays, and eastern central bay.

Keywords: foraminifera, ostracods, diatoms, radiolarian, tephra, sediment constituents, San Francisco Bay

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Synthesis of Bed Characteristics, Geochemical Tracers, in Situ Measurements and Numerical Modeling for Assessing the Provenance of Beach Sand in the San Francisco Bay Coastal System

Patrick Barnard, USGS Pacific Coastal and Marine Science Center, pbarnard@usgs.gov
Amy Foxgrover, USGS Pacific Coastal and Marine Science Center, afoxgrover@usgs.gov
Edwin Elias, Deltares, edwin.elias@deltares.nl
Li Erikson, USGS Pacific Coastal and Marine Science Center, lerikson@usgs.gov
James Hein, USGS Pacific Coastal and Marine Science Center, jhein@usgs.gov
Mary McGann, USGS Pacific Coastal and Marine Science Center, mmcgann@usgs.gov
Robert Rosenbauer, USGS Pacific Coastal and Marine Science Center, brosenbauer@usgs.gov
Kira Runtzel, USGS Pacific Coastal and Marine Science Center, kruntzel@usgs.gov
Peter Swarzenski, USGS Pacific Coastal and Marine Science Center, pswarzen@usgs.gov
Renee Takesue, USGS Pacific Coastal and Marine Science Center, rtakesue@usgs.gov
Florence Wong, USGS Pacific Coastal and Marine Science Center, fwong@usgs.gov
Don Woodrow, USGS Pacific Coastal and Marine Science Center, dwoodrow@usgs.gov

Over 150 million m^3 of sand-sized sediment has been eroded during the last half century from the central region of the San Francisco Bay Coastal System. This enormous amount of sand loss may reflect numerous anthropogenic influences, such as watershed damming, bay-fill development, aggregate mining, and deep-water dredge disposal. This reduction in sediment supply is thought to be linked to recent wide-spread erosion of adjacent beaches, wetlands, and submarine environments. A unique, multi-faceted, multi-disciplinary provenance study was performed to definitively establish the primary sources, sinks, and transport pathways of beach-sized sand in the region, thereby identifying the activities and processes that directly limit the supply of sand to the outer coast. This integrative program is based on comprehensive surficial sediment sampling of the San Francisco Bay Coastal System, including the seabed, Bay floor, area beaches, adjacent rock units, and all major drainages. Analyses of sample morphometrics and biological composition (e.g., Foraminifera) were then integrated with a suite of tracers including $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopes, rare earth elements, semi-quantitative X-ray diffraction mineralogy, and heavy minerals, and further with process-based numerical modeling, in-situ current measurements, and bedform asymmetry to robustly determine the provenance of sand in the region.

Keywords: provenance; bedforms; sediment transport; isotopes; foraminifera; heavy minerals; numerical modeling

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Sediment Dynamics in the Shallows of San Francisco Bay

Jessica Lacy, Pacific Coastal and Marine Science Center, US Geological Survey, jlacy@usgs.gov
Lissa MacVean, Pacific Coastal and Marine Science Center, US Geological Survey, jlacy@usgs.gov

Estuarine shallows retain fine sediments, and serve as a source of sediments for intertidal mudflats and marshes. The ongoing large-scale restoration of diked-off, subsided wetlands adjacent to San Francisco Bay relies largely on sediment supplied from the Bay by natural processes. These same processes will be critical in sustaining marshes as sea level rises. The details of how wind, waves, and tidal currents interact to transport sediment between channels, shallows, mudflats, and marshes are poorly understood, largely due to a historical lack of data from shallow environments. In recent years we have collected current, wave, and suspended sediment data to investigate sediment resuspension and transport in shallow regions of South Bay, Central Bay, and San Pablo Bay. This talk will summarize our findings on transport between the shallows and the channel, transport between subtidal and intertidal flats, and the evolution of wind waves over shallows. As expected, wind-wave driven resuspension produced the greatest concentrations and fluxes of suspended sediment. However, the direction of suspended sediment flux (SSF) during wind events was variable. The South Bay data show that SSF in the shallows was directed landward during moderate wind events, but towards the channel during strong wind events. The San Pablo Bay data show that SSF during wind events was directed landward at an intertidal site, and towards the channel at subtidal sites. Concentrations at the intertidal site were greater than expected for a given wave shear stress, largely due to the shallow water depths which limit the volume available for dilution. The shallow depths also limit the speed of tidal currents and thus transport. Data sets such as these are essential for calibrating and testing numerical models of sediment transport in San Francisco Bay, which are used to guide habitat restoration and regional sediment management.

Keywords: sediment transport, shallows, resuspension, wetlands, restoration

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Influence of History and Environment on the Sediment Dynamics of Intertidal Flats

Craig Jones, Sea Engineering, Inc., cjones@seaengineering.com
Bruce Jaffe, USGS, bjaffe@usgs.gov

The intertidal flats provide important, and sometimes critical, habitats for benthic communities, fish, birds, and mammals in San Francisco Bay. Additionally, these generally depositional intertidal flats can act as reservoirs for sediment bound contaminants from both historic and ongoing sources. Development of a deeper understanding of the processes governing the morphology and character of the intertidal flats presents an important problem to scientists and engineers for the enhancement of habitat and reduction of potential ecosystem and human health risks. The stability and equilibrium of the flats are constantly shifting due the influence of a wide range of physical and biological factors (Friedrichs and Perry 2001). Consequently, a large body of scientific study has been devoted to both the physical and biological factors. Physically, intertidal flats are typically comprised of cohesive sediment mixtures in coastal and estuarine environments. The lack of solid understanding of the processes controlling the erosion, transport, and subsequent deposition of cohesive sediments provides a significant stumbling block in our ability to quantitatively predict the behavior of systems dominated by cohesive sediments. The physical characteristics of the sediments in conjunction with a general system understanding can often guide a solid description of the sediment dynamics. This study outlines the merging of long-term morphologic data with measurements of sediment erosion rates and modeling to develop just such an understanding of intertidal flats in three distinct environments in South San Francisco Bay, California.

Keywords: intertidal, mudflat, sediment transport, erosion, deposition, morphology, stability modeling

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Use of Scour Monitoring Data for Sediment Budget Analysis and Model Validation in the Delta

Rene Leclerc, Northwest Hydraulic Consultants, RLeclerc@nhcweb.com
Brad Hall, P.E., Northwest Hydraulic Consultants, BHall@nhcweb.com

The California State Department of Water Resources (DWR) Scour Monitoring Program collects semi-annual cross-section data throughout the Sacramento-San Joaquin Delta. Begun in 1969, the program has expanded to include 112 cross-section sites today. These cross-section data provide a real-world basis to describe long-term sediment budget trends in Delta channels and characterize morphologic adjustments over time. A section of the Middle River and adjacent channels in the south Delta were selected to analyze available scour monitoring data over a 15 year period from 1990 to 2004. Year-to-year trends often showed significant variability, reflecting seasonal hydrology or short-term effects such as levee modifications, dredging, or specific events. Ordinary least-squares regression of the 15-year dataset showed a net decline in channel depth and cross-section area for the majority of sites selected. Sediment budget calculations using the end-area method show a slight trend of net sediment deposition on the Middle River for the 1990 to 2004 period, in agreement with analyses of long-term sediment transport records (NHC 2003). Bed material samples and recent application of project-specific multibeam bathymetric surveys by the DWR provide supplemental information to characterize morphologic change and sediment transport conditions such as sand dune migration. Sediment budget estimates from long-term cross-section records, coupled with bed material characterization, provide a real-world basis for the calibration and validation of long-term numerical model simulations of sediment transport rates and budgets in the Delta.

Keywords: delta sediment budgets, morphologic change, model validation

Wednesday, October 17, 2012: Room 306, Multi-Dimensional Modeling of Sediment Transport in the Bay-Delta – Order 1

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Tracking Sediments through the Bay-Delta System over a Water Year with a 2D Process Based Odel (D-Flow FM)

Fernanda Achete*, UNESCO IHE, f.achete@unesco-ihe.org
Mick van der Wegen, UNESCO IHE, m.vanderwegen@unesco-ihe.org
Bruce Jaffe, U.S.Geological Survey Santa Cruz, bjaffe@usgs.gov

The Sacramento-San Joaquin Delta and Watershed is the main source of sediment to San Francisco Bay. In the first part of the 20th century several hydraulic structures were built in the catchment trapping sediment upstream. Wright and Schoellhamer (2004) show that from 1957 to 2001 the sediment load carried to San Francisco bay has halved. The decay of suspended sediment in the bay prevents marsh development with impact on local ecosystems.

In this study, we couple the Delta and Bay in a unique model network (the Delta-Bay model). This coupling allows tracking of sediment from Sacramento to the Bay and through the Golden Gate, making it possible to identify dispersion and deposition areas. The model was built in two steps. First, an unstructured, process-based model (D-Flow Flexible Mesh developed by Deltares) was used to simulate the hydrodynamics of the area on a detailed, 64000-node mesh (10-200m mesh length scale). Secondly, Delft-WAQ, a post-processing tool from Deltares was used to simulate the suspended sediment concentration (SSC) based on the hydrodynamic output by D-Flow FM.

The results show that most of the sediment that deposits in the Delta comes from the Sacramento River. It also shows that subsequent high river flows (over several years) ultimately transport the sediment towards the Bay. Sensitivity analysis includes different mud characteristics as well as varying river discharge and pumping scenarios (water export towards Southern California). Sensitivity analysis shows that suspended sediment concentration in the Delta-Bay system is more sensitive to discharge changes of Sacramento River than changes in pumping volume at Clifton Court.

Keywords: Numerical Modeling, Suspended Sediment, Unstructured Mesh

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Validation of 3D Sediment Transport Modeling in the Delta

Paul Craig, Dynamic Solutions - International, LLC, pmcraig@ds-intl.biz
William McAnally, Dynamic Solutions, LLC, whmcanally@dsllc.com
Christopher Wallen, Dynamic Solutions, LLC, cmwallen@dsllc.com
Eugene Maak, U.S. Army Corps of Engineers, Eugene.C.Maak@usace.army.mil
Lam Nguyen, Dynamic Solutions - International, LLC, ntlam@ds-intl.biz
Steve Sanborn, Dynamic Solutions, LLC, scsanborn@dsllc.com

A 3-dimensional hydrodynamic and sediment transport model of the Sacramento-San Joaquin Delta to was validated for use in the U.S. Army Corps of Engineers CALFED Levee Stability Program and Delta Study.

The model uses the Environmental Fluid Dynamics Code (EFDC). The model grid includes Yolo Bypass, the Sacramento River to Verona, approximately ten miles of the American River, the San Joaquin River system to Vernalis, and Suisun Bay to the Carquinez Strait. Physical processes simulated in the model include hydrodynamics governed by currents and wind waves, temperature, salinity, and cohesive and non-cohesive sediment transport, deposition, and erosion.

The model was adjusted and validated to observed data from the years 2003 and 2004. It predicts TSS with a residual of less than a standard factor of 2 for all locations except one. The model slightly under predicts the total suspended solids (TSS) concentrations in the model domain – a model average of 49mg/l compared with 53 mg/l observed. The model under-predicts TSS at several locations due to a lack of the sediment bed characterization data and phenomena which are not modeled by EFDC, such as the re-suspension process caused by ship traffic. However, the model captures the major processes matching the magnitudes and timing of the observed TSS data.

In the main channels TSS is strongly governed by the re-suspension induced by the interaction of the tidal currents and fresh water flows. Off the main channels and in the shallow bay area, the sediment re-suspension process caused by wind waves becomes important, The sensitivity of the model results on TSS to the model parameters and inputs shows it to be most sensitive to the model parameters related to there-suspension processes, either driven by wind wave or by currents.

Keywords: Sediment Transport, 3D Hydrodynamics, validation tss efdc efdc_explorer resuspension wind

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Numerical Simulations of First Flush Sediment Dispersal throughout the Sacramento-San Joaquin Delta and San Francisco Bay

Aaron Bever, Delta Modeling Associates, Inc., aaron@deltamodeling.com
Michael MacWilliams, Delta Modeling Associates, Inc., michael@deltamodeling.com

The UnTRIM San Francisco Bay-Delta Model has been coupled to the SWAN wave and SediMorph sediment models to simulate three-dimensional sediment transport throughout the San Francisco Bay and Sacramento-San Joaquin Delta. The seabed of the Bay and Delta are initialized using observed surface grain size distributions, and sediment is supplied to the Delta from the Sacramento, San Joaquin, Cosumnes and Mokelumne Rivers and the Yolo Bypass. Both the seabed and river supplied sediment undergo erosion caused by waves and currents, deposition, and three-dimensional advective transport and mixing within the numerical modeling system. This numerical modeling system is used to simulate the sediment transport of a first flush sediment pulse from the riverine sources to locations of sediment deposition within the San Francisco Bay and Sacramento-San Joaquin Delta.

The first flush sediment is distributed throughout the San Francisco Bay. Model results highlight that more first flush sediment is deposited on the shallow shoals than in the deeper channel regions of Suisun and San Pablo Bays, following the conceptual model proposed by Krone (1979). After the first flush sediment pulse, the deposited sediment is resuspended by waves and currents and transported toward the Pacific Ocean and the South Bay. This sediment resuspension and dispersal is strongly tied to spring tides and wind wave events.

Keywords: First Flush, Sediment Transport, UnTRIM, SediMorph, SWAN, Numerical Modeling

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Three-Dimensional Coupled Wind-Wave and Mud Suspension Modeling in San Francisco Bay

Yi-Ju Chou, National Taiwan University, yjchou@iam.ntu.edu.tw
Rusty Holleman, University of California, Berkeley, rustychris@gmail.com
Sueann Lee, Stanford University, sueannsy@stanford.edu
Oliver Fringer, Stanford University, ofringer@gmail.com
Mark Stacey, University of California, Berkeley, mstacey@berkeley.edu
Stephen Monismith, Stanford University, monismith@stanford.edu
Jeffrey Koseff, Stanford University, koseff@stanford.edu

A numerical model is presented to simulate transport and suspension of cohesive sediments in San Francisco Bay. We employ the unstructured-grid SUNTANS model for hydrodynamics and within this model we implement a multiclass sediment transport model and a wind-wave model to calculate phase-averaged properties of high-frequency waves. Hydrodynamics is calculated by solving the phase-averaged Navier-Stokes equations that are coupled to the waves through the radiation stress. Transport of cohesive micro and macro flocs is computed with the advection-diffusion equation with a settling velocity for each size class. Mud suspension is computed with a mud model that interacts with a multilayer bed model that accounts for limited bed erodibility due to consolidation. Combined with a bedform model that allows parameterization of bedform-induced form drag, this allows for parameterization of wave dissipation mechanisms due to a variety of bed properties, which is of critical importance for modeling shallow water waves in estuarine systems. The model is calibrated against field observations in South San Francisco Bay, and we assess the relative importance of tidal and wind forcing on mud suspension as well as the influence of the mud suspension on the wave field.

Keywords: Sediment transport modeling

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Using Monitoring and Models to Help Manage the Evolving Marshes of the San Francisco Estuary

Jeremy Lowe, ESA PWA, jlowe@esassoc.com

Monitoring of marsh evolution, together with accretion models developed with that data, are tools that can help resource managers understand and manage marshes as sea levels rise and sediment supplies diminish. Tools such as these, focused on organic productivity and soil profile processes, can identify vulnerabilities of existing marshes. For instance: will existing marshes accrete rapidly enough to keep up with sea level rise?; if they don't, how rapidly may they "downshift" from marsh to mudflat?; how sensitive are marshes to changes in sediment supply and salinity regime? Work by PRBO and ESA PWA shows how these vulnerabilities may manifest around the Bay and provide guidance on evaluating marsh resilience.

Monitoring and models focused on inorganic sedimentation can assist in the planning of new restorations. Accretion modeling of Ponds A9-A15 in the South Bay, for the USACE Shoreline Study, demonstrates the influence of initial elevation and timing of breaching on marsh evolution. These results were used to optimize the phasing and timing of the breaching of individual ponds to increase the likelihood of project success. On a larger scale, accretion modeling has been used to assess the demand for sediment from all the existing and planned marshes in the South Bay and how this may impact future sediment budgets.

The next step is to use these tools to help develop adaptation measures that increase marsh resiliency to sea level rise. For instance, measures have been suggested that feed sediment to a marsh by placing fine sediment on adjacent mudflats and allowing it to be reworked by wave action. Measures may also include reconnecting tidal marshes to upland ecotones to allow transgression. Examples from around the Bay will be given of how accretion models allow managers to make judicious choices of which adaptation measures to implement and when.

Keywords: "sea level rise", "tidal marshes", accretion, resilience, modeling, adaptation

Wednesday, October 17, 2012: Room 307, Comprehensive Monitoring Network in Tidal Marsh Habitats under Sea Level Rise– Order 1

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The Data and Monitoring Needs of Marsh Sustainability Models Currently Being Used in the SF Estuary

Kathleen Swanson, USGS California Water Science Center, kathswan@usgs.gov
Judith Drexler, USGS California Water Science Center, jdrexler@usgs.gov
David Schoellhamer, USGS California Water Science Center, dschoell@usgs.gov
Sam Veloz, PRBO Conservation Science, sveloz@prbo.org
Jeremy Lowe, ESA PWA, JLowe@esassoc.com
John Takekawa, USGS Western Ecological Research Center, john_takekawa@usgs.gov

The Wetland Accretion Rate Model for Ecosystem Resilience (WARMER) and Marsh98, are models of marsh elevation at a point that incorporate biological and physical processes of vertical marsh accretion and have been applied to tidal saltmarshes in San Francisco Estuary. These models are tools used to better our understanding of the threat of rising sea level on marsh sustainability and habitat quality. Both models incorporate dynamic processes of relative sea-level rise, inorganic sediment accumulation, and organic matter accumulation. WARMER also incorporates elevation dependent production, decomposition, and compaction, in evaluating changes in marsh surface elevation. In order for WARMER to be applied in a particular setting, the local elevation, inundation regime, sediment porosity, decomposition, mineral sediment accumulation and organic matter accumulation parameters are needed. Marsh98, as applied to estuary sub-regions by PRBO, also requires local elevation and inundation regime together with estimates of suspended sediment concentration and organic matter accumulation for each region and applied to a seamless elevation map of the Estuary.

The quality of model inputs can have major impacts on model outputs for both models. A detailed sensitivity analysis of WARMER and the results of Marsh98 both indicate that sediment supply and the rate of sea-level rise are the primary drivers of salt marsh sustainability within the Estuary. Most of the modeled scenarios indicate that changes in elevation will degrade habitat quality on decadal timescales and that degradation will accelerate in the latter half of this century as the rate of sea-level rise accelerates. Model scenarios would be improved with better inputs related to (1) local estimates of relative sea-level rise and future tide range,(2) estimates of spatial and temporal variability of sediment supply to and accretion within the marsh, and (3) species specific organic matter accumulation and decay information.

Keywords: Marsh sustainability, sea-level rise, monitoring, numerical model

Wednesday, October 17, 2012: Room 307, Comprehensive Monitoring Network in Tidal Marsh Habitats under Sea Level Rise– Order 2

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Understanding How Climate Change and Associated Extreme Storm Events Affect Wildlife Populations: Implications for Monitoring

Karen Thorne, USGS, kthorne@usgs.gov
Kevin Buffington, USGS, kbuffington@usgs.gov
Thuy-Vy Bui, USGS, tbui@usgs.gov
Danika Tsao, CA Department of Water Resources, dtsao@water.ca.gov
John Takekawa, USGS, john_takekawa@usgs.gov

Coastal salt marshes are projected to be disproportionately impacted by climate change, including sea-level rise and changes in storm frequency and intensity. Extreme storm events will affect salt marshes by altering inundation duration and depth, changing suspended sediment supply and habitat availability for wildlife. Although the San Francisco Bay Estuary is severely fragmented and modified, it is one of the largest tidal salt marsh complexes in California and contains important habitat for federal and state-listed wildlife species. The maintenance and expansion of habitat is crucial to the successful recovery of these wildlife species, but it remains unknown how storm flooding may impact these populations. Using site-level water level monitoring within salt marshes, we were able to observed two local storm surges that resulted in extreme sea level heights in 2010 and 2011 at three salt marshes within the San Francisco Bay Estuary. Duration of salt marsh inundation during the storm episodes was respectively 1.8 and 3.1 times more than normal for that time of year. At peak storm surge, over 65% in 2010 and 93% in 2011 of the available vegetated habitat for wildlife was under water, increasing predation and drowning risk. In addition, the lowest recorded sea level pressure in the last 30 years for this region was measured during the storm in January 2010. This water level monitoring allowed the assessment of storm impacts on available habitat for the California black rail (*Laterallus jamaicensis coturniculus*) during breeding season. Results from storm monitoring and implications for salt marsh wildlife and management will be presented.

Keywords: salt marsh, climate change, sea-level rise, storm, endangered species, management

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NOAA Sentinel Sites Program: Monitoring Effects of Climate Change on Tidal Marshes in the San Francisco Estuary and Beyond

Matthew Ferner, San Francisco Bay National Estuarine Research Reserve, mferner@sfsu.edu

Sea level rise and other aspects of climate change are expected to threaten the viability of tidal marshes worldwide. The National Oceanic and Atmospheric Administration (NOAA) selected San Francisco Bay as one of five national pilot sites for a new program to provide for early detection of effects of climate change on coastal areas. The National Estuarine Research Reserve System (NERRS), a collaboration between NOAA and the coastal states, supports this program by providing for long-term monitoring of effects of sea level rise and other climate-related stressors on tidal marsh elevation, hydrology, water quality and biological communities. The NERRS coordinates nationwide data collection within 28 estuarine reserves around the country using standardized monitoring protocols to inform future research, conservation, restoration and resource management.

In the San Francisco Estuary, these monitoring efforts occur at the two NERRS reference sites of China Camp State Park in San Pablo Bay and Rush Ranch Open Space Preserve in Suisun Marsh. The NERRS monitoring programs build on a rich history of ecological research within these sites to provide critical data on marsh responses to climate change, including variation in marsh surface elevation, inundation frequency and duration, tidal currents, water temperature, salinity, pH, turbidity, meteorological conditions, and the distribution and abundance of both native and non-native species. As with data collected at other NERRS sites around the country, data collected as part of the NOAA Sentinel Sites Program in the San Francisco Estuary will be a valuable resource for scientists and managers to evaluate and inform tidal marsh conservation and restoration efforts throughout the region in the context of sea level rise and climate change.

Keywords: sea-level rise, climate change, long-term monitoring, tidal marsh, reference site

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Building a Regionally Coordinated Monitoring Network for Assessing Future Sustainability of Marsh Habitats in the San Francisco Estuary

Christina Sloop, San Francisco Bay Joint Venture, csloop@sfbayjv.org
Laura Valoppi, USGS, South Bay Salt Pond Restoration Project, laura_valoppi@usgs.gov
Judith Drexler, USGS, jdrexler@usgs.gov

Tidal marsh habitats in the SF Bay Estuary are being restored as part of the second largest wetland conservation effort in the Nation. To address challenges for future conservation and management of these wetlands as well as natural marshes within the Estuary, we held a multi-stakeholder workshop in Fall 2011 entitled, "Will They Sink or Swim? A Workshop on Managing, Monitoring, and Modeling of California's Estuarine Marshes under Sea-level Rise." It brought together scientists, managers, and consultants from across the region to discuss current management challenges and managers' needs concerning marsh sustainability under sea level rise, and how marsh accretion models could be used to aid future management of these marsh systems. In a follow-up workshop we refined managers' questions and found that main concerns relate to how/where marshes will move or transgress, whether/where there is sufficient sediment supply for marsh persistence, the effects of marsh loss on special status species, and the prioritizing of sites for future conservation. As part of a comprehensive managers' guide for assessing marsh sustainability under sea level rise, we propose a regionally coordinated monitoring network for assessing future sustainability of marsh habitats. This network will be an integral part of the regional wetland monitoring and evaluation framework the San Francisco Bay Joint Venture is currently building. As part of a special session entitled "The Role Of A Comprehensive Monitoring Network In Supporting Adaptive Management Of Marsh Habitats Under Sea Level Rise," we will seek further input and discuss the determination of a coordinated suite of metrics needed to inform marsh sustainability models for natural and restored tidal marshes throughout the Estuary. The information gleaned from our coordinated multi-stakeholder modeling and monitoring approach will provide critical insight for future conservation planning and management in the Bay-Delta region and beyond.

Keywords: Tidal marsh sustainability, sea-level rise, modeling, regionally coordinated monitoring framework

Wednesday, October 17, 2012: Room 307, Comprehensive Monitoring Network in Tidal Marsh Habitats under Sea Level Rise– Order 5

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Assessing Demographic Impacts of Climate Change on Tidal Marsh Birds: Population Modeling and Viability Analysis

Nadav Nur, PRBO Conservation Science, nnur@prbo.org
Leonardo Salas, PRBO Conservation Science, lsalas@prbo.org
Samuel Veloz, PRBO Conservation Science, sveloz@prbo.org
Julian Wood, PRBO Conservation Science, jwood@prbo.org
Leonard Liu, PRBO Conservation Science, lliu@prbo.org
Grant Ballard, PRBO Conservation Science, gballard@prbo.org

Tidal marsh habitat is of high concern because of: severe loss and degradation of habitat; endemic species, many of them threatened or endangered, depend on this habitat; and vulnerability of these species to climate change as a result of sea-level rise, changes in salinity, and the risk of extreme storms that will inundate vital habitat. To provide specific management guidance to reduce species' vulnerability and recover depleted populations, we developed interactive population dynamic models for four key marsh species: Black Rail, Clapper Rail, Common Yellowthroat, and Song Sparrow. The models can be used to assess known and potential risks, and to evaluate the efficacy of proposed management actions that may counteract threats to long-term viability. For tidal marsh Song Sparrows, available demographic information enabled us to also develop a stochastic model to project effects of changes in temperature, precipitation, and tides on future population viability. Under a high sea-level rise scenario, nest failure rates will increase and populations are expected to show strong declines (about 75% over 50 years); in contrast, populations are expected to increase assuming low sea-level rise. Extreme high tides associated with storms, which may become more common in the coming decades, were the most significant factor threatening long-term viability of Song Sparrows. However, a small reduction in predation on marsh bird nests (e.g., through predator control) can be sufficient to counteract expected population declines and exemplifies how increasing current survival and reproductive rates enhances species resilience to rapid climate change. Improvement in nest survival represents a realistic management action that can modify population trends, leading to, or enhancing population recovery. The demographic models presented quantify the expected benefits to affected species of potential management actions, integrate the impacts of environmental influences that may have opposing effects on target species, while revealing the long-term consequences to viability.

Keywords: Climate Change, Tidal Marsh, Modeling, Population Viability, Nest Survival, Flooding

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The California Climate Commons

Deanne DiPietro, Sonoma Ecology Center, dipietrodeanne@gmail.com
Grant Ballard, PRBO Conservation Science, gballard@prbo.org
James Quinn, UC Davis Information Center for the Environment, jfquinn@ucdavis.edu

Problem statement: There are countless projects generating climate change related datasets, as well as many ways of accessing and interpreting these data. Many of these products are highly technical in nature and based on a rapidly evolving set of assumptions and analytical methods, and are therefore accessible only by users with specialized skills. At the same time, natural resource managers are now required to consider climate change adaptation. Managers responsible for these efforts are faced with an untenable task of locating current, relevant data products and using them with confidence.

Approach: The California Climate Commons (climate.calcommons.org) is an initiative to help resource managers quickly find and get climate change related data and information from multiple sources, communicate with each other and with the researchers producing it, support one another in analyzing and interpreting the data for their projects, and then share lessons learned. The Commons provides technical and community support services that will result in a greater shared understanding about the best uses of climate change science toward improved conservation outcomes.

Results: In its first year the Climate Commons project created:
- an online library of climate-related data, tools, websites, and literature;
- hosting and download services for model outputs and ecological data products;
- an online environment for communication among the conservation and research/modeling communities.

In the second year we plan to engage the partners of the California Landscape Conservation Cooperative, both conservation managers and researchers, and create an active community of practice that uses the latest scientific findings in conservation planning and decision-making.

Conclusions: The California LCC provides an ideal framework for creating a shared and constantly improving understanding of the implications of climate science to natural resource management in the Bay-Delta and throughout California. The Commons is designed to maximize the potential of this framework.

Keywords: Informatics, climate change data, data access, digital library

Wednesday, October 17, 2012: Room 307, Climate Change– Order 2

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Projected Impacts of Climate Change, Urbanization, and Water Management Scenarios on Habitats and Ecology of Waterfowl and Other Waterbirds in the Central Valley of California

Elliott Matchett, USGS- WERC, Dixon Field Station, ematchett@usgs.gov
Joe Fleskes, UCSG- WERC, Dixon Field Station, joe_fleskes@usgs.gov
Mark Petrie, Ducks Unlimited, Inc., mpetrie@ducks.org
David Purkey, Stockholm Environment Institute, United States Center, dpurkey@sei-us.org
Charles Young, Stockholm Environment Institute, United States Center, cyoung@sei-us.org
Matthew Reiter, PRBO Conservation Science, mreiter@prbo.org
John Eadie, UC Davis, Dept. of Wildlife, Fish & Conservation Biology, jmeadie@ucdavis.edu
Matthew Miller, UC Davis, Dept. of Wildlife, Fish & Conservation Biology, hzmiller@ucdavis.edu
Kevin Ringelman, UC Davis, Dept. of Wildlife, Fish & Conservation Biology, kmringelman@ucdavis.edu

The Central Valley (CV) of California contains some of the most important habitats for waterfowl, shorebirds, and other waterbirds in North America. Most waterbird habitats in the CV, which include wetlands, flooded rice fields, and other agricultural lands rely on managed surface water supplies stored in reservoirs and delivered via a complex system to a wide array of competing water users. Water supplies vary with snow pack, temperature, and precipitation, all of which are projected to change substantially under some global climate models; land use and water management can also greatly impact water supplies. Waterbird food availability, which varies with the area, timing, and productivity of habitats, is a key factor limiting waterbirds during migration and winter affecting body condition and other aspects of their ecology. Thus, the Central Valley Joint Venture (CVJV) uses a food energy (bioenergetics) modeling approach to establish habitat conservation objectives for each CV basin. We developed necessary data and adapted a CV Water Evaluation and Planning (WEAP) model to investigate impacts of various climate, urbanization, and water management scenarios on waterbird habitats and ecology. For each scenario, we modeled water supplies and demands in the adapted WEAP model and estimated resulting landscape change. The area and timing of supported waterbird habitats based on WEAP results was then included in a bioenergetics model to quantify potential waterfowl food deficits. Initial modeling results focusing on Butte Basin indicate that under some scenarios, water supplies will not be adequate to maintain habitat at the levels necessary to support CVJV goal populations of waterfowl and result in late-winter food deficits for waterfowl. We are currently evaluating additional water management scenarios and expanding our efforts into other CV regions.

Keywords: bioenergetics, Central Valley, climate, model, scenario, urbanization, water, waterbird, WEAP

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Updating the San Francisco Baylands Ecosystem Habitat Goals for Climate Change

Letitia Grenier, Baylands Ecosystem Habitat Goals Update, letitia@letitia.org

The San Francisco Baylands Ecosystem Habitat Goals report is being updated to assess the likely effects of climate change on wetlands at the edge of the Bay and to provide science-based recommendations for management actions to reduce negative impacts. A group of public agency, private, and non-profit partners produced the Goals report in 1999, and it has been an inspiration for wetlands restoration and enhancement around the Bay for over a decade. Scientific guidance from the Goals report has attracted funding for a wide range of acquisition and restoration projects, contributing to the protection of 40,000 acres of baylands. The technical update will consider how climate change, including sea-level rise, extreme weather events, precipitation patterns, and temperature changes, will impact the extent, location and ecological functions of the Baylands. The ways that tidal marshes, mudflats, managed ponds and other wetland habitats will likely evolve will be explored for different future scenarios of high and low climate change for shorter (2030) and longer (2100) time horizons. Special attention will be devoted to the transition zone between wetlands at the Bay edge and adjacent upland, as well as to how climate-based changes in the Bay will affect the wetlands. Impacts to wildlife, including changes in key wetland habitat functions, will also be assessed, as will carbon sequestration in marshes. This scientific assessment of the projected impacts will provide an essential foundation for considering associated adaptation strategies. Scientific and managerial experts from across the region will develop the content of the Update, under the oversight of an independent science review panel, similar to the process for the original Goals report. The Update is a BAECCC project supported by the Coastal Conservancy and the Gordon and Betty Moore Foundation.

Keywords: Baylands, habitat goals, climate change, sea level rise, management recommendations,

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Predicted Sea-Level Rise Negatively Affects Tidal Wetland Distribution and Plant Productivity

Lisa Schile*, University of California, Berkeley, lschile@berkeley.edu
John Callaway, University of San Francisco, callaway@usfca.edu
James Morris, University of South Carolina, morris@biol.sc.edu
V. Thomas Parker, San Francisco State University, parker@sfsu.edu
Maggi Kelly, University of California, Berkeley, maggi@berkeley.edu

Sea-level is expected to rise between 70 and 180 cm in the next century and is likely to have significant effects on the distribution and maintenance of tidal wetlands; however, little is known about the effects of increased sea level on Pacific coast tidal marshes. These marshes comprise the majority of existing tidal wetland habitat in the San Francisco Bay Estuary and are particularly susceptible to increased sea-levels due to lack of upland habitat for future marsh migration. The development and calibration of a model that incorporates both physical and biological parameters is critical for investigating the predicted effects of sea-level rise. We examined the applicability and accuracy of the Marsh Equilibrium Model (MEM). MEM is a zero-dimensional model that models organic and inorganic accretion rates under a given rate of sea-level rise. MEM was calibrated using data collected from salt and brackish marshes in the San Francisco Bay Estuary. Above- and below-ground biomass from dominant marsh vegetation collected along an elevation gradient combined with results from a large field experiment simulating sea-level rise on two cosmopolitan tidal marsh species were used to calibrate the biological inputs. Both above and below-ground productivity decreased dramatically with increased inundation in one species but little to no response with the other. Under current sea-level rise conditions, MEM accurately modeled both organic and inorganic contributions to marsh accretion and the model then was run for each marsh type altering century sea-level rise and suspended sediment concentrations. Early results suggest that changes inthe contribution of plant biomass had more of an influence on marsh accretion rates than changes in the suspended sediment concentration and that marsh area decreases with increased sea-level rise. Few upland areas remain for marsh migration.

Keywords: sea-level rise, tidal wetlands, marsh accretion, vegetation

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Evaluation of Quantitative Precipitation Estimation (QPE) in Complex Terrain

Rob Cifelli, NOAA/ESRL/PSD, rob.cifelli@noaa.gov
Carroll Campbell, NOAA/ESRL/PSD, carroll.campbell@noaa.gov
Haonan Chen, NOAA/ESRL/PSD and Colorado State University, haonan.chen@noaa.gov
Lynn Johnson, NOAA/ESRL/PSD and Colorado State University, lynn.e.johnson@noaa.gov
Dave Reynolds, NOAA/ESRL/PSD and University of Colorado, david.reynolds@noaa.gov
Ellen Sukovich, NOAA/ESRL/PSD and University of Colorado, ellen.sukovich@noaa.gov
Delbert Willie, NOAA/ESRL/PSD and Colorado State University, delbert.willie@noaa.gov

Quantitative Precipitation Estimation (QPE) is extremely challenging in regions of complex terrain due to a combination of issues related to sampling. In particular, radar beams are often blocked or scan above the liquid precipitation zone while rain gauge density is often too low to properly characterize the spatial distribution of precipitation. Due to poor radar coverage, rain gauge networks are used by the National Weather Service (NWS) River Forecast Centers as the principal source for QPE across the western U.S. However, there has been little evaluation to determine the relative performance of gauge-only, radar, and blended radar-gauge QPE products in the western U.S.

The National Water Center (NWC) is intended to develop and provide new-generation and interoperable water information and services in support of the NWS, and other NOAA and federal agencies. To support the need for stream flow forecasts from the NWC, River Forecast Centers (RFCs) and other federal agencies, the best possible QPE is needed to serve as input forcing for hydrologic models to produce accurate and timely stream flow forecasts. Therefore, QPE evaluations are needed to determine the relative merits of different algorithms and sensors as well as to develop uncertainty estimates for QPE products.

In this study, an evaluation of radar-only, merged radar-gauge, and gauge-only QPE products is performed on precipitation events occurring in the Russian-Napa River basin in northern California using independent data sets, including rain gauge data from the NOAA Hydrometeorology Testbed (HMT). The evaluation is performed with the Multi-sensor Precipitation Estimator (MPE) and National Mosaic and Multi-sensor QPE (NMQ) algorithms, using a retrospective case study approach. The retrospective analyses allow for sensitivity tests using different gauge and radar input.

Keywords: precipitation, streamflow, radar, rain gauge

Wednesday, October 17, 2012: Room 307, Bay Area Precipitation Monitoring Activities by the NOAA Hydrometeorology Testbed Program– Order 1

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Water Management Applications of Advanced Precipitation Products

Lynn Johnson, NOAA Earth System Research Laboratory, Boulder, CO, Lynn.E.Johnson@noaa.gov
Greg Braswell, San Francisco Department of Public Works, San Francisco, CA, Greg.Braswell@sfdpw.org
Chris Delaney, Sonoma County Water Agency, Santa Rosa, CA, Chris.Delaney@scwa.ca.gov
David Reynolds, Noaa Earth System Research Laboratory, David.Reynolds@noaa.gov

Advanced precipitation sensors and numerical models track storms as they occur and forecast the likelihood of heavy rain for time frames ranging from 1 to 8 hours, 1 day, and extended outlooks out to 3 to 7 days. Forecast skill decreases at the extended time frames but the outlooks have been shown to provide "situational awareness" which aids in preparation for flood mitigation and water supply operations. In California the California-Nevada River Forecast Centers and local Weather Forecast Offices provide precipitation products that are widely used to support water management and flood response activities of various kinds. The Hydrometeorology Testbed (HMT) program is being conducted to help advance the science of precipitation tracking and forecasting in support of the NWS. HMT high-resolution products have found applications for other non-federal water management activities as well.
This presentation will describe water management applications of HMT advanced precipitation products pertinent to the Bay-Delta region. Two case examples will be highlighted, 1) reservoir operations for flood control and water supply, and 2) urban storm water management. Application of advanced precipitation products in support of reservoir operations is a focus of the Sonoma County Water Agency. Examples include: a) interfacing the high-resolution QPE products with a distributed hydrologic model for the Russian-Napa watersheds, b) providing early warning of in-coming storms for flood preparedness and water supply storage operations. For the storm water case, San Francisco wastewater engineers are examining a plan to deploy high resolution gap-filling radars looking off shore to obtain longer lead times on approaching storms. A 4 to 8 hour lead time would provide opportunity to optimize storm water capture and treatment operations, and minimize combined sewer overflows into the Bay.

Keywords: advanced precipitation products, reservoir operations, urban storm water, combined sewer

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A 21st-Century Observing Network for California

Allen White, NOAA Earth System Research Laboratory, allen.b.white@noaa.gov
Mike Anderson, California Department of Water Resources, manderso@water.ca.gov
Mike Dettinger, USGS/Scripps Institution of Oceanography, mddettin@usgs.gov
Marty Ralph, NOAA Earth System Research Laboratory, marty.ralph@noaa.gov
Art Hinojosa, California Department of Water Resources, hinojosa@water.ca.gov
Dan Cayan, Scripps Institution of Oceanography, dcayan@ucsd.edu

During northern hemisphere winters, the western coast of North America is battered by land falling, extra tropical storms. The impact of these storms is a paramount concern to California, where aging water supply and flood protection infrastructures are being challenged by the effects of age, increased standards for urban flood protection, and projected climate change impacts. In addition, there is a built-in conflict between providing flood protection and the other functions of major water storage facilities in California: water supply, water quality, hydropower generation, water temperature and flow for at risk species, and recreation. In order to improve reservoir management and meet the increasing demands on water, improved forecasts of precipitation, especially during extreme events, will be required. In this paper we describe how the California Department of Water Resources is addressing their most important and costliest environmental issue (too much or too little water), in part, by partnering with the NOAA Earth System Research Laboratory and Scripps Institution of Oceanography to develop and implement a 21st-century observing, modeling, display, and decision support system to improve NOAA's ability to forecast, detect, and monitor wintertime extreme events. With better confidence in the forecasts of these events, water managers can make improved decisions with increased lead time, which ultimately will benefit Bay-Delta management and provide ecosystem sustainability for at risk species across California.

Keywords: observations, extreme events, precipitation, forecasting, floods, water management

Wednesday, October 17, 2012: Room 307, Bay Area Precipitation Monitoring Activities by the NOAA Hydrometeorology Testbed Program– Order 3

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Estimating Basin Drainage Characteristics Using Spatially and Temporally Limited Soil Moisture Observations

Robert Zamora, NOAA Earth System Research Laboratory, robert.j.zamora@noaa.gov
Lynn Johnson, NOAA Earth System Research Laboratory, lynn.e.johnson@noaa.gov
Chengmin Hsu, NOAA Earth System Research Laboratory, chengmin.hsu@noaa.gov
Rob Cifelli, NOAA Earth System Research Laboratory, rob.cifelli@noaa.gov

The NOAA Hydrometeorological Testbed Program (HMT) began deploying soil moisture observing stations in the North Fork (NF) of the American River Basin and the Russian River Basin in 2002. Currently there are seven stations in the Russian and nine in the NF American. The HMT program has begun using these soil moisture observations to validate both conceptual stream flow and full physics land surface models. The spatial variability of precipitation, soil properties, and land use limits our ability to interpret in-situ soil moisture measurements.

In our presentation we will examine a method for estimating basin drainage characteristics by combining data obtained from HMT soil moisture stations over four years with soil survey data taken in the NF American basin. The American River is a major tributary of the Sacramento River and understanding how this sub-basin responds to precipitation events is of interest to numerous agencies including the National Weather Service, Army Corps of Engineers, and the California Department of Water Resources.

Research recently completed in the NF American indicates that the geological origins of the soils in the basin play a primary role in how the upper and lower portions of the basin drain. Preliminary results suggest that only two to five years of direct soil moisture sampling may be needed to characterize basin response to precipitation.

Keywords: Soil Moisture, Flood Forecasting, Evapotranspiration

Wednesday, October 17, 2012: Room 307, Bay Area Precipitation Monitoring Activities by the NOAA Hydrometeorology Testbed Program– Order 4

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Pacific Atmospheric Rivers: Impacts on Extreme Rainfall, Flooding and Water Supply in California

David W. Reynolds, Cooperative Institute for Research in the Environmental Sciences CU Boulder, CO, david.reynolds@noaa.gov
F. Martin Ralph, NOAA ESRL Boulder, CO, marty.ralph@noaa.gov
Paul J. Neiman, NOAA ESRL Boulder, CO, Paul.J.Neiman@noaa.gov
Jason M. Cordeira, NOAA ESRL Boulder, CO, jason.cordeira@noaa.gov
Gary A. Wick, NOAA ESRL Boulder, CO, gary.a.wick@noaa.gov
Allen B. White, NOAA ESRL Boulder, CO, allen.b.white@noaa.gov

Atmospheric Rivers (ARs) are long, narrow regions in the atmosphere (>2000 km and<1000 km, respectively) that are responsible for most of the horizontal water vapor transport outside of the tropics. ARs translate with extra tropical cyclones and number four to six in the mid-latitudes at any given time. Zhu and Newell (1998) found that most of the water vapor was transported in relatively narrow regions of the atmosphere (over 90% of the transport occurred typically in these 4-6 long, narrow regions roughly 400 km wide), and coined the term atmospheric river. ARs are found in both the Atlantic and Pacific Basins of the northern and southern hemispheres. Pacific Atmospheric Rivers are key phenomena that are highly correlated to extreme precipitation and winter floods along the West Coast of the US (Ralph et al. 2006; Neiman et al. 2008; Leung and Qian2009; Smith et al. 2010; Ralph et al. 2010). They also contribute 30 to 40 % of the annual rainfall and up to 50 to 60% of the annual stream flow along the West Coast (Dettinger, et al, 2011).
ARs can lead to flooding in higher altitude, inland mountain watersheds because they are accompanied by anomalously high freezing levels, which combined with the orographically enhanced precipitation exacerbate the flood threat. At the highest elevations, ARs contribute significantly to snowpack replenishment (Guan et al. 2010), which, in turn, provides much-needed water to area reservoirs during the snowmelt season.

This talk will focus on the key physical processes that form ARs in the North Pacific Basin, as well as our current capabilities to forecast these phenomena impacting northern and central California with sufficient lead-time to manage reservoir operations to conserve water supplies while still protecting downstream human, biological/ecological, and material assets. A decade of research from NOAA's Hydrometeorological Testbed contributed to these results.

Keywords: Flooding, Water Supply, Reservoir Management Forecasting

Wednesday, October 17, 2012: Room 307, Bay Area Precipitation Monitoring Activities by the NOAA Hydrometeorology Testbed Program– Order 5

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Analysis of Flood Statistics for Flood Risk Management in the Far South San Francisco Bay

Lisa Andes, U.S. Army Corps of Engineers, San Francisco District, Lisa.C.Andes@usace.army.mil
Frank Wu, U.S. Army Corps of Engineers, San Francisco District, Frank.Wu@usace.army.mil
Jen-Men Lo, Santa Clara Valley Water District, jlo@valleywater.org
Michael MacWilliams, Delta Modeling Associates, Inc, michael@deltamodeling.com
Chia-Chi Lu, Noble Consultants, Inc., cclu@nobleconsultants.com
Robert Dean, University of Florida, dean@coastal.ufl.edu

The ability to estimate flood stage frequency is a critical step in flood risk management. In many cases, such as the far south San Francisco Bay (SSFB), limited site specific data is available for use in this effort. However, the San Francisco tide station has over 100 years of tide data. To estimate flood frequency in SSFB a sensitivity analysis of various sampling criteria of predicted and residual tide were used to identify and sample significant flood events at the Golden Gate tide station. The probability distribution functions of the sampled predicted and residual tides and in-bay wind direction and speed were used to design hydrodynamic model simulations that covered the full range of these controlling parameters to transfer water elevation surface (WSE) to the SSFB. WSE was transferred in the form of a look-up table for existing (Yr-0) and future conditions (Yr-50 with NRC III sea level rise) project conditions for the establishment of WSE data base at the project site for use in statistical analysis.

Monte Carlo Simulation (MCS) model was used to estimate the flood stage frequency at the project site. The transferred WSE from the San Francisco tide station, static and dynamic levee failure mechanisms, local wind wave induced run-up and overtopping, and annual flood event occurrence were all implemented in the MCS model. The extreme probability analysis and Joint Probability Method were also employed to calculate the flood stage frequency curves for comparison. Reasonable flood stage frequency curves with uncertainty were using the MCS method under all the scenarios studied. The comparisons of flood stage frequency results among the different statistical approaches seem very reasonable. It's concluded that the technical approaches developed, using hydrodynamic and Monte Carlo simulations, would provide a reasonable way for the establishment of coastal flood stage frequency at the project site.

Keywords: Flood Frequency Statistics, Flood Risk Management

Wednesday, October 17, 2012: Room 307, Flood and Levee Management– Order 1

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Modeling the Establishment of Riparian Habitat Vegetation with Applications to *Populus fremonti* on the Sacramento River, California

Michael Tansey, US Bureau of Reclamation, mtansey@usbr.gov
Charles Young, Stockholm Environment Institute, cyoung@sei-us.org

The existence of healthy riparian forests in the Sacramento, San Joaquin and other tributaries of the Bay-Delta is important for successfully managing the estuary for both human and ecosystem benefits. These riparian forests provide important ecological services including stream bank stabilization, shade, nutrient inputs, and physical habitat for terrestrial and aquatic species. The survival and renewal of riparian forests requires the periodic establishment of cottonwood and other riparian vegetation seedlings in near-river sediments in order to replace trees lost to natural mortality and other causes. Determining under what conditions riparian vegetation seedlings will survive is an important consideration in managing river flows for both human and ecological objectives.

To address this need, a hydro-biological conceptual model describing the growth and survival of riparian vegetation from germination through the first year of seedling growth was developed. This Riparian Habitat Establishment Model (RHEM) was developed by integrating the conceptual model into the well-known HYDRUS-2D numerical model. RHEM dynamically simulates seedling root and shoot growth and plant survival as the combined effects of sediment texture, meteorological conditions, and water table depth. Using the RHEM model, an analysis based on water table controlled cottonwood (*Populus Fremonti*) growth experiments revealed that the seedlings do not experience significant water stress until a critical water table depth is reached. This depth depends on sediment texture with finer textured sediments having greater critical depths. Additional analyses showed that, for the conditions simulated in this study, sediment texture has a larger effect on seedling survival than meteorological conditions. The RHEM model was also used to derive and evaluate a simple cottonwood seedling density and survival model which was applied to observed seedling growth and survival conditions on the Sacramento River, CA. The density model was able to successfully replicate the decline in seedling density observed as river stage declined.

Keywords: Riparian vegetation modeling

Wednesday, October 17, 2012: Room 307, Flood and Levee Management– Order 2

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Holland Tract Levee - Case History

Gilbert Cosio, MBK Engineers, cosio@mbkengineers.com
Nate Hershey, MBK Engineers, hershey@mbkengineers.com
Kevin Tillis, Hultgren-Tillis Engineers, tillis@hultgrentillis.com

Delta Levees provide protection for the lands and habitat behind the levees. The highly altered waterways now depend on the levees to maintain water flows through the delta and to protect critical habitat. The levee on Holland Tract has a long history of concerns and the levee failed in 1980. The presentation will include a history of levee construction and engineering concerns with the Holland Tract levee. In the 30 plus years since levee failure, the Holland Tract levee has included several phases of construction to raise, widen and improve the levee. Recent funding though the DWR special studies program has provided additional funding for rehabilitation of the levee.

Rehabilitation of the delta levees is widely recognized as necessary to protect to protect the ecosystem and to protect the water supply of California. The presentation will provide a historical perspective of how the levee improvements are helping to achieve these goals. The Holland Tract levee improvements will allow for future improvement to counteract the effects of sea level rise and to provide a more robust levee to resist earthquake forces. The existing designs will be presented along with potential schemes for sea level rise and seismic improvements.

Keywords: Levee Case History

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Identifying High-Risk Islands and Modeling Levee Failure Scenarios Using the Adaptive Hydraulics Model (ADH)

Stephen Sanborn, Dynamic Solutions, LLC, scsanborn@dsllc.com
Eugene Maak, USACE, Sacramento District, eugene.c.maak@usace.army.mil
William McAnally, Dynamic Solutions, LLC, whmcanally@dsllc.com
Christopher Hall, Dynamic Solutions, LLC, clhall@dsllc.com
Christopher Wallen, Dynamic Solutions, LLC, cmwallen@dsllc.com

Flooding in the Sacramento – San Joaquin Delta presents significant risks to residents of the Delta, the ecosystem, and the state's economy. Areas of the Delta are at high risk for levee failures which would put hundreds of lives at risk and cause billions of dollars in damage. Army and Corps of Engineers guidance documents define risk as the "probability and severity of loss linked to hazards" and prescribe a composite risk assessment method to be used in Corps projects. Information regarding the relative probability of hazards and the severity of risk was taken from the Delta Risk Management Strategy (DRMS) Phase I and II documents and put into the Corps' Composite Risk Matrix (CRM). From these results, four areas were chosen to demonstrate levee failure scenarios using the ADH hydrodynamic model using criteria of; life loss risk index, economic loss risk index, tidal and shear stress impacts, and annual failure rate. The four islands chosen for analysis were Sargent Barnhart Tract, Smith Tract, SM-124 near Suisun City, and Brannan-Andrus Island. Detailed computational meshes, developed for each island based on LiDAR data, were connected to a calibrated ADH model of the entire Delta. ADH has been tested extensively for dam and levee failure scenarios and its computational scheme makes ADH accurate and efficient for these studies. Worst case failure scenarios were run for each of the four islands. Local flooding patterns and rates were evaluated as well as system-wide hydrodynamic and salinity effects. Study results can be used to inform and prioritize emergency response planning and provide insight for Delta management strategies to mitigate salinity intrusion and persistence which would affect the water supply and ecosystem.

Keywords: Levee failure, Flooding, Risk analysis, Modeling, ADH, Emergency management

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Economic Consequences of Levee Failure Associated with Subsidence and Accretion, Sacramento-San Joaquin Delta

Steven Deverel, HydroFocus, Inc., sdeverel@hydrofocus.com
Jeremy Proville, Environmental Defense Fund, jproville@edf.org
Christine Schoenzart, Environmental Defense Fund, cschoenzart@edf.org
Belinda Morris, American Carbon Registry, Winrock International, bmorris@winrock.org

Subsidence of Delta organic soils and sea level rise results in increasing hydraulic forces on levees and seepage through and under levees. Conversion of Delta islands to managed impounded marshes can stop and reverse the effects of subsidence and reduce hydraulic forces and seepage. We used subsidence and wetland accretion models and economic analysis to assess the potential financial benefit of conversion of farmed islands to shallow flooded wetlands that sequester carbon. We conducted an analysis of the costs of levee failure over the next several decades on Twitchell Island under two land management scenarios. The first (baseline) assumes Twitchell Island continues to subside. The second scenario assumes the island has been converted to wetland and land and water levels increase over time

The economic effects of the two management alternatives were simulated using a Monte-Carlo modeling framework. We simulated hydraulic forces on island levees under the two scenarios and with sea level rise. Estimates of future hydraulic forces were applied to probabilities of levee failure, according to CA-DWR estimates based on sunny-day, seismic event and flooding risks.

We calculated a range of in-delta costs associated with levee failure for a single island (Twitchell). Preliminary results indicate substantial potential for avoided costs. During the next 100 years, we estimated a Net Present Value savings of 1to 3 billion in avoided levee-failure costs. We conclude that widespread conversion to wetlands could provide substantial economic benefit.

Keywords: subsidence, wetlands, levees, economics

Wednesday, October 17, 2012: Room 307, Flood and Levee Management– Order 5

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Habitat Characteristics of the North Delta Arc

John Durand, University of California, jrdurand@ucdavis.edu

The North Delta Arc refers to the suite of interconnected littoral and shallow water habitats along the northern rim of Suisun Bay and the Delta which wrap around the base of the Montezuma Hills. It includes Suisun Marsh, Sherman Lake, the Cache-Lindsey Slough Complex, and Liberty Island. These habitats tend to be more productive and more biologically diverse than other regions of the Delta. While multiple stressors have been implicated fish declines throughout the Estuary, there are multiple physical and trophic drivers that support fishes in the Arc, providing a slower rate of decline for a number of native species. These drivers include reticulate geomorphic structure, a bathymetric gradient extending from above to below sea level, complex residence times due to tidal exchange, and the influence of high net fresh water flows in adjacent channels. These conditions promote the essential needs of local fishes: they provide physical and hydrodynamic structure for habitat, trophic structure that supports multiple foraging strategies, and corridors for transit or recruitment among habitats. Comparisons with other regions of the Delta demonstrate that these conditions are not met throughout much of the ecosystem; the North Delta Arc is an exception.

Keywords: Native fishes, habitat, Cache-Lindsay Slough, Suisun Marsh, food webs, geomorphology

Wednesday, October 17, 2012: Room 308-310, Cache-Liberty Complex: Last Refuge for Native Fishes? – Order 1

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The North Delta: A Cache of Native Fishes in the Upper San Francisco Estuary

Denise De Carion, Department of Environmental Science & Policy, University of California-Davis, dpdecarion@ucdavis.edu
Brian Schreier, Aquatic Ecology Section, Department of Water Resources, bschreie@water.ca.gov
J. Louise Conrad, Aquatic Ecology Section, Department of Water Resources, jlconrad@water.ca.gov
Matthew Young, Department of Wildlife, Fish & Conservation Biology, University of California-Davis, mjyoung@ucdavis.edu
Jared Frantzich, Aquatic Ecology Section, Department of Water Resources, jfrantzich@water.ca.gov
Andrew Sih, Department of Environmental Science & Policy, University of California- Davis, asih@ucdavis.edu

The northern Delta is presumed to provide refuge for fishes native to the upper San Francisco Estuary, and is often identified as a model ecosystem for regional restoration efforts. However, the species composition and community structure among these various habitats remains understudied. We conducted comprehensive electrofishing surveys throughout Lindsey and Cache Sloughs, Liberty Island and the Sacramento Deep Water Ship Channel in the spring of 2011. Using spatial analyses, we evaluated the distribution and abundance of fish species. On average, native species comprised 41% of catch-per-unit effort (CPUE). These results differ markedly from comparable electrofishing data collected in other regions of the Delta in the springs of 2009 and 2010, where native species represented only 5% and 7% of average CPUE, respectively. Tule perch and Sacramento sucker, the most abundant native species, occurred along shallow vegetated banks. Juvenile chinook salmon frequented nearshore habitats along channel corridors and backwater sloughs. Delta smelt occupied shallow open water habitat near exposed beaches and riprap banks, and along a submerged road in Liberty Island. These findings provide important data on the species occurrence and distribution in the northern Delta, which has implications for habitat restoration goals aimed at encouraging native fish populations in the Delta.

Keywords: Fish communities, native fishes, shallow water habitats, habitat restoration

Wednesday, October 17, 2012: Room 308-310, Cache-Liberty Complex: Last Refuge for Native Fishes? – Order 2

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Larval and Juvenile Fishes of Liberty Island

Lori Smith, US Fish and Wildlife Service, lori_smith@fws.gov
Joseph Kirsch, US Fish and Wildlife Service, joseph_kirsch@fws.gov

Liberty Island is a tidally influenced freshwater marsh that is hypothesized to provide important habitat to the early life stages of many fishes found within the Sacramento – San Joaquin River Delta, in particular, Delta smelt (*Hypomesus transpacificus)*. The Stockton office of the U.S. Fish and Wildlife Service has been monitoring the fish communities inhabiting Liberty Island since the early 2000's, although not continuously. We looked at the occupancy and temporal distribution of delta smelt, splittail (*Pogonichthys macrolepidotus*), Chinook salmon *(Oncorhynchus tshawytscha)*, and longfin smelt *(Spirinchus thaleichthys)* captured in our larval trawls and beach seines from 2010-2012. We used species specific hierarchical models to investigate the effects of water quality characteristics, hydrogeomorphology, spatial position within the wetland, and weather on juvenile and larval fish occupancy. The relative abundance estimates for most species were the highest in the spring; however delta smelt appear to be using the island year round. Based on model output, temperature influenced the occupancy probability for all species and gear type except larval delta smelt. In addition, results indicated that different water quality characteristics had unique effects on species. Splittail was our second most abundant species and was the only species modeled to show spatial preference within the island. Through our continued monitoring of Liberty Island we hope to gain a better understanding of the habitat use by native fishes within a restoring wetland and to inform future restoration efforts in the Cache Slough and Yolo Bypass areas.

Keywords: Liberty Island, beach seine, larval fish trawl, occupancy

Wednesday, October 17, 2012: Room 308-310, Cache-Liberty Complex: Last Refuge for Native Fishes? – Order 3

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Some Like it Fresh: Evidence of Year-Round Freshwater Residence of Delta Smelt in the North Delta

James Hobbs, Wildlife, Fish and Conservation Biology, UC Davis, jahobbs@ucdavis.edu
Naoaki Ikemiyagi, CA Dept. of Water Resources, Aquatic Ecology Section, nikemiya@water.ca.gov
Georgia Ramos, Wildlife, Fish and Conservation Biology, UC Davis, tigresaramos@gmail.com
William Bennett, Center for Watershed Science, UC Davis, wabennett@ucdavis.edu
Ted Sommer, CA Dept. of Water Resources, Aquatic Ecology Section, tsommer@water.ca.gov
Julio Adib-Samii, California Department of Fish and Game, Bay Delta Region, JADIBSAMII@dfg.ca.gov

The north delta including Liberty Island, the Deep water Ship Channel and the Cache-Lindsey Slough complex has been identified as a critical area for the conservation of native fishes including the delta smelt. Increased focus on this area has suggests that delta smelt can reside year-round in this freshwater habitat, which is counter to the traditional understanding of the life history of this species. In this study we summarize the existing IEP monitoring data supporting freshwater residence for delta smelt and utilize otolith geochemistry to identify freshwater residence among a mixed stock of delta smelt collected during the Fall Midwater Trawl and Spring Kodiak Trawl Surveys.

IEP monitoring surveys during the past decade have observed at least some delta smelt in all seasons We examined a subsample of delta smelt from the Fall Midwater Trawl(1999,2000,2001.2005,2006,2007, & 2011) and Spring Kodiak Trawls(2002,2004,2005,2006) for the presence of freshwater resident delta smelt. Otolith data demonstrated resident freshwater fish in all years and surveys except Fall Midwater Trawl 2006. We observed the largest number of resident fish in the 2003 Spring Kodiak Trawl (n=32). A majority of resident fish were collected in the north delta beginning in November, and as far downstream as station 704 along the lower Sacramento River.

Conclusion/Relevance: Delta smelt can reside in freshwater habitats year round and forego movements into low salinity waters. This life history could have significant implications for the conservation and management of delta smelt.

Keywords: North Delta, Delta Smelt, Otolith

Wednesday, October 17, 2012: Room 308-310, Cache-Liberty Complex: Last Refuge for Native Fishes? – Order 4

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Climate Change Effects on North Delta Fishes

Peter Moyle, Center for Watershed Sciences, UC Davis, pbmoyle@ucdavis.edu
Rebecca Quinones, Center for Watershed Sciences, UC Davis, rmquinones@ucdavis.edu
Patrick Crain, ICF INTERNATIONAL, Sacramento, PCrain@icfi.com
Kiernan Joseph, NOAA Fisheries, Southwest Fisheries Science Center, Joseph.Kiernan@noaa.gov

Problem: The North Delta is regarded as potential large-scale conservation habitat for native fishes but its characteristics will change as result of climate change. Can it persist as a refuge for native fishes when water temperatures will be increasingly warmer, tidal action will likely be muted, and outflows will be more variable (bigger floods, longer droughts)? *Approach:* Using twenty metrics, we evaluated the likely responses of native and alien fishes to climate change. *Results:* Most populations of native fishes will decline, some to extinction, and most populations of alien fishes will increase or remain steady, if present trends continue. *Conclusions:* The North Delta has considerable potential for management to mitigate for climate change effects on native fishes, including improving connectivity to other habitat areas both upstream and downstream, increasing habitat complexity, and improving flows through aquatic weed control and other measures. Studies are needed to more precisely determine habitat requirements of most species and how to provide for them under changing conditions.

Keywords: delta smelt, splittail, native fishes, alien fishes, Delta, hitch

Wednesday, October 17, 2012: Room 308-310, Cache-Liberty Complex: Last Refuge for Native Fishes? – Order 5

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Insights into Colonization and Expansion Dynamics of *Schoenoplectus californicus* at Liberty Island, California

Mark Hester, University of Louisiana, mhester@louisiana.edu
Jonathan Willis, University of Louisiana, jmwcoastal@gmail.com
Taylor Sloey, University of Louisiana, taylorsloey@gmail.com

Understanding plant colonization and expansion dynamics is an essential component in the development of sustainable restoration plans. As part of a larger, multidisciplinary collaboration at Liberty Island, we conducted both observational and manipulative studies that focused on colonization and expansion dynamics of vegetation at the site, particularly *Schoenoplectus californicus* (tule). Our approach had multiple components, including: 1) a seed-bank assay, 2) a field transplant study of *S. californicus, S. acutus, and Typha latifolia*, and 3) a field transect study in areas that are currently dominated by *S. californicus.* Results of the seed-bank assay revealed greater species richness of viable seeds than is currently displayed in the emergent wetland plant community at the site, suggesting that environmental conditions limit the successful germination and persistence of many of these species. Transplant establishment success was greatest in adult transplants (versus rhizomes),and although all three species assessed were able to establish both adjacent to the existing marsh edge and in slightly deeper open water areas, *S. californicus* rapidly became the dominant species and exhibited high rates of vegetative expansion. The transect study revealed interesting differences between the east and west sides of Liberty Island with *S. californicus* growing at lower elevations on the east side where plant height and stem densities were also generally lower than on the west side. Additionally, west-side transects exhibited a trend of soils becoming more compacted and displaying higher bulk densities along a gradient from the marsh platform interior to adjacent open water areas, whereas east-side transects displayed an abrupt increase in unconsolidated sediments in adjacent open water areas and less soil organic matter accumulation in the vegetated marsh platform. Our findings illustrate the importance of recognizing multiple factors and dynamic interactions between the plant community and the abiotic environment when considering restoration thresholds.

Keywords: Liberty Island, wetland restoration, *Schoenoplectus*, Typha, colonization, expansion, elevation

Wednesday, October 17, 2012: Room 308-310, BREACH III: Evaluating and Predicting 'Restoration Thresholds' of Liberty Island– Order 1

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Restored Marshes in Liberty Island: How 'Deltaic' are the New Wetlands?

Denise Reed, The Water Institute of the Gulf, djreed@uno.edu
Ross Del Rio, University of New Orleans, rdelrio@uno.edu
Lindsay Dunaj, University of New Orleans, ldunaj@my.uno.edu

All plans for ecosystem restoration in the Bay-Delta call for increasing the area of tidal marsh and the question of how and where tidal marsh restoration is feasible must be addressed. Sites with relatively little subsidence and a supply of riverine sediment are often viewed as more suitable and the 'restoration' of some tule marshes on Liberty Island following levee breach provides an opportunity to explore the dynamics of the new wetlands.

As part of the BREACH III study, measurements of surface elevation change, grain size, and gravimetric and volumetric contributions of organic and mineral material are being made at Liberty. Data collection includes the transition from mudflat to marsh, and sites with varying exposure to wind waves. In addition, the character of these 'new' marsh soils was compared with growing deltaic wetlands in Louisiana to elucidate the applicability of traditional delta building concepts to marsh restoration in the Delta.

Results show 'protected' areas had higher rates of elevation increase than exposed sites independent of absolute elevation. Over the almost 2 years of data the mean rate of elevation change exceeded 1 cm/yr at protected sites. Soil development is dominated by the mineral fraction both gravimetrically and volumetrically. In contract to Louisiana deltaic marshes, where a strong relationship between elevation change and seasonal water level has been established, elevation change at Liberty does not seem to be controlled by stage.

This study supports the finding of previous work on natural and restored marshes in the Delta - that despite the traditional view of delta wetlands as being peat dominated systems, mineral sediment is an essential component of soil development and vertical building. Plans to restore marshes in the Delta must account not only for areas where subsidence is low but also for the supply of sediment for continued marsh growth.

Keywords: restoration; marsh; Liberty Island; sedimentation

Wednesday, October 17, 2012: Room 308-310, BREACH III: Evaluating and Predicting 'Restoration Thresholds' of Liberty Island– Order 2

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The Importance of Vegetated Ponds to Water Quality and Phytoplankton Carbon Production in Liberty Island, California

Peggy Lehman, Division of Environmental Services, California Department of Water Resources, plehman@water.ca.gov
Shawn Mayr, North Central Region Office, CA Department of Water Resources, sdmayr@water.ca.gov
Brett Larsen, North Central Region Office, CA Department of Water Resources, blarsen@water.ca.gov
Mike Dempsey, Division of Environmental Services, California Department of Water Resources, mdempsey@water.ca.gov

Liberty Island is a freshwater tidal wetland that is thought to provide habitat and food resources for the endangered delta smelt. However, little is known about the mechanisms that control environmental conditions and carbon production in the wetland. This study was designed to address the question: Do the small vegetated ponds in the upper portion of Liberty Island contribute significantly to the overall water quality and phytoplankton production of the wetland? To address this question, a suite of physical, chemical and biological variables were measured at four locations in three wetland ponds between 2010 and 2011. Continuous measurements of water temperature, pH, specific conductance, dissolved oxygen, turbidity and chlorophyll *a* fluorescence with YSI 6600 water quality sondes provided information on water quality conditions. Continuous phytoplankton carbon production was predicted from continuous Turner Phytoflash photometers, Li-COR underwater light measurements and chlorophyll *a* fluorescence. Continuous and discrete monthly measurements provided baseline information on nutrient availability. Calibration data were collected semi-monthly to monthly throughout the study. Chlorophyll *a* concentration, water temperature, specific conductance and turbidity were greater in the vegetated ponds. On average, phytoplankton cells were growing at 45% to 48% of their maximum potential yield (Fv/Fm) throughout the ponds. Average daily yield was similar among the three ponds at 0.38 $\pm$ 0.10 to 0.41 $\pm$ 0.11 Fv/Fm and ranged from 70% to 10% of the maximum potential yield. In situ 24 hr light and dark bottle dissolved oxygen incubation studies indicated both the net primary productivity and maximum photosynthetic potential were greater in the vegetated ponds. Phytoplankton production was supported by elevated nitrate, ammonium, soluble reactive phosphorus and silica concentrations that were often greater in the vegetated ponds. Initial findings suggest vegetated ponds are a potential source of suspended solids, salt and phytoplankton carbon to the wetland.

Keywords: freshwater tidal wetland, primary productivity, carbon flux, material flux

Wednesday, October 17, 2012: Room 308-310, BREACH III: Evaluating and Predicting 'Restoration Thresholds' of Liberty Island– Order 3

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Hydrodynamic, Wind-Wave, and Sediment Transport Modeling to Inform Ecological Response at Liberty Island

Matt Brennan, ESA PWA, mbrennan@esassoc.com
Michelle Orr, ESA PWA, morr@esassoc.com
Eddie Divita, ESA PWA, edivita@esassoc.com
Steve Crooks, ESA PWA, scrooks@esassoc.com

Long-term planning for the Delta has identified habitat restoration as a key element for reconciling human impacts with ecosystem function in the Delta. However, the linkages between physical processes and the resulting habitat evolution are not well understood. As part of the BREACH III project team, we have developed hydrodynamic, wind-wave, and sediment transport models for Liberty Island, a former diked area restored to flow, to understand these linkages.

We have represented the northwest portion of the Delta, encompassing Liberty Island and surrounding channels, with a two-dimensional hydrodynamic model (Delft3D) coupled with a wind-wave model (SWAN). These two hydraulic models are used to predict the re-suspension, transport, and deposition of suspended sediment. The model is forced with a range of inputs, including tides, wind, and river discharge, including the Yolo Bypass. The model, calibrated to water level, discharge, wave, and suspended sediment observations, is used to characterize the spatial and temporal distribution of wave energy, circulation, and sediment transport. By analyzing the predicted response to different forcing conditions and ambient sediment conditions, we assess the relative role of different forcing mechanisms (wind-waves, channel-mudflat connectivity, and the Yolo Bypass) to creating the elevated suspended sediment conditions in the region and the trends in geomorphic change. By paring the modeling with ecosystem data (vegetation, plankton, and fish), we intend to assist in improving understanding of habitat evolution and species use.

This physical-process perspective on ecological response is anticipated to inform projections of habitat evolution as well as potential impacts. Alternative design strategies to enhance the performance of restoration projects can then be evaluated. Finally, this modeling supports the development of ecological modeling tools.

Keywords: Tidal marsh restoration, modeling, suspended sediment, waves, Delta

Wednesday, October 17, 2012: Room 308-310, BREACH III: Evaluating and Predicting 'Restoration Thresholds' of Liberty Island– Order 4

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Liberty Island Landscape Vegetation Model

Enrique Reyes, Dept. of Biology, East Carolina University, reyese@ecu.edu

A landscape vegetation model was developed to provide a predictive level of understanding about abiotic and biotic controls on vegetation colonization and expansion on Liberty Island, with the goal of investigating how to restore wetlands integrating historical and concurrent environmental data, and assess the evolving wetland features at the landscape scale

The initial conceptual model developed from the BREACH studies was used as base for an evolutionary path from subtidal open water, through emergent mudflats to vegetation colonization and ultimately mature marshes. This conceptual model identified different stages in wetland development and articulated the interactions among these factors for intertidal pioneer and mature tule (*Schoenoplectusacutus*) conditions.

We implemented this conceptual model unto a large-scale dynamic model to understand how hydrologic and geomorphic changes and ecological responses at different scales from local to the entire restoration site, and relationships to the adjoining landscape. The result was a multiple-scale biophysical model for the Liberty Island marshes capable of simulating long-term regional habitat change. This mechanistic process-based ecological landscape model assessed "restoration thresholds" of emerging wetlands. This type of spatial model incorporates location- specific algorithms to allow feedback between the local processes and landscape dynamics. Thus, the biophysical model for Liberty Island compiles physical and biological information at different scales in three modules: hydrodynamic, soil, and macrophyte productivity dynamically coupled via a *unit ecosystem model.* Calibration results show that plant colonization is highly correlated to water depth and wave exposure. Model results could be used to assess how restoration goals can be met using water transport and routing influence changes in habitat composition within the basin.

Keywords: watershed modeling, plant response, long-term simulations

Wednesday, October 17, 2012: Room 308-310, BREACH III: Evaluating and Predicting 'Restoration Thresholds' of Liberty Island– Order 5

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Migratory Patterns and Survival of Juvenile Salmonids in the Yolo Bypass

Myfanwy Rowlands, UC Davis, mrowlan1@gmail.com
Phillip Sandstrom*, UC Davis, ptsandstrom@ucdavis.edu
A. Peter Klimley, UC Davis, apklimley@ucdavis.edu
Ted Sommer, California Department of Water Resources, tsommer@water.ca.gov

The Yolo Bypass is likely an important rearing habitat for outmigrating juvenile salmonids. We deployed seven monitors within the Toe Drain in order to assess usage of the Yolo Bypass by juvenile salmonids during a dry year. Twenty-five juvenile chinook salmon (100-125mm FL) and twenty-five juvenile steelhead trout were implanted with VEMCO V5 and V7 coded tags, respectively. The smolts were released 91 river kilometers upstream from the base of the Cache Slough Complex. The migratory patterns of chinook salmon down the Toe Drain and out to Chipps Island were monitored with an array of VEMCO VR2W 180kHz receivers. Steelhead trout were monitored using the 69kHz receiver array maintained by the California Fish Tracking Consortium, allowing us to monitor their movements to the Golden Gate. We calculated residence time in the Toe Drain, as well as rates of survival. All survival rates were calculated using Program MARK. Juvenile chinook salmon survival rate from the release site to Lisbon Weir was 0.92 (0.05+/- SE). Survival from Lisbon Weir to the base of the Toe Drain was 0.80 (0.09+/- SE). The average observed movement rate of chinook salmon was 5.94 km/day from the release site to the base of the Toe Drain.

Keywords: salmonids, outmigration, Yolo Bypass, floodplain, telemetry

Wednesday, October 17, 2012: Room 308-310, Yolo Bypass: Managed Floodplain as Seasonal Habitat for Fish– Order 1

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Testing Hypotheses about Fish and Food Web Responses in Managed Habitat in Yolo Bypass Floodplain

Ted Sommer, California Department of Water Resources, tsommer@water.ca.gov
Louise Conrad, California Department of Water Resources, jlconrad@water.ca.gov
Steve Brumbaugh, California Department of Water Resources, sbrumbau@water.ca.gov
Gina Benigno, California Department of Water Resources, gbenigno@water.ca.gov
Josh Martinez, California Department of Water Resources, jamartin@water.ca.gov
Jacob Katz, UC Davis, jvkatz@ucdavis.edu
Carson Jeffres, UC Davis, cajeffres@ucdavis.edu
Nicholas Corline, UC Davis, njcorline@ucdavis.edu
Josh Israel, US Bureau of Reclamation, JAIsrael@usbr.gov

Monitoring data in Yolo Bypass and other seasonal habitat of the Central Valley suggests that floodplain habitat has major benefits to downstream migrating juvenile Chinook salmon. These results have led to increased interest in the use of managed floodplain to improve the aquatic habitat of the region. To begin examining the potential use of managed habitat for fish rearing, we stocked hatchery juvenile Chinook salmon into a flooded Yolo Bypass field constructed with three basic habitats: rice, fallow, and disked soil. During a winter 2012 study we examined the responses of physical, chemical, and biological metrics to seasonal inundation. Overall, water quality was consistently good throughout the study. Water temperatures were warmer than the adjacent Sacramento River channel, although trends were highly influenced by wind forcing. Salmon growth was high relative to historical data for Yolo Bypass, Sacramento River, and Cosumnes River. Growth rates were likely enhanced as a result of relatively warm temperatures and high densities of zooplankton (ostracods). Salmon survival could not be estimated accurately because an unknown number of fish escaped, but appeared relatively good. Chlorophyll *a* levels in the pilot study were high relative to measurements in Sacramento River and a perennial channel of Yolo Bypass. Contrary to predictions, chlorophyll *a* levels decreased between the pond inlet and outlet, likely because of grazing pressure from zooplankton.

Keywords: Yolo Bypass, floodplain, Chinook salmon, restoration, food web, zooplankton, habitat

Wednesday, October 17, 2012: Room 308-310, Yolo Bypass: Managed Floodplain as Seasonal Habitat for Fish– Order 2

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Residence Time of White Sturgeon in the Yolo Bypass and Subsequent Movements in the Sacramento River Watershed in a Dry Year

Myfanwy Rowlands*, UC Davis, mrowlan1@gmail.com
Phillip Sandstrom, UC Davis, ptsandstrom@ucdavis.edu
A. Peter Klimley, UC Davis, apklimley@ucdavis.edu
Ted Sommer, California Department of Water Resources, tsommer@water.ca.gov

Although the Yolo Bypass floodplain has been demonstrated to benefit a suite of native fishes, particularly in flood years, little is known about movement patterns and residence time of native fishes in the Yolo Bypass. In cooperation with the Department of Water Resources (DWR), we implanted 68 white sturgeon with VEMCO V16 coded tags. The sturgeon were caught in the DWR fyke net, located just below Lisbon Weir in the Toe Drain (the perennial channel that runs along the eastern side of the Yolo Bypass). Using an array of VEMCO VR2W 69kHz monitors, including those maintained by the California Fish Tracking Consortium, the sturgeon's movement patterns were monitored within and throughout the Toe Drain (a total reach of 38.45 river kilometers) and into the San Francisco Bay. Variables of consideration for behavioral movement analysis included sex and fork length. Average individual residence time in the Yolo Bypass was 19 days (2.94+/- SE).

Keywords: white sturgeon, Yolo Bypass, telemetry, animal movement, floodplain, residence

Wednesday, October 17, 2012: Room 308-310, Yolo Bypass: Managed Floodplain as Seasonal Habitat for Fish– Order 3

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A Long-Term Examination of Juvenile Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*) Utilization of the Yolo Bypass as Rearing Habitat

Lynn Takata, Department of Water Resources, ltakata@water.ca.gov
Ted Sommer, California Department of Water Resources, tsommer@water.ca.gov
Louise Conrad, California Department of Water Resources, jlconrad@water.ca.gov
Kevin Reece, Department of Water Resources, creece@water.ca.gov

Natural floodplains of the Sacramento-San Joaquin River Delta historically supported aquatic ecosystems with high biological productivity, but are largely absent from the Central Valley today due to large-scale construction of levees on river channels. The Yolo Bypass is a 59,000 acre floodplain originally engineered to provide flood protection for cities in the Sacramento region. When the Bypass floods (approximately 70% of years), it provides the most extensive floodplain habitat in the northern Delta and is thus a model system for understanding how fish species of concern use this rare, but important habitat.

Since 1997, the Department of Water Resources' Yolo Bypass fisheries monitoring program has been collecting data on fishes that utilize the bypass, including fall-run juvenile Chinook salmon. In addition, the program released groups of coded wire tagged (CWT) juvenile hatchery Chinook at the north end of the bypass each February/early March during 1998-2009. We used these long-term datasets to examine how environmental factors such as flow, floodplain inundation and temperature influence juvenile Chinook residence time, apparent growth, survival, and emigration timing in the Yolo Bypass. Previous analyses using CWT, wild fish, and experimental enclosures have shown that such rearing result in elevated growth rates in comparison to the Sacramento River, and may enhance survival. Analyses on the larger long-term dataset show that apparent growth rates varied from -0.09 to nearly 0.9 mm/day, while median residence times ranged from 12 to 66 days. In wet years, emigration from the floodplain occurs after peak seasonal flows have subsided and as stage descends from their highest January-March levels. This information will be particularly relevant for restoration projects planned for the Delta, and for the management of seasonal shallow water habitat to benefit native fishes.

Keywords: juvenile Chinook salmon, floodplain, Yolo Bypass, rearing habitat

Wednesday, October 17, 2012: Room 308-310, Yolo Bypass: Managed Floodplain as Seasonal Habitat for Fish– Order 4

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Parameterizing a System Optimization Model for Flood Extent, Location, and Timing on the Yolo Bypass

Robyn Suddeth*, UC Davis, rjsuddeth@ucdavis.edu

A comprehensive plan for fish habitat expansion in the Yolo Bypass and other managed floodplains requires analysis of a broad range of topics, including agricultural economics, waterfowl habitat, and hydrodynamics (both for fish habitat and to evaluate changes in flood carrying capacity). A balanced management approach for ecosystem services attempts to minimize economic costs to all human land/resource uses, while still satisfying habitat requirements. On the Yolo Bypass, this habitat requirement can take the form of acres flooded, residence time of water, depth, and/or a sum value that depends on type of land flooded, duration of flooding, accessibility for fish, and other relevant factors.

This presentation focuses specifically on the metrics developed to quantify important physical habitat and bioenergetic factors for fish and waterfowl success on the bypass, and their integration into an optimization model built to assess tradeoffs between these and other economic functions within the system. These metrics are being developed from various tools and concurrent efforts, including hydrodynamic models, expert surveys, and invertebrate (food base) studies.

The high-resolution hydrodynamic modeling capability and parameterized optimization model developed in this study will eventually represent a decision analysis tool to identify management alternatives that provide desired ecosystem services while maximizing economic returns to land owners in the Yolo Bypass. The methodology will be broadly applicable to similar floodplains with the potential for conjunctive use for human and ecosystem services.

Keywords: Yolo Bypass, systems optimization, salmon, splittail, waterfowl, agricultural economics, RMA

Wednesday, October 17, 2012: Room 308-310, Yolo Bypass: Managed Floodplain as Seasonal Habitat for Fish– Order 5

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Building a Landscape Perspective for Ecosystem Planning: Lessons from Historical Ecology

Alison Whipple, San Francisco Estuary Institute-Aquatic Science Center, alison@sfei.org
Robin Grossinger, San Francisco Estuary Institute-Aquatic Science Center, robin@sfei.org
Daniel Rankin, California Department of Fish and Game, drankin@dfg.ca.gov

Considerable effort is currently dedicated to planning large-scale restoration in the Delta that achieves a more functional ecosystem for native species. Developing a landscape perspective to help inform what restoration could look like requires an understanding of natural patterns and processes. Historical ecology research contributes to this important foundation. In the recently completed three-year Delta Historical Ecology Study, we synthesized numerous disparate historical sources (e.g., maps, textual accounts, photographs) using GIS and conceptual models to reconstruct the land cover types of the early 1800s Delta and to describe associated physical processes. We found complex habitat mosaics were arranged in distinct patterns across broad physical gradients. Substantial differences existed between the north, central, and south Delta landscapes, distinguished by characteristics such as relative proportion of habitat types, size and position of features, and hydrologic connectivity. In the central Delta, myriad sinuous tidal channels wove within a tidal wetland plain of freshwater emergent vegetation (predominantly tule) and willows. Northward along the Sacramento River, wide riparian forest bordered flood basins consisting of broad zones of tidal wetland transitioning into non-tidal wetland. In the south Delta along the San Joaquin River, a maze of active and abandoned channels were part of a floodplain characterized by locally-complex habitat patterns with riparian forest, patches of willow thicket, seasonal wetlands, and grassland intermixed with expanses of tule and perennial and intermittent ponds. Understanding such patterns and related processes is especially relevant in places like the Delta that have been profoundly altered. With limited land and resources today, successful ecological planning in the Delta will depend upon knowledge of what functional elements future landscapes can and should contain. Rather than a template to rebuild the past, historical ecology contributes valuable information concerning how different elements within the future Delta might best fit together to support ecosystem health.

Keywords: Delta, landscape, large-scale, historical ecology, habitat restoration, ecosystem, reconciliation

Wednesday, October 17, 2012: Room 308-310, The Once and Future Delta– Order 1

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Envisioning a Reconciled Delta Based on Empirical Data from Healthy Landscapes

Robin Grossinger, SFEI, robin@sfei.org
Letitia Grenier, consultant, letitia@letitia.org
Alison Whipple, SFEI, alison@sfei.org

The Delta Landscapes project contributes a needed dimension to Delta planning by providing a landscape-scale perspective on restoration opportunities and recommendations that is founded in a sound understanding of ecological functions provided by the Delta prior to substantial human modification. Using historical data indicates both how the Delta system tends to function in response to physical processes and the conditions to which native species are adapted. This information is critical to planning for a future Delta that is reconciled to support as much native biodiversity as possible with minimal management effort. This information is also important for establishing landscape units with sufficient scale, diversity, and connectivity along physical gradients to adapt to future changes. Detailed, spatially explicit early 1800s habitat information from the Delta Historical Ecology Study is being examined through a lens of key ecological functions that supported Delta wildlife historically. With a team of experts in ecology and physical process, we are interpreting the historical Delta landscapes to define these with quantifiable metrics that represent different suites of functions provided by the different physical settings within the larger Delta. Conceptual models and other planning tools will demonstrate how the functions and metrics are related. These models can then be applied to the current Delta to identify areas where similar functions might be restored and maintained over time. Landscapes will not necessarily be reestablished in the same places or at the same scale as they were historically, but with similar metrics such that functionality is regained. The approach of drawing key functions and metrics from the historical landscape – and then applying those to contemporary and future conditions through landscape-scale conceptual models – can help maximize the value of contemporary restoration, beginning to reconcile the past with the future.

Keywords: ecological functions, historical ecology, landscape, Delta, physical gradients, restoration

Wednesday, October 17, 2012: Room 308-310, The Once and Future Delta– Order 2

ED_000733_DD_NSF_00015174-00113

The Pre-Export Delta: How Flow and Water Quality Changed Over the Last 60 years

William Fleenor, UC Davis, wefleenor@ucdavis.edu
Laura Doyle, UC Davis, ladoyle@ucdavis.edu

While many changes had already occurred within the Delta by 1950, the ecosystem was still supporting fisheries. Many more changes have occurred since federal pumping started in 1951 and state pumping in 1968. Physical bathymetry changes include deepening of the Stockton Deep water Ship Channel and the creation of the Sacramento Deep Water Ship Channel. Suisun Marsh Gates were installed to help keep the Suisun Marsh area fresh, and the Delta Cross Channel and gates were installed to facilitate moving fresh water south through the Delta to the export pumps. Temporary agricultural barriers have been seasonally installed in the south Delta to control water quality and water levels, and the fish barrier at the head of old river is seasonally installed to encourage a more successful path for salmon out-migration. Other more natural changes have also occurred including the permanent flooding of Little Franks Tract, Liberty, Mildred and Little Sherman Islands. The current Delta network bathymetry has been changed to represent the best understanding of the 1950 Delta. A modeling study examined the changes in flow and water quality from pre- to post-exports. The results provide some insights to why pre-export conditions, while significantly modified from natural conditions, still provided better ecological conditions than today's operations.

Keywords: modeling, pre-exports, historical changes

Wednesday, October 17, 2012: Room 308-310, The Once and Future Delta– Order 3

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Managing a Reconciled Future Delta Ecosystem

Jeffrey Mount, UC Davis, mount@geology.ucdavis.edu
Peter Moyle, UC Davis, pbmoyle@ucdavis.edu
William Bennett, UC Davis, wabennett@ucdavis.edu
John Durand, UC Davis, jdurand@ucdavis.edu
William Fleenor, UC Davis, wefleenor@ucdavis.edu
Brian Gray, UC Hastings College of the Law, graybe@me.com
Ellen Hanak, Public Policy Institute of California, hanak@ppic.org
Jay Lund, UC Davis, jrlund@ucdavis.edu

The Delta presents a major challenge for water resource and ecosystem management due to its novel characteristics. In our publication *Where the Wild Things Aren't: Making the Delta a Better Place for Native Species*, we propose a reconciliation approach that addresses the multiple stressors impacting the Delta. Management guided by reconciliation ecology involves acknowledging and adapting to ecosystem change, rather than just attempting to reverse it. It includes improving conditions for native species, while recognizing that the Delta is irrevocably altered and managed to support multiple human goals. Managing a reconciled Delta will require the following: 1) Recognition that natural processes place limits on all water and land management goals. Not all habitats can be created everywhere and not all water resource demands can be met all the time. 2) Different parts of the Delta should be specialized for different functions. An arc of connected habitat should link Suisun Marsh to the northwestern Delta. Conversely, non-tidal marsh and riparian habitat should be created in the south Delta. Riparian and seasonal floodplain habitat is most appropriate for the eastern and northeastern Delta. Deep-water estuarine lakes are best for the deeply-subsided portions of the central and western Delta. 3) Levees, channels and flow management are essential tools that can improve conditions in vital habitats while steering native species away from bad conditions. 4) Acknowledge the fact that it will take decades to achieve biological goals and objectives, and that some may prove impossible to achieve, requiring course corrections. 5) All efforts should be based on an integrated, rather than coordinated, scientific and adaptive management program that does not over-negotiate the details up front and provides flexibility for future action. There is one certainty in the uncertainty of managing the Delta: there will be surprises.

Keywords: Reconciliation, ecosystem management, restoration, flow management

Wednesday, October 17, 2012: Room 308-310, The Once and Future Delta– Order 4

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2011 Georgiana Slough Non-Physical Fish Barrier

Ryan Reeves, CA Department of Water Resources, rreeves@water.ca.gov
Jacob McQuirk, CA Department of Water Resources, jacobmc@water.ca.gov

A non-physical fish barrier, called the Bio-Acoustic Fish Fence™ (BAFF, Fish Guidance Systems; Southamton, UK), was evaluated in 2011.The approximately 650 foot long BAFF was deployed in the Sacramento River just upstream of the divergence of Georgiana Slough. Acoustic telemetry was used to estimate BAFF deterrence and overall efficiency for 1,500 Chinook salmon smolts implanted with Hydroacoustic Technology, Inc. (Seattle, WA) acoustic tags. Deterrence efficiency, the percentage of fish that showed greater than a 25 degree turn away from the BAFF, was 50.4% with the BAFF on and 28.5% with BAFF off. This improvement of 21.9% deterrence translated into improved overall efficiency, the percentage of Chinook smolts continuing passed the divergence in the Sacramento River, with overall efficiency equal to 90.8% with the BAFF on compared to 73.4% with the BAFF off. Statistical analyses showed these differences, both deterrence and overall efficiency, were significant. And, the statistically significant differences between BAFF on and BAFF off occurred under low and high light conditions as well as under low and high across barrier velocities. A Generalized Linear Model analysis showed the two most important predictors of a Chinook remaining in the Sacramento were cross-stream position and BAFF on or off. The predation rate on Chinook smolts in the area of the BAFF was 3.7%.

Keywords: Sacramento River, barrier, Chinook, salmon, hydroacoustic, biotelemetry

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 1

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Effectiveness of a Non-Physical Barrier on Route Entrainment of Migrating Juvenile Salmonids in the Sacramento-San Joaquin River Delta

Russel Perry, USGS, WFRC, Columbia River Research Laboratory, rperry@usgs.gov
Jason Romine, USGS, WFRC, Columbia River Research Laboratory, jromine@usgs.gov
Noah Adams, USGS, WFRC, Columbia River Research Laboratory, nadams@usgs.gov
Aaron Blake, USGS, California Water Science Center, ablake@usgs.gov
Mark Bowen, AECOM, Mark.D.Bowen@aecom.com
Jon Burau, USGS, California Water Science Center, jburau@usgs.gov
Sam Johnston, Hydroacoustic Technologies Inc., sjohnston@htisonar.com
Theresa Liedtke, USGS, WFRC, Columbia River Research Laboratory, tliedtke@usgs.gov

The interior of the Sacramento-San Joaquin River Delta is a location of high mortality for out-migrating ESA listed juvenile salmonids, relative to alternative migration routes. Reducing entrainment to the interior delta is one approach to increasing juvenile salmonid survival. In the spring of 2011, a non-physical barrier (Bio-Acoustic-Fish-Fence or BAFF) was placed at the confluence of the Sacramento River and Georgiana Slough in an effort to deter smolts from entering Georgiana Slough and passing into the interior delta. The BAFF uses a combination of intermittent light, a bubble curtain, and modulated sound to deter fishes. Concurrently, 1,500 smolts were acoustically tagged and passively telemetered to determine the effectiveness of the BAFF at reducing entrainment into Georgiana Slough. Overall, 7.7% of the fish were entrained into Georgiana Slough when the BAFF was on, and 22.3% were entrained when the BAFF was off, but a number of other factors influenced performance of the BAFF. The effectiveness of the BAFF declined with increasing river discharge, likely because increased water velocities reduced the ability of fish to avoid being swept across the BAFF into Georgiana Slough. The BAFF reduced entrainment probability by up to 40 percentage points near the critical streakline which defines the streamwise division of flow vectors entering each channel. However, the effect of the BAFF declined moving in either direction away from the critical streakline. Our study shows how acoustic telemetry provided novel insights about how behavior and the environment interacted to influence the performance of a non-physical behavioral barrier in an applied setting.

Keywords: acoustic telemetry, salmon, non-physical barrier, migration, strobe lights, bubble-curtain, sound

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 2

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Advantages of a Shuttle Box System in Capturing Behavior of the Endangered Delta Smelt

Michael Park, VM: APCB, One Shields Ave. University of California Davis, mopark@ucdavis.edu
Joan Lindberg, Fish Conservation and Culture Lab, UC Davis, lindberg@steeper.us
Swee Teh, VM: APCB, One Shields Ave. University of California Davis, sjteh@ucdavis.edu

Recent evidence has demonstrated that physical habitat parameters, especially water clarity, temperature, and salinity, are strong determinates of delta smelt distribution within the Sacramento-San Joaquin Estuary. To gain a better understanding of the smelts' movement patterns within the estuary, we explored the use of an electronic shuttle box system (LoligoSystems©) which allows for continuous recording and control of environmental variables and simultaneous tracking of their movement and position. Our previous behavior trials tested delta smelt under static conditions (unpublished data) but, as tested, these trails were less productive. By using the shuttle box system, individuals are able to behaviorally modulate their exposure to different levels of an environmental variable (e.g. water clarity, temperature, and salinity). Preliminary analysis of delta smelt temperature trials in the shuttle box system indicates that significant differences can be distinguished, in terms of residence time, between acclimation (13°C±1) temperature and final temperature (18°C ±1)through the use of this dynamic system. Understanding the delta smelts volitional movements in a dynamically changing laboratory setting improves the ability to understand and interpret field data. In order to develop strong management tools for delta smelt conservation and recovery, it is critical to understand the environmental parameter levels that are beneficial to the animal, and the tipping point(s), or boundary conditions, where parameters are negative, and the subjects choose, repeatedly, to move out of that environment.

Keywords: shuttle box, temperature, delta smelt, behavior, endangered, conservation management

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 3

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Comparison of Effective Population Sizes for the Two Splittail Populations in the San Francisco Estuary

Brian Mahardja*, University of California - Davis, Genomic Variation Laboratory, Department of Animal Science, bmahardja@ucdavis.edu
Bernie May, University of California - Davis, Genomic Variation Laboratory, Department of Animal Science, bpmay@ucdavis.edu
Frederick Feyrer, U.S. Bureau of Reclamation, ffeyrer@usbr.gov
Melinda Baerwald, University of California - Davis, Genomic Variation Laboratory, Department of Animal Science, mrbaerwald@ucdavis.edu

Splittail (*Pogonichthys macrolepidotus*) is a fish species of special concern endemic to the San Francisco Estuary. Although a number of studies on the life history and habitat use of splittail have been conducted, a majority assumed that the species is composed of a single panmictic population. Therefore, the discovery of two genetically distinct splittail populations (one spawning in the Central Valley and another in the Napa and Petaluma rivers) indicates that our understanding of the species' ecology is incomplete. As part of an overarching interdisciplinary study to better understand the species' population dynamics, we have identified new genetic markers and estimated the effective population size (Ne) of the two discrete populations. Effective population size provides crucial information for conservation and wildlife management to predict the persistence of populations. We present our results obtained through the use of over thirteen microsatellite markers genotyped from age-0 splittail of multiple year-class (2002-03, 2011) collected from several known major spawning grounds. Furthermore, we also report on the discovery of 24 novel microsatellite loci which cross-amplified and were polymorphic for at least one of five additional California cyprinid species (*Ptychocheilus grandis*, *Siphateles bicolor*, *Lavinia exilicauda*, *Orthodon microlepidotus* & *Mylopharodon conocephalus*).

Keywords: *Pogonichthys macrolepidotus*, effective population size, cyprinidae, microsatellite

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 4

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Toxicity of Selenium to White and Green Sturgeon

William Beckon, U.S. Fish and Wildlife Service, William_Beckon@fws.gov

Fish of the genus *Acipenser* (sturgeon) are likely to be among the most vulnerable to selenium exposure in the San Francisco Estuary because these fish feed predominantly on benthic invertebrates, including the Asian clam, *Corbula amurensis*. This clam is an efficient bioaccumulator of selenium. The best data available for the most sensitive endpoint for sturgeon come from studies in which the survival of larvae was monitored following micro-injection of organic selenium (L-selenomethionine) into the yolk sacs of newly hatched larvae. Benchmark larval selenium concentrations from these studies were translated, by means of regressions, to selenium concentrations in the tissue and diet of adult white and green sturgeon. This analysis indicates that white and green sturgeon are among the most sensitive of fish to adverse effects of selenium, with the listed green sturgeon being the more sensitive of these two species. These levels of sensitivity evidently put sturgeon at substantial risk at current levels of exposure in the San Francisco Bay area. Selenium concentrations in food items of sturgeon in the San Francisco Bay area are almost always high enough that they may cause at least 10 percent mortality in hatchling green sturgeon (≥3.58 μg/g), and they are frequently high enough that they may cause at least 10 percent mortality among hatchling white sturgeon (≥10.8 μg/g) as well.

Keywords: sturgeon, selenium, toxicity, sensitivity, criteria

Wednesday, October 17, 2012: Room 311-313, Fish Biology (I) – Order 5

ED_000733_DD_NSF_00015174-00120

Comparative Acoustic Tag Detections at Control Sites versus Artificial Reefs Sites in the San Francisco Estuary

Robert Abbott, Environ International, rabbott@environcorp.com
Rena Obernolte, Isla Arena Consulting, obernolte@comcast.net
Ken Schwab, UC Berkeley, ken.schwab@berkeley.edu

Vemco VR2W (69kHz) receivers installed at two reef sites in San Francisco Bay detected Chinook salmon, striped bass, white & green sturgeon, 7-gill shark, and steelhead. Sites include locations on both sides of SF Bay; Marin Rod and Gun Club to the west and Berkeley to the east. Analysis of data collected from January 2009 through May 2012 for the number of detections, duration of unique visits, and repeated visits clearly shows that fish are detected more often and stay longer at the artificial reef sites than featureless mudflats which are characteristic of the control sites. At the Berkeley site the pattern of detections suggest primarily striped bass, sturgeon, and 7-gill sharks. The pattern of striped bass detections suggest a long period of time at the reef site, then leave for extended periods, and then return again indicating a territorial range for some individuals. The detection patterns at the Marin Rod and Gun Club suggest extensive utilization by salmonids due to the repeated detections at multiple receivers over an extended period of time. Notably both adult salmon and steelhead gilts were detected at the MRGC site.

* striped bass - DWR funding, pm Cynthia LeDoux-Bloom

Keywords: acoustic, biotelemetry, salmon, artificial reefs, sturgeon, striped bass, vemco

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 6

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Population Dynamics and Predation Impacts of Three Invasive Hydrozoan Jellyfish in the Upper San Francisco Estuary

Jessica Donald*, SFSU, RTC, jdonald@mail.sfsu.edu
Lindsay Sullivan, SFSU, RTC, ljswr@sfsu.edu
Wim Kimmerer, SFSU, RTC, kimmerer@sfsu.edu

The wide temperature and salinity ranges of three introduced hydromedusae (*Blackfordia virginica, Maeotias marginata*, and *Moerisia lyonsi*) spatially and temporally overlap with several protected fish species in the San Francisco Estuary (SFE), including delta smelt and longfin smelt. In addition, the zooplankton diets of these hydromedusae overlap with those of protected fish, resulting in the potential for competition. Here we report the distribution, abundance, and feeding ratesof hydromedusae within four brackish-water tributaries of the SFE (Petaluma River, Napa River, Suisun Slough, and Montezuma Slough) during 2010 and 2011. Medusae and their prey were sampled weekly and environmental variables were recorded. Their distributions were similar to that reported in the literature with *B. virginica* and *M. lyonsi* found at all four sites and *M. marginata* found in the sloughs. All three species were found at similar temperatures (19–22°C), but *B. virginica* and *M. lyonsi* occurred at higher salinities (16–19) than *M. marginata* (2–4). Abundances of *B. viriginica* were higher than previously reported, and abundances of *M. lyonsi* and *M. marginata* were within the range previously reported. Feeding rates of *B. virginica* were measured in laboratory incubations with natural prey. Feeding rates ranged from 2 to 12 liters cleared of prey per medusa per day. Using clearance rates from laboratory experiments, at the maximum abundance of *B. virginica* in the Napa River, the calculated predation impact on adult *Acartia* sp. (calanoid copepod) was 150% per day, much higher than typical prey population growth rates. Thus, *B. virginica* may suppress prey populations. The high clearance rate of *B. virginica* combined with the spatial and temporal overlap with protected fish suggests a strong potential for competition. Monitoring hydromedusae is necessary to predict potential negative impacts on vulnerable fish populations in both the tributaries and the open bay of the SFE.

Keywords: Hydromedusa, *B. virginica*, San Francisco Estuary, Predation Impacts, Distribution

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 7

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Feeding of Adult Delta Smelt During Their Yearly Spawning Migration into the Upper San Francisco Estuary

Aaron Johnson*, Romberg Tiburon Center, SFSU, aarondavidjohnson@yahoo.com
Wim Kimmerer, Romberg Tiburon Center, SFSU, kimmerer@sfsu.edu
Jon Burau, California Water Science Center, USGS, jrburau@usgs.gov
Bill Bennett, Center for Watershed Sciences & Bodega Marine Laboratory, UC Davis, wabennett@ucdavis.edu

Since their protection under California State and Federal Endangered Species Acts, delta smelt have become a major focus of environmental and water management in the San Francisco Estuary. As a result, numerous studies have been conducted to fill gaps in knowledge about delta smelt life history, habitat requirements, and factors limiting abundance. The Delta Smelt Turbidity Study was designed to provide critically needed information about the annual spawning migration of delta smelt into the upper estuary. Goals of the ongoing study include determination of the extent of prey selectivity in migrating delta smelt, and assessment of diet variability at the adult life stage. To address these goals, zooplankton were sampled concurrently with hourly fish sampling over a full tidal cycle every day from December 21, 2010 to January 1, 2011. Gut samples from a selection of delta smelt collected during sampling were analyzed to compare prey availability to prey ingested. Previous studies of the diet of juvenile delta smelt have emphasized pelagic invertebrates, specifically calanoid copepods as their main food source, whereas the most frequent prey organisms ingested by delta smelt sampled during this study were cladocerans and epibenthic amphipods. Comparison of zooplankton samples to gut samples suggests delta smelt selected for amphipods, although abundance of amphipods is not well characterized by sampling with plankton nets. If further sampling and analysis confirms this finding, it implies a very different foraging strategy and perhaps a different foraging habitat for adult delta smelt than for juveniles. Information of this kind is critical to understanding adult delta smelt foraging behavior and identifying foraging habitats. This information will also be useful in constructing and refining life-cycle models of delta smelt. With refinement, these models may help devise and evaluate management strategies to reduce delta smelt mortality and restore delta smelt habitat in the estuary.

Keywords: delta smelt, migration, diet selectivity, feeding habitat

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 8

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Persistence of Delta Smelt DNA in the Gut of Mississippi Silversides and Other Preliminary Experiments for Detecting Prey in Non-Native Fish Stomachs Using Real-Time PCR

Scott Brandl*, UC Davis, scbrandl@ucdavis.edu
Brian Schreier, DWR, bschreie@water.ca.gov
Louise Conrad, DWR, jlconrad@water.ca.gov
Melinda Baerwald, UC Davis, mrbaerwald@ucdavis.edu

The Bay-Delta Conservation Plan has identified predation by non-native piscivores as a major stressor to threatened native fish in the delta. Our primary objective is to investigate the frequency of predation by non-native bass and the native Sacramento pikeminnow on larval and sub-adult threatened and endangered species using quantitative PCR. The data on incidence of predation will be used to identify locations non-native piscivores prey heavily on at-risk species. With this data habitat restoration efforts can focus on areas that minimize danger to at-risk species.

Genetic gut content analysis offers two notable advantages over visual gut contents studies. The sensitivity of the method allows us to identify prey species for a longer time post-ingestion and species composed of soft tissue, namely larval fish, can be identified. Our current objective is to characterize the genetic assay and optimize the methods to be used in the primary study. We conducted a series of preliminary experiments in which we fed delta smelt larvae to Mississippi silverside and striped bass in a controlled environment. Three questions were addressed during these experiments: How long is DNA of a prey fish detectable in the stomach of a predator? Can we detect multiple prey of a given species in a stomach using microsatellite DNA? Lastly, what method of preservation keeps the most usable DNA intact during field sampling?

DNA barcoding and qPCR will be introduced and the results from our preliminary experiments will be discussed.

Keywords: predation, qPCR, delta smelt, silverside, chinook salmon bass, genetics

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 9

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Food Web Relationships for Delta and Longfin Smelt

Bryan Manly, West, Inc., BManly@West-inc.com
BJ Miller, San Luis & Delta-Mendota Water Authority, bjmiller41@gmail.com
Tom Mongan, San Luis & Delta-Mendota Water Authority, tmongan@gmail.com
Phyllis Fox, Environmental Consultant, phyllisfox@gmail.com
David Fullerton, Metropolitan Water District of Southern California, dfullerton@mwdh2o.com
Alison Britton, San Luis & Delta-Mendota Water Authority, ASBritton@aol.com

Several analyses have identified zooplankton prey density as an important factor affecting the abundance of longfin and Delta smelt in the San Francisco Estuary. We analyzed numerous factors that influence zooplankton abundance in an attempt to develop statistical correlations that link these factors to each other and to zooplankton densities in different parts of the estuary. We compared our results to those from more complex food web mathematical models. Our analyses produced statistically significant but relatively weak relationships between zooplankton densities and the densities of certain classes of phytoplankton. We confirmed the strong relationships between the densities of certain classes of phytoplankton and filtration rates of the clam, *Potamocorbula amurensis*. We found relationships between phytoplankton densities and concentrations of ammonium and between concentrations of ammonium and densities of zooplankton. We found evidence that ammonium concentrations are linked to inflow to the Delta, with inflow providing the dilution of ammonium loadings from wastewater treatment plants.

Keywords: food web, delta smelt, longfin smelt, zooplankton, phytoplankton, nutrients

Wednesday, October 17, 2012: Room 311-313, Fish Biology (II) – Order 10

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Habitat Affinity Analysis as a Tool to Guide Environmental Restoration for Delta Smelt

Scott Hamilton, Center for California Water Policy and Management, shamilton@calwatercenter.org
Dennis Murphy, University of Nevada, Reno, ddmurphy@biodiversity.unr.edu

Habitat restoration efforts in the Sacramento-San Joaquin Delta in central California move forward under the state's ambitious Bay Delta Conservation Planning process, despite a paucity of information on the habitat needs of many of the plan's targeted species. The endemic delta smelt, protected as threatened under the federal Endangered Species Act, is a primary focus of those efforts despite key uncertainties regarding many aspects of its relationship with the estuary's physical and biotic resources. Here we carry out habitat affinity analysis for multiple life stages of the delta smelt drawn from time-series data from four trawl surveys, and data on environmental attributes taken from throughout the distribution of the fish. Ranges of conditions acceptable to delta smelt for each of seven environmental attributes were identified. Low turbidity and high water temperatures render a large portion of the estuary seasonally unacceptable to delta smelt. Within areas that experience largely acceptable water quality conditions, patterns of delta smelt occurrences indicate that habitat occurs where deep channels adjoin shallow-water circumstances and extensive patches of emergent vegetation. Habitat suitability indices show that favored environmental circumstances vary with life stages, and delta smelt move as they mature to access suitable areas with environmental attributes in acceptable ranges. Areas that exhibit highest geometrically weighted average HSI values for environmental attributes are displayed on maps, and can be viewed as representing potential priority target areas for habitat restoration efforts. Delta smelt should benefit in priority target areas with channel modification and directed wetlands restoration efforts.

Keywords: delta smelt, affinity analysis, habitat suitability index

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 11

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The Pelagic Organism Decline and the Game of Clue

BJ Miller, San Luis & Delta-Mendota Water Authority, bjmiller41@gmail.com

Several hypotheses have been advanced to explain the sharp decline in abundance of four pelagic fish in the San Francisco estuary early this century. This study examined the hypothesis that because the declines exhibited by those species were initiated within a year or two of each other, they were caused by a common environmental stressor, or by a very few such factors. Many other fish species that co-occur in the same waters showed no similar declines and, in some cases, showed sharp increases in abundance, suggesting that the factor(s) acting on the four pelagic fishes did not act on the others. In this study the search for common and uncommon stressor factors was restricted to environmental factors that exhibit direct effects on reproduction and survival. Data was assembled on each of specifics (for example, specific zooplankton species preyed upon) of these factors for each of the four pelagic fishes and for species of fish that did not exhibit a sharp decline in abundance early this century. The search for common factors proceeded much like the game of *Clue*, in which a succession of clues combine to reveal the identity of the murderer, the location of the crime, and the weapon. Among those candidate environmental factors acting on fish in the San Francisco Estuary, the availability of select zooplankton (prey density) is the most likely common factor that explains the pelagic organism decline; predation on fishes and turbidity are other candidates. If confirmed by more rigorous, quantitative analyses, management actions to reverse declines in the abundances of the four pelagic fish can be better focused and are more likely to succeed.

Keywords: food web, pelagic fish, environmental stressors

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The Spatial and Temporal Distribution of Delta and Longfin Smelt

Lloyd Fryer, Consultant, State Federal Water Contractors Association, lfryer@l-squared.com
David Fullerton, Metropolitan Water District of Southern California, dfullerton@mwdh2o.com
BJ Miller, Consultant, San Luis & Delta-Mendota Water Authority, bjmiller41@gmail.com

These two species of fish are of major concern in the San Francisco Estuary. Their distribution affects their susceptibility to entrainment, their co-occurrence with important prey species, and other important attributes of their habitat. We evaluated data from routine surveys that sample for these fish. We attempted to correct catch data for gear efficiency and to eliminate sources of bias that could be quantified. We considered changes in bathymetry and, therefore, water volume, over time in different parts of the estuary. Using corrected catch and water volume data, we estimated the fraction of each species in different parts of the estuary for each survey over the last several decades with respect to both fish density and abundance. We compared these distributions with seasonal values of X2, the distance of the 2 ppt isohaline from the Golden Gate Bridge, to test the importance of X2 as a factor affecting distribution. We also compared distributions with turbidity and investigated several other factors that might influence distribution. We conclude that that longfin smelt are never found in significant percentages near the export pumps, that delta smelt move short distances toward fresh water sources when estuary waters become turbid in the early winter, rather than making an upstream migration run, and that effects of winter or spring X2 on the distribution of delta and longfin smelt are questionable. Previous analyses have reported relationships between X2 and distributions of delta and longfin smelt, although these analyses have not covered the currently known range of the fishes or evaluated mechanisms behind the relationship. The understanding of the relationship between X2 and the fishes' distribution is evolving, which will affect the possible management actions that could be taken, helping to identify effective and efficient options from an ecological perspective.

Keywords: delta smelt, longfin smelt, X2, distribution, migration

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 13

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FLaSH: Multivariate Analyses of Delta Smelt Health Indices in the Upper San Francisco Bay Delta Estuary

Alireza Javidmehr*, Aquatic Health Program, UC Davis, ajavidmehr@ucdavis.edu
Shawn Acuña, Aquatic Health Program, UC Davis, scacuna@ucdavis.edu
Dolores Baxa, Aquatic Health Program, UC Davis, dvbaxa@ucdavis.edu
Saikrithika Gandhi, Aquatic Health Program, UC Davis, saikrithi@gmail.com
James Hobbs, Wildlife and Fisheries Conservation Biology, UC Davis, jahobbs@ucdavis.edu
Tomofumi Kurobe, Aquatic Health Program, UC Davis, tkurobe@ucdavis.edu
Michael Park, Aquatic Health Program, UC Davis, mopark@ucdavis.edu
Swee Teh*, Aquatic Health Program, UC Davis, sjteh@ucdavis.edu

The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with the California Department of Fish and Game (CDFG), researchers from state, federal agencies and the University of California set out to investigate the impacts of increased freshwater outflow in the fall of 2011 on delta smelt. Samples were collected from CDFG long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl *during fall 2011 to spring 2012.*This study used a novel epidemiological approach to identify patterns and potential causative factors affecting delta smelt health in the upper San Francisco Estuary. Due to confounding variables, univariate analyses did not show any clear trends or causative effects among measured health indices and recorded water quality parameters. Multivariate analyses such as canonical and multiple linear regression methods were utilized to assess several potential predictors such as salinity, temperature and turbidity, simultaneously. *Over 700 delta smelt fish were used to model the presence of any causative relationship while controlling for confounding effects. The multivariate analysis revealed a significant causative correlation between multiple biomarkers and water quality parameters of salinity, temperature and turbidity. This study is still ongoing and additional years of analysis will enhance the precision of the method.*

Relevance: This study demonstrates multivariate analysis as a novel managerial tool for environmental studies of delta smelt. Researchers can apply this analytical tool to evaluate multiple independent predictor variables while alleviating bias from measured confounders.

Keywords: Delta smelt, modeling, habitat

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 14

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Revisiting Longfin Smelt Population Dynamics in the San Francisco Estuary

Jonathan Rosenfield, The Bay Institute, rosenfield@bay.org
Matthew Nobriga, United States Fish and Wildlife Service, Matt_Nobriga@fws.gov
Igor Lacan, The Bay Institute, ilacan@cal.berkeley.edu

The San Francisco Estuary population of Longfin smelt (LFS), *Spirinchus thaleichthys,* has declined precipitously, with current abundance estimated at 3-4 orders of magnitude lower than in recent decades. Although a significant long term correlation has long been reported between LFS recruitment and Delta outflow or its covariates, other covariates reflecting a changing food web – changes in exotic clam distribution, plankton composition, and dissolved ammonium – have been suggested as potentially important, and previous studies have not included LFS stock-recruit relationships (SRR) in their regression models.

This study first examined how Delta outflows were correlated with inter-generational LFS population change (using Fall Midwater Trawl data; FMWT), and what levels of outflow related to LFS population growth. Then we developed an alternate version of the model that could be applied to time series of Delta outflow. This alternative model explicitly accounted for the influence of spawning stock, including density dependence that appears to have historically influenced longfin smelt abundance in years when Delta outflow was low. We used this model to evaluate what effect the eight decades of changes to Delta outflow alone may have had on LFS.
We found that SRR (sum of the two-prior-years FMWT) combined with estimates of spring Delta outflow was most successful in removing the time trend in regression residuals, enabling us to isolate the effect of flow. SRR was nonlinearly related to spring Delta outflow because of density dependence, and inter-generational population growth was observed only when spring Delta outflow exceeded 1259 m3/s.

Our study is directly relevant to management of the imperiled LFS population, as it demonstrates the importance of Delta outflow, its interaction with SRR, and the potential for density dependence at low flow conditions. The results of this study also point to the value of long-term population monitoring (the FMWT dataset).

Keywords: *Spirinchus thaleichthys*; Delta outflow; water exports; stock-recruit; density dependence, longfin.

Wednesday, October 17, 2012: Room 311-313, Fish Biology (III) – Order 15

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Saving San Francisco Bay-Delta Native Fishes: Hatchery Management and Reintroduction Strategy Modeling

Kathleen Fisch, San Diego Zoo Global, kfisch@sandiegozoo.org
Jamie Ivy, San Diego Zoo Global, jivy@sandiegozoo.org
Oliver Ryder, San Diego Zoo Institute for Conservation Research, oryder@sandiegozoo.org
Robin Waples, Northwest Fisheries Science Center, NOAA, robin.waples@noaa.gov

Native fishes in the San Francisco Bay-Delta and Central Valley have recently seen a drastic decline in abundance, resulting in an increasing need to bring these fish into conservation hatcheries to prevent their extinction. A number of mandated hatchery-related projects exist in the Central Valley as part of NOAA Fisheries and US Fish and Wildlife Biological Opinions. Current and proposed hatchery operations make it imperative that we study appropriate genetic management, as planning for hatchery genetic management is necessary to determine the best management strategies that account for possible reintroductions and dynamics between hatchery and wildfish populations. Ideally, fish hatcheries would be managed to promote the long-term genetic and demographic viability of their populations, but genetic management is often lacking due to logistical constraints. Many captive fish populations accumulate detrimental genetic changes that decrease the genetic integrity of wild populations when their stocks are used for reintroduction. To improve fish hatchery management and reintroduction success, this study evaluates three methods of incorporating molecular data into hatchery management plans and their utility in preserving the genetic integrity of wild supplemented populations in the context of hatchery activities in the San Francisco Bay-Delta and Central Valley. Methods of molecular data incorporation include pedigree reconstruction and molecular relatedness estimation. Individual-based demogenetic simulations are used to model hatchery genetic management strategies for four proposed hatchery species and three species currently captively-bred in the San Francisco Bay-Delta. As hatchery genetic management is a relatively contemporary idea, in addition to improving the logistics of hatchery genetic management, this study aims to establish a new culture of hatchery management, which should incorporate considerations of the genetic health of both captive and wild populations in the San Francisco Bay-Delta.

Keywords: Fish hatcheries, modeling, individual-based model, simulations, genetic management, pedigree reconstruction

Wednesday, October 17, 2012: Room 311-313, Genetics – Order 1

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Genetic Analysis of Natural and Hatchery Origin Steelhead in the Central Valley Reveals Population Structure and Odavdarigins

John Carlos Garza, NOAA Southwest Fisheries Science Center/University of California Santa Cruz, carlos.garza@noaa.gov
Devon Pearse, NOAA Southwest Fisheries Science Center/University of California Santa Cruz, devon.pearse@noaa.gov

Steelhead (*Oncorhynchus mykiss*) that spawn in the Sacramento, San Joaquin and their tributary rivers form the Central Valley Steelhead Distinct Population Segment (DPS), which is listed as threatened under the US and California Endangered Species Acts. There are four hatchery programs in the basin that produce steelhead, and two of the associated stocks, Nimbus and Mokelumne River, are excluded from the DPS, due to a past practice of using broodstock imported from other basins. We use a combination of different genetic markers and analytical techniques to elucidate the population structure and origins for Central Valley steelhead. We present data for 112 genes, a combination of single nucleotide polymorphism (SNP) and microsatellite markers, collected from almost all of the numerically significant populations of steelhead below barrier dams, as well as from many populations of resident trout above barrier dams. We describe analyses that help to understand both historical and present migration between populations and to define the genetic impacts of releases of both hatchery steelhead and rainbow trout in the Central Valley. The use of data from other steelhead DPSs in California further helps to unravel the effects of recent events from the long-term history of Central Valley steelhead. Additionally, analyses of approximately 4,000 adult returns to the four hatchery programs were analyzed with 95 SNP markers and the data used to understand migration between them and potential levels of inbreeding in hatchery mating. These genotypes serve as intergenerational genetic tags that form the basis for future ecological investigation of steelhead in the Delta, including evaluation of stock-specific rates of migration and their underlying genetic mechanisms.

Keywords: Steelhead, genetics, single nucleotide polymorphisms, hatcheries, genetic stock identification

Wednesday, October 17, 2012: Room 311-313, Genetics– Order 2

ED_000733_DD_NSF_00015174-00132

Estimates of Hatchery Contribution to California's Central Valley Chinook Salmon Populations: Results of 2010 and 2011 Coded-Wire Tag Recovery Data

Brett Kormos, CA Dept Fish and Game, bkormos@dfg.ca.gov
Melodie Palmer Zwahlen, CA Dept Fish and Game, mpalmer@dfg.ca.gov
Alice Low, CA Dept of Fish and Game, alow@dfg.ca.gov

Annually, over 32 million fall-run Chinook salmon are produced at five hatcheries in California's Central Valley (CV). Production from these hatcheries contributes to a major ocean and inland fisheries and annual escapement. Until 2007, releases of fall-run Chinook were not marked and coded-wire tagged with consistency. Beginning with brood year 2006, a minimum 25% of production releases of fall-run Chinook have been adipose fin clipped and coded-wire tagged in the Central Valley Constant Fractional Marking Program (CFM). This program is a cooperative effort of the California Department of Fish and Game, Department of Water Resources, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, East Bay Municipal Utility District, and Pacific States Marine Fisheries Commission. The remaining Merced Hatchery fall-run, Coleman Hatchery late-fall, and Feather River Hatchery spring-run Chinook are 100% marked and tagged. Coded-wire tags are recovered from adult fish in ocean and inland fisheries and inland escapement. 2010 and 2011 are the first years that the majority of fall-run Chinook recovered in harvest and escapement were marked and tagged at a minimum 25% rate. Brood years 2006-2009 were represented by age two, three, and four Chinook recovered in 2010 and 2011.

This work evaluates the 2010 and 2011 CV fall, late-fall, and spring-run Chinook coded-wire tag recovery data. Estimates of hatchery and natural proportions in escapement to the CV are reported in addition to estimates of hatchery contribution to ocean harvest. Stray and recovery rates as they pertain to release strategy are also reported.

Results of the CFM program, along with aging work will provide the best opportunity to manage CV Chinook based on scientifically defensible data. Age-specific rates of ocean harvest, maturation, survival, and straying can be calculated. Such analyses may provide the basis for changing hatchery practices, release strategies, and improving fisheries management.

Keywords: Chinook salmon, coded-wire tag, marking, hatcheries, fisheries management, salmon escapement

Wednesday, October 17, 2012: Room 311-313, Genetics– Order 3

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Application of Genetic Methods to Salvaged Winter-Run Chinook Salmon

Scott Blankenship, University of California, Davis; Cramer Fish Sciences, GENIDAQS, szscottb@ucdavis.edu
Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Gregg Schumer, University of California, Davis; Cramer Fish Sciences, GENIDAQS, greggs@fishsciences.net
Kevin Reece, California Department of Water Resources, creece@water.ca.gov

Current monitoring methods at the South Delta export fish salvage facilities are insufficient for detecting and estimating loss of Endangered Species Act (ESA) listed salmonids. Current salvage monitoring is incapable of determining stock (race, tributary of origin) specific mortality, with long-term genetic information suggesting approximately 40% of the winter-run juveniles identified using length-date criteria are not actually winter run in origin. Additionally, salvage loss cannot be scaled to stock abundance, which is an ongoing issue under litigation. The fundamental inadequacies of current methods hinder establishing appropriate operation triggers (including real-time monitoring) and prevent us from effectively evaluating the efficacy of flow alterations, barrier operations, predator control and other conservation measures.

In coordination with Department of Water Resources, California Department of Fish and Game, National Marine Fisheries Service, US Fish and Wild Service, and other resource management agencies, we have implemented a pilot genetic monitoring program (2011 and 2012 water years) that will accomplish two objectives for South Delta export loss monitoring: 1) We will compare single nucleotide polymorphism (SNP) genotypes to reference allele frequencies to rapidly and accurately detect and quantify loss of natural origin winter-run Chinook salmon; and 2) As a pilot study, we will investigate whether the fraction of stock-specific juvenile production lost to South Delta water exports can be estimated using Parental Based Tagging (PBT) methods on natural-origin winter-run Chinook. As current regulatory actions associated with loss are derived from a length-at-date model (i.e., Delta Model), we will compare our direct observations from genetically-partitioned salvage loss to current regulatory take determinations. Further, the statistical importance of race determination method to the overall mathematical variability associated with loss estimation will be reported.

Keywords: Delta salvage, loss estimation, genetic monitoring, mixed-stock analysis, parental-based tagging

Wednesday, October 17, 2012: Room 311-313, Genetics– Order 4

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Results of Parentage Based Tagging at the Feather River Hatchery: Pedigree Reconstruction and Ocean Tag Recoveries

Anthony Clemento*, UC Santa Cruz and NOAA Fisheries SWFSC Santa Cruz, anthony.clemento@noaa.gov
Eric Anderson, NOAA Fisheries SWFSC Santa Cruz, eric.anderson@noaa.gov
John Carlos Garza, NOAA Fisheries SWFSC Santa Cruz, carlos.garza@noaa.gov

Hatcheries in California produce and release millions of juvenile salmon and steelhead annually. This production is intended to mitigate for the loss of natural spawning and rearing habitat due to the construction of large dams. Parentage based tagging (PBT) is a genetic method for identifying the origin and cohort of hatchery salmon, crucial information for modern stock assessment models that is currently supplied by the aging coded wire tag program. PBT takes advantage of the fact that every fish already has a uniquely identifying tag, its sequence of nucleotide variation, which is passed from one generation to the next. So by genotyping a single pair of parents, 100% of their offspring are "tagged", thereby providing age and source population when offspring are encountered in fisheries, ecological sampling or at escapement. PBT also produces pedigree information, which allows inference about the inheritance of life history traits, variance in reproductive success, domestication selection and inbreeding; all critical concerns of Central Valley hatchery programs.
This talk will briefly review the methodological considerations of implementing a PBT program. We will present the results of reconstructing multigenerational pedigrees of spring-run Chinook salmon sampled from 2006-2011 at the Feather River Hatchery. We will also demonstrate the PBT recovery of Feather River spring and fall Chinook in 2010 and 2011 mixed-stock ocean fisheries off of California. Having shown that PBT works, we will argue that widespread implementation of genetic tagging at California hatcheries can provide high quality data for informing management and conservation of the species.

Keywords: Chinook salmon, genetics, hatchery, Central Valley, parentage based tagging (PBT)

Wednesday, October 17, 2012: Room 311-313, Genetics– Order 5

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Differential Response in Vegetation Community Dynamics in Riparian and Grassland Communities After Removal of Invasive Perennial Pepperweed Highlights the Importance of Seed Dispersal and Priority Effects

Rachel Hutchinson*, University of Idaho/UC Davis, rahutchinson@ucdavis.edu
Alexander Fremier, Department of Fish and Wildlife Resources, University of Idaho, akfremier@uidaho.edu
Joshua Viers, Center for Watershed Sciences, University of California, Davis, jhviers@ucdavis.edu

A primary goal of habitat restoration in Bay-Delta watersheds is to create contiguous and highly functioning ecosystems. Invasions by non-native species can limit the success of restoration efforts and requires ecosystem managers to reconcile community response and restoration techniques. In this study, we examined plant community composition dynamics after invasive species removal in two ecologically unique communities - an abiotically-controlled seasonal riparian zone and abiotically-controlled oak-grassland savanna. We hypothesized that riparian communities would be more invasible post-treatment due to priority effects and invasive propagule pressure while grassland habitats would be colonized by adjacent vegetation and the seed bank.

To determine how community composition trajectories changed through time, we use NMS to analyze plant community composition after invasive species control of perennial pepperweed (*Lepidium latifolium*). We then compared species turnover and composition by calculating inter-annual turnover rates in both communities throughout a seven year period. We found that riparian community turnover rates were significantly higher (Jaccard>0.92) than turnover in grassland communities (Jaccard<0.87, $p<0.0001$) and had fewer ($p<0.0001$) non-native species than grassland communities through time. Inter-annual trends in non-native species diversity were constant ($p>0.05$) in grasslands but drier years resulted in more non-native species in riparian sites when compared to wetter years ($p<0.0001$).

Our data suggests that more open, frequently disturbed communities are more strongly influenced by priority effects – that chance early colonizers control community trajectories – than closed communities, and that seed dispersal plays a dominant role in promoting self-sustaining populations of native vegetation. Thus, understanding specific ecosystem processes – namely seed dispersal in relation to disturbance regime, invasion susceptibility, hydrochorous dispersal, and priority effects – is necessary to reconcile and manage today's ecosystems.

Keywords: *Lepidium latifolium*, perennial pepperweed, invasive species, floodplain restoration

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (I) – Order 1

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Salinity and Inundation Effects on the Growth and Interactions of Two Dominant Tidal Marsh Plants

Stephanie Bishop*, San Francisco State University, stephanierostvoldb@gmail.com
V.Thomas Parker, San Francisco State University, parker@sfsu.edu

Climate change is predicted to raise sea level and lower fresh water inputs into the San Francisco Bay Estuary (SFBE). Few studies have looked at how dominant salt and brackish marsh species within SFBE will respond to these changes. We studied two dominant tidal marsh plant species, *Salicornia pacifica* and *Distichlis spicata*, to determine how they grow and compete at different salinity and inundation levels. Cuttings were collected from a brackish marsh, propagated in a greenhouse, and then used for concurrent greenhouse and field experiments. A greenhouse experiment exposed the plants to three different salinity and inundation regimes over three months. The field experiment tested these species under two different salinity and inundation regimes at one salt marsh and one brackish marsh within SFBE. The results show that salinity and inundation significantly affected growth for *S. pacifica* and *D. spicata*. In the greenhouse, *D. spicata* grew best at high inundation (12 hrs/day) and low salinity (12 ppt) and often outcompeted *S. pacifica* at these treatment levels. *S. pacifica* outcompeted *D. spicata* in the low inundation (1.5 hrs/day) at the middle salinity level (23 ppt). However, in the field both *S. pacifica* and *D. spicata* grew poorly in high inundation (6 hrs/day) and both species were unaffected or negatively affected by competition. *Salicornia pacifica* will clearly be negatively impacted by sea-level rise, but may still expand in high marsh areas up the SFBE due to increasing salinity. *Distichlis spicata* may not be negatively impacted by increases in inundation but other factors associated with increased inundation appear to limit its growth. As climate change shifts multiple factors, anticipating how plant distributions might change becomes complex. Understanding how these two plant species might respond to future conditions is important in order to understand how to best restore and manage tidal marshes within SFBE.

Keywords: Climate change, Salinity, Inundation, Tidal marsh, *Salicornia pacifica*, *Distichlis spicata*

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (I) – Order 2

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Location, Location, Location: Where is the Best Neighborhood for Olympia Oysters Growing up in San Francisco Bay?

Andrew Chang, University of California Davis, andchang@sfsu.edu
Anna Deck, University of California Davis, akdeck@gmail.com
Preston Malm, University of California Davis, pdmalm@gmail.com
Karissa Willits, University of California Davis, kwillits@gmail.com
Sarikka Attoe, University of California Davis, saattoe@gmail.com
Jennifer Fisher, University of California Davis, jlfisher@ucdavis.edu
Steven Morgan, University of California Davis, sgmorgan@ucdavis.edu

PROBLEM STATEMENT: The Olympia oyster, *Ostrea lurida*, is a target of restoration efforts in the San Francisco Estuary. Identifying high quality Olympia oyster habitat is key for conservation, but oysters have a complex life cycle with sessile adults and mobile larvae whose habitat requirements may differ. How are the various aspects of oyster population dynamics spatially patterned within the San Francisco Estuary? Our goals were to (1) estimate regional connectivity patterns and (2) link geographic variation in habitat quality and connectivity patterns to recruitment, growth, and survivorship.

APPROACH: We investigated *O. lurida* population dynamics and larval dispersal patterns using population surveys, recruitment monitoring, and trace elemental fingerprinting at sites from San Pablo Bay to the South Bay. We examined oyster populations during 2009 to 2011, a three year period encompassing the end of a three-year drought with low winter freshwater flow conditions (2009), a winter of intermediate flow conditions (2010), and a winter of higher flow conditions (2011).

RESULTS: Oyster abundance and size distribution differed significantly along the salinity gradient; maximum densities occurred in brackish waters near China Camp State Park, with over 1000 oysters / m2 in 2009-2010. Regional variation in temperature and salinity correlated with differences in the onset and peaks of fecundity and settlement. Mortality linked to high freshwater flow levels in early 2011 had the greatest impact in the northern region of the Bay, with near complete mortality in areas that previously had the highest population densities. Regional connectivity data showed some evidence of local recruitment, but also longer dispersal, and connectivity patterns varied between years.

CONCLUSIONS/RELEVANCE: While there is some evidence that different factors may promote fecundity and recruitment, it seems that habitat quality influences both the production and settlement of oyster larvae, with higher quality sites supplying larvae to lower quality sites.

Keywords: Ostrea oyster native population connectivity dispersal habitat quality restoration

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (I)– Order 3

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Monitoring to Optimize Invasive Spartina Control

Ingrid Hogle, San Francisco Estuary Invasive Spartina Project, ibhogle@spartina.org
Drew Kerr, San Francisco Estuary Invasive Spartina Project, dwkerr@spartina.org
Erik Grijalva, San Francisco Estuary Invasive Spartina Project, ekgrijalva@spartina.org

The State Coastal Conservancy's Invasive *Spartina* Project (ISP) was initiated in 2000 to address the threat of invasive species and hybrids of cordgrass (*Spartina* sp.) in the San Francisco Bay. Full scale treatment with the herbicide imazapyr was permitted and began in 2005. The ISP Monitoring Program was tasked with monitoring the efficacy of treatment efforts. The program uses annual inventory monitoring, combining field and remote sensing techniques as appropriate, to accomplish this task. GIS techniques are used to map and analyze data. Through GIS analysis of data collected from 2005 to present, we are able to track the efficacy of treatment efforts Bay-wide and by site. We have found that Bay-wide invasive *Spartina* acreage has decreased steadily each year, but that the rate of decline within marsh sites can vary. Based on existing information, we believe that degree of efficacy is dependent on multiple factors including timing of herbicide application, application method, thoroughness of treatment, extent of infestation within site, and susceptibility of the site to new propagules. These conclusions have relevance to improving programmatic success and must be addressed through adaptive management techniques. For example, GPS-led treatment monitoring was implemented beginning in 2009 to improve thoroughness of treatment as remaining target plants became more difficult to locate and identify as a result of successful control efforts. The impact of these surveys to treatment success will be analyzed by comparing efficacy of control at sites with and without such treatment monitoring efforts.

Keywords: invasive, Spartina, monitoring, imazapyr, herbicide

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (I)– Order 4

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Invasion of San Francisco Bay by *Upogebia major*: A Newly Recognized Non-Native Species with Potentially Large Ecosystem Consequences

Michael McGowan, Maristics, maristics@comcast.net
John Chapman, Oregon State University, john.chapman@oregonstate.edu
Ralph Breitenstein, Oregon State University, breitera@onid.orest.edu
Andrew Cohen, C.R.A.B., acohen@bioinvasions.com
Kathy Hieb, California Department of Fish and Game, khieb@dfg.ca.gov

In 2010 large numbers of mud shrimp *Upogebia* sp., second only in abundance to bay shrimp *Crangon* spp., were collected in San Pablo Bay while monitoring for entrainment of longfin smelt *Spirinchus thaleichthys* during channel dredging by the U.S. Army Corps of Engineers hopper dredge *Essayons*. The high abundance of mud shrimp, thought to be *U. pugettensis*, was notable for three reasons. A recent report stated that mud shrimp were not now and perhaps never were abundant in San Francisco Bay, *U. pugettensis* populations have declined on the West Coast likely due to castration by the non-native isopod *Orthione griffenis,* and *U. pugettensis* is an intertidal species that is not known to occur at the subtidal depths where it was collected in 2010. Two 2010 mud shrimp voucher specimens from the dredging collections have been identified as *U. major*, an Asian species. These specimens were not infected with *O. griffenis* although *U. major* is a natural host of *O. griffenis* in Asia with low prevalence rates of the parasite. This first documented occurrence of *U. major* in West Coast estuaries raises several questions. Is this a newly introduced species? Has it been here for years but misidentified as *U. pugettensis*? CDFG trawls and plankton nets may have collected it in 2009 or earlier. Is it a vector or reservoir for *O. griffenis* driving the native *Upogebia* to extinction? What role do these populations of "ecosystem engineers" play in the subtidal trophic ecology of the Bay? Additional subtidal mud shrimp, likely *U. major*, were collected in northern San Francisco Bay in 2011. Basic research and monitoring that includes species level taxonomy is essential to understanding and managing the San Francisco Estuary. The discovery/documentation of *Upogebia major* is a prime example of the need for research to support science-based management.

Keywords*:* *Upogebia*, mudshrimp, non-native species, subtidal ecology, host-parasite, taxonomy, dredging, monitoring

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (I)– Order 5

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Habitat Evolution Modeling

Brian Fulfrost, Brian Fulfrost and Associates, bfaconsult@gmail.com
David Thomson, San Francisco Bay Bird Observatory, d.x.thomson@gmail.com

The results of a three year pilot project building a semi-automated model to track the evolution of marsh habitats and mudflats (~30,000 acres) for the South Bay Salt Pond Restoration Project (SBSPRP) will be presented. Habitat mapped as part of the study included mudflats, tidal marshes, and restored ponds; and to a lesser degree, managed marshes, levee tops and uplands. We mapped a total of 24 specific habitat types including 16 vegetation alliances and/or associations representing salt, brackish and freshwater marshes, 6 "abiotic" habitats (e.g. mud), and 2 vegetation types specific to uplands. We utilized a supervised classification (maximum likelihood) of multispectral Ikonos imagery between 2009-2011. We conducted extensive ground truthing (~1000 total field surveys) to best characterize the spatial and taxonomic variability of vegetation throughout the study area as well as for model validation. We achieved 76% overall attribute accuracy for tidal marshes in 2011 and similar results for 2009 and 2010. We also successfully tracked floral colonization within restored ponds (e.g. A21) as well as floral colonization in some fringe marshes (e.g. Calavares marsh, top of Pond A6). Overall, the distribution and extent of marsh habitats appeared to be relatively stable (~10,000 acres) over the three year period, although there was some indication of the growth of invasive (e.g. Perennial Pepperweed) species relative to other habitats. The datasets also provide valuable information regarding the distribution and extent of high marsh (e.g. Pickleweed/Gumplant), especially within localized areas (e.g. Laumeister). Both the methodology and results of our study provide a strong baseline for better understanding the distribution and extent of habitats at a high level of spatial and taxonomic resolution, and ultimately, for tacking changes to these habitats into the future.

Keywords: Vegetation, Modeling, Remote Sensing, GIS, Wetland Restoration, Marsh Habitats, Conservation

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (II) – Order 6

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Pepperweed Invasion Increases Soil Nitrogen Cycling Rates and Nitrous Oxide Emissions in a Drained Peatland Pasture

Wendy Yang, University of California, Berkeley, wendy_yang@berkeley.edu
Evan Portier, University of California, Berkeley, eportier@berkeley.edu
Yit Teh, University of St. Andrews, yat@st-andrews.ac.uk
Whendee Silver, University of California, Berkeley, wsilver@berkeley.edu

Perennial pepperweed (*Lepidium latifolium*) is a pervasive exotic species that has spread throughout the western United States, invading natural and agricultural systems including the Bay Delta. Pepperweed has been documented to increase soil microbial enzyme activity associated with nitrogen (N) mineralization, but the effect of pepperweed on soil N cycling has not been determined. We measured gross N cycling rates and net N_2O emissions from replicate plots in a drained peatland pasture on Sherman Island, CA that were dominated by pepperweed versus dominated by an invasive annual grass (*Hordenum murinem*) with no pepperweed present (n= 6 per cover type). We also used trace gas stable isotope pool dilution, a novel technique, to measure gross N_2O production and consumption rates across four landforms in the pasture, only one of which was invaded by pepperweed.
The pepperweed plots exhibited significantly higher soil ammonium (NH_4^+) concentrations, gross N mineralization rates, dissimilatory nitrate (NO_3^-) reduction to NH_4^+ rates, and net N_2O emissions ($p < 0.05$, ANOVAs). Gross mineralization rates in surface soils (0-20 cm) averaged 30.1 ± 4.3 µg g^{-1} d^{-1} in grass-dominated plots and 81.5 ± 15.3 µg g^{-1} d^{-1} in pepperweed-dominated plots. Gross mineralization rates were positively correlated to soil NH_4^+concentrations ($R^2 = 0.54$), which averaged 8.4 ± 4.3 µg g^{-1} in grass-dominated plots and 27.3 ± 4.4 µg g^{-1} in pepperweed-dominated plots. Gross N_2O production rates were high, averaging 8.4 ± 3.2 mg N m^{-2} d^{-1}, and were most strongly correlated to mineral N ($NH_4^+ + NO_3^-$) concentrations and denitrifying enzyme activity ($R^2 = 0.73$). The only pepperweed-invaded landform exhibited the highest N_2O emissions and the highest mineral N concentrations.
Our results suggest that pepperweed has the potential to increase gross mineralization rates to alter soil N cycling and increase N_2O emissions as it spreads through the Bay Delta.

Keywords: ammonium; invasive; Lepidium latifolium; mineralization; nitrogen; nitrous oxide; pepperweed; soil

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (II)– Order 7

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Tidal Wetlands Alter Suspend Sediment Composition Through Tidally Driven Exchange

John Franco Saraceno, US Geological Survey, Sacramento, saraceno@usgs.gov
Brian B Bergamaschi, US Geological Survey, Sacramento, bbergmas@usgs.gov
Scott Wright, US Geological Survey, Sacramento, sawright@usgs.gov
Dave Evans, CSU Sacramento, dave_evans@csus.edu

Tidal wetlands provide valuable ecosystem services such as buffering inland areas from storm surges. However, due to their hydrologic complexity, the role that tidal wetlands play in cycling estuarine particulate matter is unclear. This study employed hydro-optical and hydrodynamic measurements in a tidal wetland channel, Browns Island, located in the western San Francisco Bay Delta. The study period covered a weeklong period in early January, 2006 and coincided with the spring tide. Tides were semidiurnal with a tidal range of 1.5 meters around a mean water depth of four meters. In addition to water depth and current velocity, turbidity, spectral beam attenuation and particle size were measured twice hourly at mid channel depth. Particle information derived from these instruments indicates that changes in both the abundance and size of particulate matter varied coincidentally with the tides, highlighting the link between hydrodynamics and suspended sediment characteristics in tidal wetlands. Assuming linearity between sediment concentration and optical signal, turbidity and beam attenuation were highest during the flood, and were lowest during ebb, indicating a higher concentration of sediment in island flood waters compared to ebb. Size spectra indicated three dominant pools of sediment with relative abundances changing throughout the tidal cycle. D50, or median particle size, increased to nearly 140 um at slack tide following island draining, while it plummeted to<33 um at peak flood velocity, likely due to shear induced floc break-up. The timing of peaks in size and concentration relative to the local hydrodynamics are likely due to the interaction of the tides and bathymetry, marsh flooding and draining as well as flocculation and breakup. Future restoration efforts should consider these findings. Further, this information should be incorporated into sediment transport and marsh inundation models.

Keywords: flocculation, sediment, attenuation, estuary

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (II)– Order 8

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Sediment Budget for the Far Southern Reach of San Francisco Bay: Importance of Hydrodynamics to the Supply of Sediment Available for Habitat Restoration

Gregory G. Shellenbarger, US Geological Survey, CA Water Science Center, Sacramento, CA 95819, gshellen@usgs.gov
Scott A. Wright, US Geological Survey, CA Water Science Center, Sacramento, CA 95819, sawright@usgs.gov
David H. Schoellhamer, US Geological Survey, CA Water Science Center, Sacramento, CA 95819, dschoell@usgs.gov

The South Bay Salt Pond Restoration Project is restoring 6,000 hectares of former commercial salt-evaporation ponds to tidal marsh or managed wetlands in the southern reach of San Francisco Bay (SFB). Sections of the project area have subsided and, given current sea level, will require about 32 million cubic meters of sediment to sufficiently raise bed elevations to appropriate levels for colonization of tidal marsh plants. The two main tributaries to this reach have been gaged for flow and suspended sediment since 2004, but the water and sediment flux at the bayward margin of the reach was unknown. In late 2008, a flow and suspended sediment monitoring station was established on the Dumbarton Bridge, the bayward margin of the southern reach of SFB. This allowed the calculation of daily sediment budgets for 2009-2011 for the reach using the sediment flux data from the tributaries, local waste-water treatment plants, and Dumbarton Bridge. Overall, the sediment budget for this reach is controlled by the sediment flux past Dumbarton Bridge. The tributary sediment loads are important for filling the subsided space on roughly a millennial time-scale, while the tidal load at the Dumbarton Bridge varies dramatically by season and year. Although the net sediment flux during 2009 and 2010 was into far south SFB, the direction of springtime sediment flux was out of far south SFB in 2011, and appears to be determined by the salinity gradient between central SFB and far south SFB. Fresher springtime conditions in central SFB lead to residual flows to the north and the flux of sediment out of the project area. Preliminary results suggest that there is a strong positive relationship between annual freshwater inflow from the Delta and the strength of northward sediment flux past the Dumbarton Bridge.

Keywords: Suspended-sediment flux, tidal, restoration, tributary, San Francisco Bay, sediment transport

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (II)– Order 9

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The Influence of Surface Water Mixing on Gas Budgets in Restored Wetlands

Cristina Poindexter*, UC Berkeley, cpoindexter@berkeley.edu
Evan Variano, UC Berkeley, variano@ce.berkeley.edu

There are three pathways by which gasses (including methane, oxygen, and carbon dioxide) are exchanged between wetland soils and the atmosphere. We show that one of these (dissolved gas transport through the surface water) is often underestimated in importance, and provide a quantitative prediction method for the relevant surface water fluxes. We focus on the specific case of restored wetlands in the Delta, considering a tule marsh in an enclosed basin in which water depth is held constant and the main source of mixing energy is the atmosphere (i.e. wind and thermal forcing). Field studies are used to motivate a set of laboratory measurements, from which we find a parameterization of the air-water gas transfer rate in terms of easily measured environmental variables. This parameterization is intended to support biogeochemical modeling, and a simple biogeochemical model is used to illustrate the importance of surface water mixing on wetland methane emissions.

Keywords: Wetland, Mixing, Budget, Water, Methane, Oxygen, Tule, Marsh, Flux, Budget

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (II)– Order 10

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Estimating Abundance of California Clapper Rails: Trends, Spatial Patterns and Effects of Climate Change

Julian Wood, PRBO Conservation Science, jwood@prbo.org
Leonardo Salas, PRBO Conservation Science, lsalas@prbo.org
Leonard Liu, PRBO Conservation Science, lliu@prbo.org
Nadav Nur, PRBO Conservation Science, nnur@prbo.org
Dennis Jongsomjit, PRBO Conservation Science, djongsomjit@prbo.org
Samuel Veloz, PRBO Conservation Science, sveloz@prbo.org
Grant Ballard, PRBO Conservation Science, gballard@prbo.org

The California Clapper Rail (*Rallus longirostris obsoletus*) is a federally listed endangered subspecies; over-hunting, non-native predators, and habitat loss and degradation throughout the SF Estuary have caused severe declines in the past 250 years. Estimation of population sizes, trends and spatial patterns are imperative for effective management and prioritization of rail habitat for conservation. Sea-level rise poses an imminent threat, potentially degrading or overtaking many current marshlands and should also be considered in decision-making. PRBO and partner institutions conducted surveys of Clapper Rails in 262 sites throughout the Estuary and consolidated 7years (2005-2011) of monitoring data. Because of patchy occurrence and less than 100% detectability, survey counts included a high frequency of zeros reflecting both true absence and failure to detect individuals ('false zeroes'). We used zero-inflation models to produce estimates of Clapper Rail abundance adjusted for imperfect-detection. These models adjusted for the effects of factors such as wind speed, temperature, and time of day on detectability. The resulting statistical models allowed us to better estimate the changes in rail density at survey sites throughout the study period, and the variables most influencing abundance and detection, which will help monitoring, management and marsh restoration efforts. We contrasted the estimated trends for South SF Bay with those for the North Bay and explored reasons for the difference. We then used these estimates as part of a landscape-level model to estimate Clapper Rail abundance throughout the Estuary. We also incorporated effects of future sea-level rise (elevation, proportion of marsh habitats and slope) and changes in salinity to project future population trends and spatial patterns of abundance. The resulting projections (along with those for three other species) are used for a prioritization of tidal marsh restoration and management that incorporates climate change effects.

Keywords: Clapper Rail, abundance, sea-level rise, climate change, endangered

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (III)– Order 11

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Macroinvertebrate Colonization and Avian Community Response Following Restoration of Salt Ponds in Northern San Francisco Bay

John Takekawa, USGS, Western Ecological Research Center, john_takekawa@usgs.gov
Isa Woo, USGS, Western Ecological Research Center, iwoo@usgs.gov
Ashley L. Smith, U. S. Geological Survey, Western Ecological Research Center, alsmith@usgs.gov
Yun Chan, USGS, Western Ecological Research Center, wchan@usgs.gov
Lacy M. Smith, USGS, Western Ecological Research Center, lmsmith@usgs.gov
Tanya Graham, USGS, Western Ecological Research Center, tgraham@usgs.gov
L. Arriana Brand, USGS, Western Ecological Research Center, arriana_brand@usgs.gov
Karen C. Taylor, CA Department of Fish and Game, KCTAYLOR@dfg.ca.gov
Renee Spenst, Ducks Unlimited, rspensts@ducks.org

The Napa-Sonoma Marshes Wildlife Area is located in the northern reach of San Francisco Bay and comprises more than 6,000 ha of former salt evaporation ponds that have been restored and breached to tidal action. In November 2008, we initiated a study to examine macroinvertebrate colonization and waterbird response to breaching of Ponds 9 and 10 along the Napa River. Because the ponds were formerly used to make salt, the bottoms of the ponds were covered with a salt crust, thus no benthic macroinvertebrates were initially present. However, we found that benthic macroinvertebrates were colonizing the site within seven months following restoration of tidal flows (May 2009). The earliest colonizers were Cumacea, Amphipoda, Polychaeta, Oligochaeta and Diptera larvae that collectively comprised 72% of all individuals. By the spring of 2010, macroinvertebrates in the restoration site were more abundant than in the reference sites in the adjacent river. We then used historical surveys of reference sites and the project area to examine avifaunal changes. No ducks and a monthly mean of <250 shorebirds were counted during the winter in the units prior to restoration from 2006-2008, and all observations were of non-foraging birds. Following restoration breaching, we observed an immediate numerical response by >1,000 waterbirds, and within three years, the mean monthly number of birds observed during the winter increased to >2,000 waterbirds. On high tides, dabbling and diving ducks increased as did small and large shorebirds to a lesser extent, and on low tides, small shorebirds and diving ducks greatly increased. Our study indicated that both macroinvertebrates and waterbirds responded quickly to salt pond restoration, and macroinvertebrate densities in these newly formed habitats exceeded those in reference areas.

Keywords: salt ponds, breach, invertebrate, shorebirds, waterbirds, colonization

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (III)– Order 12

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Submerged Surprise in Suisun: Extensive Beds of Native SAV

Katharyn Boyer, Romberg Tiburon Center, San Francisco State University, katboyer@sfsu.edu
Jeffrey Lewis, Romberg Tiburon Center, San Francisco State University, jeffreythomaslewis@gmail.com
Whitney Thornton, Romberg Tiburon Center, San Francisco State University, whitneythornton@gmail.com
Rosa Schneider, Romberg Tiburon Center, San Francisco State University, rosaschneider@gmail.com
Evyan Borgnis, Romberg Tiburon Center, San Francisco State University, elborgnis@gmail.com
Peter Baye, Annapolis Field Station, baye@earthlink.net

Though invasive submerged aquatic vegetation (SAV) in the Delta region of the San Francisco Estuary is known to clog waterways and may enhance predation on native fishes, the abundance and ecology of native SAV beds in the low-salinity waters of Suisun Bay have yet to be examined. In summer 2011 and 2012, we mapped ~1000 acres of the pondweed genus *Stuckenia* in the open waters of Suisun Bay and the west Delta. We collected voucher specimens in each bed, keying them to the native species *S. filiformis* (most specimens) and *S. pectinata* (widespread distribution but fewer specimens). Neither of these species was previously documented in the open waters of this region, although *S. pectinata* was historically an important food for Canvasback ducks in the diked Suisun Marsh. To map the beds, we digitized polygons of suspected SAV based on interpretation of Bing and USGS aerial imagery, then ground-truthed these polygons by boat, adjusting size and shape to match field observations as needed. Because digitization of imagery closely matched field patterns, this was determined to be an effective method for future surveys. Images since 1993 show the characteristic open growth pattern of *Stuckenia* spp. along the west side of Chipps and Winter Islands and a few other locations. However, many beds, such as along Ryer Island and the south side of Chipps Island are not evident in images until ~ 5 years ago; hence, we cautiously suggest that native SAV beds are expanding within Suisun Bay and the west Delta, perhaps in concert with a trend of increasing water clarity. The extent and position of these beds along islands through major migratory paths of native fishes, along with preliminary evidence of abundant invertebrates as potential food resources, suggest that these beds deserve further attention in conservation and management within the region.

Keywords: *Stuckenia*, pondweed, Suisun, SAV, GIS

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (III)– Order 13

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Structure of Estuarine Fish Communities: Three Decades of Observation in the San Francisco Estuary, California, USA

Fred Feyrer, USBR, ffeyrer@usbr.gov
Larry Brown, USGS, lrbrown@usgs.gov
Kathy Hieb, DFG, khieb@dfg.ca.gov
Randy Baxter, DFG, rbaxter@dfg.ca.gov
Max Fish, DFG, mfish@dfg.ca.gov

A major focus of ecology has been to generalize ecosystem structure and function. In particular, understanding how and why community structure varies along environmental gradients has provided substantial insights into the roles of local and regional processes affecting ecosystems. A common approach to studying estuarine fish communities involves describing how species composition and distribution vary as a function of salinity. The literature is filled with numerous accounts of how fish communities in various estuaries vary along salinity gradients or how salinity zones could be characterized based on fish distribution. The fundamental role of gross salinity in structuring estuarine fish communities is unquestionable. However, a better understanding of how salinity varies in space and time and how it interacts with other abiotic and biotic factors would provide important improvements in our understanding of how estuaries function and support fish communities. We provide new insights on how fish communities are structured in estuaries based upon an examination of over thirty years of monthly data collected in San Francisco Estuary. This monitoring program, started in 1980 by the Interagency Ecological Program, samples both demersal and pelagic fishes and has resulted in over 30,000 samples containing over 8 million fishes. It is perhaps the most comprehensive estuarine fish data set in the world. The insights we have gained from exploring the data set indicate that ecologists must move beyond the salinity zone paradigm to better understand the structure and function of estuarine fish communities.

Keywords: San Francisco Estuary, fish community, fish assemblage, salinity zones, IEP

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (III)– Order 14

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Going to Extremes: Evidence of Refuges for Native Fishes from the Sacramento River to San Francisco Bay

Brian Schreier, California Department of Water Resources, bschreie@water.ca.gov
Ted Sommer, California Department of Water Resources, tsommer@water.ca.gov
Louise Conrad, California Department of Water Resources, jlconrad@water.ca.gov

The San Francisco Estuary is home to a diverse community of native fishes, but has also been heavily invaded by alien fishes over the past 150 years. However, the effects of these alien fishes on the landscape-scale patterns of native fish community composition can be hard to elucidate given multiple covarying impacts. We examined patterns in fish community composition based on a transect from upstream in the Sacramento River to the lower Estuary using data from a long-term, near-shore fish monitoring program. Utilizing catch data from 1998-2011 at 26 stations from Colusa to central San Francisco Bay, we compared native and alien fish abundance and diversity among the various stations and years. We found extremely high abundances of natives in San Francisco and San Pablo bays (93-99% native species), a sharp decrease in native fish abundance in Suisun marsh and the confluence (2-9% native species), and then a progressive increase in native fish abundance moving upstream of the Delta (13-81% native species). Analyses of concurrently collected water temperature and salinity showed that the variance in these environmental variables helped to explain the drop in native abundance Carquinez Strait, but neither temperature nor salinity explained the subsequent increase in natives upstream of the Delta. Additional analyses comparing wet vs. critically dry water-year types indicated that the lower Sacramento River saw increased abundances of natives in wet years while in the upper Sacramento River saw higher abundances of natives during critically dry years. In general, we found decreasing diversity in fish communities in progressively drier water-year types. Our research suggests that the upper Sacramento River and the lower Estuary serve as important refuges for native fishes.

Keywords: Native fish, fish communities, long-term data

Wednesday, October 17, 2012: Room 314, San Francisco Bay Ecology (III)– Order 15

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Mercury Cycling in Blacklock Wetland: A Study of a Restored Tidal Marsh

Wesley Heim, Moss Landing Marine Laboratories, wheim@mlml.calstate.edu
Mark Stephenson, California Department of Fish and Game, mstephenson@mlml.calstate.edu
Adam Newman, Moss Landing Marine Laboratories, adam.newman@spyglassbio.com
Stuart Siegel, Wetlands and Water Resources, stuart@swampthing.org
Dan Gillenwater, Wetlands and Water Resources, dan@swampthing.org
Kenneth Coale, Moss Landing Marine Laboratories, coale@mlml.calstate.edu

Historically Suisun Bay Marsh included ~68,000 acres of tidal wetlands. From mid-1800's to early 1900's over 90% of the wetlands were reclaimed for agriculture. Currently, planning efforts to restore 65,000 acres of Delta and Suisun tidal habitat are in final stages of development. The 70 -acre Blacklock tidal marsh restoration site, located in northeast Suisun Marsh, was restored by DWR in 2006 after having been used for livestock grazing and duck hunting activities since 1946. This study is the first effort at estimating the impact on mercury cycling of converting a managed wetland with limited water exchange to tidal marsh with daily tidal inundations. The goals of this study were to estimate changes in total mercury and methyl mercury concentrations in fish, sediment and water within the restoration site before and after restoration. Field sampling took place January, 2005 to September, 2009. Results of two-sample t-test indicate aqueous methylmercury concentrations post breach ($t_{(2), 8} = 6.19$; $p < 0.05$) were significantly lower than pre-breach concentrations. Lower methylmercury sediment concentrations and less variability between sample locations within the restoration site were observed at Blacklock during the final two years of the study relative to the first year. Inland Silverside mercury concentrations decreased significantly post breach. Greater connectivity of tidal wetlands with surrounding open water areas resulted in decreased methylmercury concentrations in water, sediment, and fish. Two possible explanations may account for these results. First, wetland biogeochemistry in a daily inundated tidal regime does not support mercury methylation at levels observed for the site when it had seasonal wetland inundation regimes. Second, mercury-laden substrate has been buried with new sedimentation, thereby isolating the available mercury from methylation. It is hoped that the scientific knowledge gained as a result of this restoration about mercury cycling will aid future restoration efforts in the Bay-Delta.

Keywords: Mercury cycling; Wetlands; Mercury; Methylmercury

Wednesday, October 17, 2012: Room 314, Mercury– Order 1

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The Song Sparrow as a Biosentinel for Methylmercury in Riparian Food Webs of the San Francisco Bay Area

April Robinson, San Francisco Estuary Institute, april@sfei.org
Letitia Grenier, San Francisco Estuary Institute, letitia@sfei.org
Marcus Klatt, San Francisco Estuary Institute, marcusk@sfei.org
Shira Bezalel, San Francisco Estuary Institute, shira@sfei.org
Meredith Williams, San Francisco Estuary Institute, meredith@sfei.org
Josh Collins, San Francisco Estuary Institute, josh@sfei.org

Recent studies in the Bay Area and elsewhere have documented unexpectedly high concentrations of methylmercury in terrestrial invertebrate-eaters, such as songbirds, indicating that risk from harmful methylmercury exposure can occur in these food webs. Such discoveries, and the knowledge that mercury is already a problem in local watersheds, prompted interest in developing a biosentinel for methylmercury in stream riparian food webs of the Bay Area. The Song Sparrow (Melospizamelodia) was determined to be the best riparian biosentinel candidate on the basis of its natural history, sampling feasibility, and sensitivity to mercury.The ability of Song Sparrows to reflect a wide a range of mercury concentration in their blood, and to therefore distinguish methylmercury risk between conditions,was assessed by sampling individuals from riparian sites across the Bay Area.Sampling sites were chosen according to a conceptual model that identified total mercury in sediment and net methylation environment as the primary drivers for determining methylmercury exposure in riparian wildlife. Sampling sites were classified according to conceptual model categories (High or Low in Total Mercury, and High or Low in Net Methylation Environment) on the basis of reported sediment mercury values from other projects and landscape level indicators of total mercury or methylation environment. The presence of Song Sparrows at all sampling sites, and their ability to distinguish mercury exposure risk between sites, confirms their appropriateness as a biosentinel species. Differences in mercury between conceptual model categories, despite the rough measures used to classify sites, supports the idea that net methylation environment and total mercury are critical factors in determining methylmercury exposure in riparian food webs. Mercury concentrations at the site with the highest risk were associated with a decline in reproductive success in songbirds of greater than 25%, underscoring the need to understand and monitor methylmercury exposure in these systems.

Keywords: Methylmercury, Song Sparrow, Riparian, Biosentinel

Wednesday, October 17, 2012: Room 314, Mercury– Order 2

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Mercury in Motion: Wetland Restoration in South San Francisco Bay and the Legacy of Historic Mercury Contamination

Mark Marvin-DiPasquale, U.S. Geological Survey, mmarvin@usgs.gov

With a 50-year time horizon for its completion, the ongoing 6,500 hectare wetland restoration project in South San Francisco Bay represents one of the largest wetland restoration efforts in the world. Apart from its large scale, one of the biggest challenges faced by project managers is legacy mercury (Hg) buried in primary slough channels and former salt ponds within the restoration area. The source of this Hg is primarily drainage from the former New Almaden mining district, the largest cinnabar (HgS) mine in North America, which produced over 37 tons of Hg from the dawn of the gold rush until 1976. The current restoration project is tasked with the conversion of former salt production ponds ringing South San Francisco Bay, to a mosaic of restored tidal salt marsh and managed ponds for wildlife habitat and flood control. Levee breaches associated with the restoration project are causing vast changes in the hydrology of the restoration area, and these changes are projected to mobilize legacy Hg buried in the sloughs and marshes. Since 2003, USGS scientists have been involved in multiple projects aimed at understanding how much of this Hg has been or will be mobilized as a result of restoration management actions, and to what extent these actions will exacerbate or mitigate Hg bioaccumulation in the local or regional food web. This presentation will highlight a number of these related Hg studies, both past and ongoing, and give a synopsis of 'lessons learned' to date, as well as projection for the future. The insights offered by this body of Hg research has direct implications for wetland restoration efforts that are ongoing and planned in many regions of the San Francisco Bay, its watershed, and globally.

Keywords: mercury, wetland restoration, biogeochemistry

Wednesday, October 17, 2012: Room 314, Mercury– Order 3

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Use of Coagulation to Remove Inorganic Mercury and Methylmercury from Solution

Yumiko Henneberry, University of California, Davis, yumberry@ucdavis.edu
Tamara Kraus, US Geological Suvery, California Water Science Center, tkraus@usgs.gov
William Horwath, University of California, Davis, wrhorwath@ucdavis.edu
Phillip Bachand, Bachand and Associates, phil@bachandassociates.com
Jacob Fleck, US Geological Survey, California Water Science Center, jafleck@usgs.gov
David Krabbenhoft, US Geological Survey, Wisconsin District, dpkrabbe@usgs.gov
Peter Nico, Earth Sciences Division, Lawrence Berkeley National Laboratory, psnico@lbl.gov

The approval of the methylmercury (MeHg) TMDL for the Sacramento – San Joaquin Delta (Delta) has highlighted the need to identify best management practices that will reduce the concentration and export of mercury (Hg) from both point and non-point sources. Results from our laboratory studies demonstrate the promise of metal-based coagulants (e.g. iron sulfate, polyaluminum chloride) for removing Hg and MeHg from water. These coagulants are commonly used in the drinking water industry to remove dissolved organic matter (DOM) prior to disinfection to reduce the formation of toxic disinfection by-products. Because both inorganic Hg and MeHg are known to associate closely with DOM, it follows that removal of DOM leads to the concomitant removal of Hg from solution and its incorporation into the organo-metal complex, termed floc, which precipitates out of solution. Previous studies which concluded that coagulation does not effectively remove Hg from solution were conducted using high concentrations of Hg that do not apply to natural waters. Treatment of water collected from Delta subsided island drainage water high in both DOM and Hg demonstrated up to 97% of inorganic Hg and 80% of MeHg can be removed from solution by coagulation. Once formed, the organo-metal floc shows the capacity to adsorb additional Hg. Exposure of the floc to highly reducing conditions in the laboratory indicated that this material may remain stable in a wetland environment, potentially sequestering both carbon and Hg in the sediment over the long-term. Further research is being conducted on Twitchell Island to assess the feasibility of using on-site coagulation to 1) remove constituents of concern including DOM and Hg, and 2) mitigate land-surface subsidence through retention of the floc in constructed wetlands. If proven effective, coagulation may be a feasible technique to reduce Hg and MeHg concentrations and loads in Delta waters.

Keywords: mercury, methylmercury, coagulation, best management practices, Hg, MeHg, TMDL

Wednesday, October 17, 2012: Room 314, Mercury– Order 4

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Strategies for Resolving Low Dissolved Oxygen and Methylmercury Events Originating in Diked Managed Wetlands of Suisun Marsh

Stuart Siegel, Wetlands and Water Resources, stuart@swampthing.org
Phil Bachand, Tetra Tech Research and Development, phil.bachand@gmail.com
Dan Gillenwater, Wetlands and Water Resources, dan@swampthing.org
Stephen Chappell, Suisun Resource Conservation District, schappell@suisunrcd.org
Bruce Wickland, Suisun Resource Conservation District, bwickland@suisunrcd.org
Orlando Rocha, Suisun Resource Conservation District, orocha@suisunrcd.org
Mark Stephenson, Moss Landing Marine Lab, DFG, mstephenson@mlml.calstate.edu
Wes Heim, Moss Landing Marine Laboratory, DFG, wheim@mlml.calstate.edu
Chris Enright, Delta Science Program, cenright@deltacouncil.ca.gov
Peter Moyle, UC Davis, pbmoyle@ucdavis.edu
Bryan Downing, United States Geological Survey, bdowning@usgs.gov
Brian Bergamaschi, United States Geological Survey, bbergama@usgs.gov

Suisun Marsh diked seasonal marshlands management is geared toward wintering waterfowl habitats: mixed open water and emergent vegetation. Management includes summertime drawdown for vegetative growth and wetland maintenance, fall flood up for wintering waterfowl habitat, and late winter/early spring drawdown and flushing for salt leaching. The high organic matter of wetland vegetation plus soil organic carbon in these peat-rich diked wetlands, when flooded in the fall after the summer drawdown, provide ideal conditions for depleting water column dissolved oxygen. Discharging carbon-rich, oxygen-depleted waters into smaller tidal sloughs during fall flood up and, to a lesser extent during winter/spring leaching, can lead to periods of low dissolved oxygen in those sloughs. This hypoxia, and occasionally anoxia, can block access to upstream aquatic habitats and, in the most severe cases, has resulted in fish kills. Wetland soil biogeochemistry also supports methylmercury production via anaerobic microbial activity, resulting in methylmercury loadings to the tidal sloughs. Methylmercury is a potent neurotoxin and export to the tidal sloughs make it bioavailable to fish populations and ultimately poses a human health risk through consumption of mercury contaminated fish. Fishing is commonplace in Suisun Marsh. Our study explored processes affecting production of low DO and methylmercury in Suisun managed wetlands and identified management practices that might reduce or eliminate these problems while supporting productive waterfowl habitats. The study found that human management activities (water, soils, and vegetation management) interact with three key environmental variables (wind, air temperature, and tides). When fall flood up corresponds with windy conditions, cooler air temperatures, and spring tides, modifying managed wetlands practices may lessen adverse water quality conditions. In contrast, low winds, hot temperatures, and neap tides render most management efforts ineffective and poor water quality conditions often ensue. Our study identified sixteen management approaches with potential to reduce adverse water quality conditions.

Keywords: dissolved oxygen, methylmercury, wetlands, Suisun, fish

Wednesday, October 17, 2012: Room 314, Mercury– Order 5

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Will Salt Pond Restoration in South San Francisco Bay Cause Erosion of Mudflats and Sloughs?

Bruce Jaffe, US Geological Survey, bjaffe@usgs.gov
Amy Foxgrover, US Geological Survey, afoxgrover@usgs.gov
David Finlayson, US Geological Survey, dfinlayson@usgs.gov
Theresa Fregoso, US Geological Survey, tfregoso@usgs.gov
John Takekawa, US Geological Survey, jtakekawa@usgs.gov
Mark Marvin-DiPasquale, US Geological Survey, mmarvin@usgs.gov

A key question for the ongoing South Bay Salt Pond Restoration project is: How do sediment sinks created by opening ponds to tidal exchange alter local mudflat and tidal channel morphology? If sediment supply is insufficient, existing mudflats will erode. A decrease in mudflat area and the associated altered inundation regime may negatively impact the food web structure on the mudflats, reducing their value for migratory birds. In addition, scour of tidal sloughs, which is expected because of the increased currents generated by the greater post-restoration tidal prism, has the potential to remobilize buried legacy contaminants, such as mercury.

Future morphologic changes to mudflats and sloughs in South San Francisco Bay are being evaluated using long-term, seasonal, and initial post-restoration data. A series of bathymetric surveys collected from1858 to 2005 reveal long-term geomorphic changes in both space and time that give insight into the pre-restoration morphodynamic system. Our analyses indicate that mudflat change is related to north-to-south sediment redistribution and to new sediment input. To quantify intra-annual variability and to document initial post-restoration changes, swath bathymetric surveys were collected from 2008 to 2012 using state-of-the-art interferometric sidescan sonar. On average, there is little seasonal change on the mudflats in the study area. However, the surveys indicate scour of mudflats and tidal sloughs occurred after the initial restoration, with up to a meter of scour adjacent to breeches in Alviso ponds.

The next logical step to strengthen the assessment of future geomorphic change is to model the hydrodynamic/sediment transport/geomorphic system to improve our understanding of the effects of sediment input and redistribution within the Bay. This will allow us to separate restoration effects from regional effects and help in managing restoration of South San Francisco Bay salt ponds.

Keywords: mudflat sediment slough sea level rise restoration salt ponds

Thursday, October 18, 2012: Room 306, Latest Science Updates from the South Bay Salt Pond Restoration Project– Order 1

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Sediment Dynamics in Restored Salt Ponds and Tidal Wetlands in San Francisco Bay

John C. Callaway, University of San Francisco, callaway@usfca.edu
Lisa M. Schile, University of California, Berkeley, lmschile@gmail.com
Evyan L. Borgnis, San Francisco State University, elborgnis@gmail.com
V. Thomas Parker, San Francisco State University, parker@sfsu.edu
Jennifer A. Gagnon, University of San Francisco, gagnon.ja@gmail.com
Donna Ball, H. T. Harvey & Associates, dball@harveyecology.com

Problem statement: There is large-scale interest in restoring tidal wetlands in the San Francisco Bay Estuary, and many of these restoration sites have subsided substantially, including those within the South Bay Salt Pond Restoration Project. When levees are breached at subsided sites, significant sediment accumulation is necessary to reach threshold elevations for plant establishment.

Approach: We measured sedimentation rates at a number of restored wetlands across the Bay using sediment pins at two restored salt ponds (Pond A21 in the Island Ponds and Pond A6) and feldspar marker horizons and Surface Elevation Tables (SETs) at Muzzi Marsh and Crissy Field.

Results: Highly subsided salt ponds within the South Bay have the potential for very rapid accumulation, as they are frequently inundated and suspended sediment rates within the South Bay are relatively high. More than 20 cm of sediment accumulated in the first three years post-breach at the Island Ponds in the South Bay, with a gradual reduction in sediment accumulation over time as the site increased in elevation. Vegetation established rapidly at the site once suitable elevations were reached. Pond A6 was breached in December 2010 and started at elevations substantially below the Island Ponds; even more rapid rates of sediment accumulation occurred during the first year post-breach at Pond A6. Muzzi Marsh and Crissy Field have not accumulated sediment as rapidly as the subsided salt ponds in the South Bay, likely due to higher initial elevations and restrictions in tidal flow.

Conclusions: On-going monitoring of sediment dynamics across a range of wetlands within the Bay will allow for the development of models which can be used to predict the development of future restoration projects, as well to understand long-term sustainability of natural and restored wetlands under scenarios of increased sea-level rise and reduced suspended sediment concentrations.

Keywords: restoration, sedimentation, tidal wetland, salt ponds

Thursday, October 18, 2012: Room 306, Latest Science Updates from the South Bay Salt Pond Restoration Project– Order 2

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Balancing Act: Protecting Waterbirds and Providing Public Access

Lynne Trulio, San Jose State University, lynne.trulio@earthlink.net
Jana Sokale, Sokale Environmental Consulting, janaslc@aol.com
Heather White, ICF/Jones and Stokes, number1schmead@yahoo.com
Caitlin Robinson Nilsen, San Francisco Bay Bird Observatory, cnilsen@sfbbo.org
Kevin Lafferty, U S Geological Survey, klafferty@usgs.gov

Projects throughout the Bay-Delta, such as the South Bay Salt Pond Restoration Project in the south San Francisco Bay, seek to achieve the potentially-competing goals of improving wildlife habitat while increasing public access. Science-based management of habitat and people is essential to balancing these goals. Of particular concern is the effect of trail use on migratory shorebirds and waterfowl that spend the winter foraging in ponds and tidal wetlands around the Bay, as well as impacts on the western snowy plover (*Charadrius nivosus nivosus*), a threatened shorebird that nests in dry ponds. As part of the adaptive management approach for the South Bay Salt Pond Restoration Project, we studied the effect of trail use on waterbirds around the Bay and found bird responses were both species and situation dependent. The abundance, species richness and proportion of foraging migratory shorebirds showed little difference between sites adjacent to existing trails versus non-trail use sites. However, nesting snowy plovers and migratory waterfowl reacted strongly when exposed to new trail use. Plovers flushed off nests in response to trail users at distances averaging 145m (SE 14m) and flushed at rates seven times that of nests not exposed to trail use. Waterfowl moved away from trails in response to trial use, maintaining buffer distances of approximately 100m or more. To understand the human side of this interaction, we combine these results with our study of people's satisfaction with their trail experience. Public demand for bay-side recreation continues to grow. This research integrates social and avian science to provide managers with information useful in protecting birds from trail use disturbances while allowing people to enjoy the beauty of the wetlands.

Keywords: Migratory waterbirds, western snowy plovers, trails, public access

Thursday, October 18, 2012: Room 306, Latest Science Updates from the South Bay Salt Pond Restoration Project– Order 3

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Effects of Wetland Management on Carrying Capacity of Duck and Shorebird Benthivores in a Coastal Estuary

L. Arriana Brand, USGS, Western Ecological Research Center, arriana_brand@usgs.gov
John Y. Takekawa, USGS, Western Ecological Research Center, John_takekawa@usgs.gov
Tanya Graham, USGS, Western Ecological Research Center, tgraham@usgs.gov
Kevin Buffington, USGS, Western Ecological Research Center, kbuffington@usgs.gov
Joel Shinn, U.S. Geological Survey, Western Ecological Research Center, joel_shinn@fws.gov
Sarah Spring, U.S. Geological Survey, Western Ecological Research Center, sarah_spring@usgs.gov
A. Keith Miles, U.S. Geological Survey, Western Ecological Research Center, keith_miles@usgs.gov

With global loss of natural wetlands, managed wetlands increasingly support energy requirements for wintering shorebirds and waterfowl. Despite numerous studies of energetics in freshwater systems, little is known of estuarine systems. Managed ponds in San Francisco Bay form part of the largest wetland restoration on the Pacific coast of North America. We compared energy requirements and availability for eight shorebird and four diving duck species during winters of 2007-2010 in 4 types of managed ponds - shallow seasonal and deeper circulation ponds in two salinity classes. We applied a daily-ration model to evaluate carrying capacity of managed ponds as potential bird-days that a site can support. We estimated diving duck abundances of 35,450 in average and 45,458 in peak years with > 95% in circulation ponds, and shorebird abundances of 64,253 in average and 108,171 in peak years with > 64% in seasonal ponds. Macroinvertebrate energy density was highest in mesohaline (5-30 ppt) circulation ponds and low in seasonal ponds for both guilds. Greatest energy requirements by diving ducks in mesohaline followed by low-hyperhaline (30-80 ppt) circulation ponds were mostly supported by available prey energy. Available energy for shorebirds was substanitally less than required in seasonal ponds but exceeded that required in mesohaline circulation ponds, which supported an average of 9,443 +/- 1,649 shorebird bird-days per ha of available habitat and 2,297 +/- 402 diving duck bird-days per ha of available habitat. This was about twice that of low-hyperhaline circulation ponds for both guilds and > 5 times than seasonal ponds. Our results indicate that salinity reduction to mesohaline levels and alteration of depth to increase accessiblity would substantially increase energy available for wintering waterbirds.

Keywords: benthic macroinvertebrates, carrying capacity, shorebirds, diving ducks, salinity, waterdepth

Thursday, October 18, 2012: Room 306, Latest Science Updates from the South Bay Salt Pond Restoration Project– Order 4

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Examining Fish Usage of Recently Restored Saltmarshes

Nicholas Buckmaster, Department of Wildlife and Fish Conservation Biology, University of California, Davis, ngbuckmaster@ucdavis.edu
Patrick Crain, ICF International (Jones and Stokes), PCrain@icfi.com
Peter Moyle, Department of Wildlife and Fish Conservation Biology, University of California, Davis, pbmoyle@ucdavis.edu
James Hobbs, Department of Wildlife and Fish Conservation Biology, University of California, Davis, jahoobs@ucdavis.edu

The effects of tidal marsh restoration on fish species and aquatic communities remains one of the largest enigmas in the San Francisco Estuary; however, marsh restoration also remains one of the most viable options for improving the current state of the estuary's ecosystem. The South Bay Salt Pond Restoration Program is the largest wetland restoration program in the United States and has breached several shallow intertidal salt ponds adjacent to South San Francisco Bay. This restoration has provided an excellent venue to assess the initial impacts of tidal restoration on fish and aquatic communities. We have developed a flexible and comprehensive monitoring program that has assessed abundances and composition of fish communities in restored salt ponds, historic marshes, managed wetlands, and adjacent sloughs. Because of the dynamic nature of these novel habitats, we have been using several complementary gear types to compare breached habitats with adjacent areas. Additionally, we have been investigating the health of a resident intertidal sentinel species, longjaw mudsucker (*Gillichthys mirabilis),* by using growth, recruitment, and survival to further determine the function and quality of the restored habitats. Fish abundance in restored habitats has been seasonal and has been highest in summer, while diversity within the ponds has been highest in spring. Fish moved from the sloughs into the ponds during spring and summer months, resulting in a high degree of similarity between the species assemblages observed in the breached salt ponds and the adjacent sloughs. Sentinel species have also been colonizing the salt ponds and condition factors have been better in the pond habitat than in adjacent areas.

Conclusions/Relevance: This study provides information about the potential of tidal restoration to shallow, off-channel habitats to fish communities in the Bay-Delta, which can be used by management to guide future.

Keywords: Tidal marsh, restoration, fish communities, sentinel species, salt marsh

Thursday, October 18, 2012: Room 306, Latest Science Updates from the South Bay Salt Pond Restoration Project– Order 5

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How Long Will it Take? Factors Affecting the Schedule for Salt Pond Restoration from Land Acquisition through Salinity Reduction to Completion of Construction

Susanne von Rosenberg, GAIA Consulting, Inc., susanne@gaiainc.com

Restoration scientists are frequently asked to predict how long it will take before construction of restoration features can be completed. Correctly predicting the overall time required to take a project from the planning stage to completion of restoration construction is critical in developing credibility with stakeholders including funders, regulatory agencies, and the public. In addition to the numerous other factors that must be considered, the salinity reduction process can present special challenges and has the potential to delay implementation of the restoration effort. This talk compares and contrasts two North Bay salt pond restoration projects, including their salinity reduction challenges, management considerations, and planning factors influencing the time required to complete the projects. The appropriate salinity reduction approach depends on the form and quantity of salt or brine remaining in the pond to be restored. The experience with these two projects shows that the appropriate process, salinity reduction can be accomplished within months, even where large quantities of salt remain in the site. Salinity reduction, therefore, becomes only one factor in determining in the overall time required to complete construction of a restoration project, and the importance of management and planning factors increases. Understanding the various factors as they apply to a specific project allows the project team to focus on those elements that have the greatest potential for delaying or accelerating the implementation of restoration construction, and thereby increase the credibility of the project with its stakeholders and continue to build support for restoration activities as a whole.

Keywords: Salinity reduction, salt ponds, crystallizers, management factors, restoration schedule, planning

Thursday, October 18, 2012: Room 306, Napa-Sonoma Marshes Wildlife Area Restoration–Order 1

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Access, Airspace, and Avocets – Crafting a Solution

Francesca Demgen, URS Corp., francesca.demgen@urs.com
Seth Gentzler, URS Corp., seth.gentzler@urs.com

Wetland restoration is often near one of the Bay Area's three major airports, 2 Federal airports, or 16+ general aviation airports. The California Department of Fish and Game's restoration of North Unit of Napa Plant Site is so close to the Napa County airport that runway 6/24 safety area and safety zone are situated in Pond 10. The FAA told Napa County Airport authority staff there had been 32 bird strikes, not the 5 in 6 years reported to them. These birds had a relative hazard rating of between 5 and 55, according to the FAA Circular on Wildlife Hazard Management at Airports. DFG's response to the concerns regarding public safety at the airport included eliminating the managed pond as part of plan, adding dredged material to raise surface elevation and to be a good neighbor, during construction DFG placed fill the size and shape of a runway safety area in the corner of Pond 10.

To reduce bird strike potential, dredged material was used to raise the marsh plain surface by 1 to 2 feet, closer to an elevation at which emergent vegetation grows. A revegetation model was developed that predicted within 10 years the area would be growing emergent plant cover, reducing bird strike hazards. Tidal action was restored to the North Unit on October 13, 2008, approximately 3 and a half years ago and a 10 to 20 foot wide band on the edges of the site and the lowered levee footprints are becoming vegetated with pickleweeed, bulrush and cordgrass. In addition to birds and airplanes, trail advocates were seeking a route north to connect American Canyon with Napa, also using the edge of the runway safety zone. The airport was concerned and there was no rail crossing to allow safe access from Green Island Road

Keywords: wetland restoration, dredged material reuse, bird strikes, public access

Thursday, October 18, 2012: Room 306, Napa-Sonoma Marshes Wildlife Area Restoration–Order 2

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Trajectory of Early Tidal Marsh Restoration: Elevation, Sedimentation and Colonization of Breached Salt Ponds in the Northern San Francisco Bay

Lacy M. Smith, U.S. Geological Survey, lmsmith@usgs.gov
L. Arriana Brand, U.S. Geological Survey, arriana_brand@usgs.gov
John Y. Takekawa, U.S. Geological Survey, john_takekawa@usgs.gov
Nicole D. Athearn, U.S. Fish and Wildlife Service, nicole_athearn@fws.gov
Karen Taylor, California Department of Fish and Game, kctaylor@dfg.ca.gov
Gregory G. Shellenbarger, U.S. Geological Survey, gshellen@usgs.gov
David H. Schoellhamer, U.S. Geological Survey, dschoell@usgs.gov
Renee Spenst, Ducks Unlimited, rspenst@ducks.org

Tidal marsh restoration projects that cover large areas are critical for maintaining target species, yet few large sites have been studied. A tidal marsh restoration project in the northern San Francisco Bay consisting of three breached salt ponds (≥300 ha each; 1175 ha total) is one of the largest on the west coast of North America. These diked sites were subsided and required extensive sedimentation for vegetation colonization, yet it was unclear whether they would accrete sediment and vegetate within a reasonable timeframe. We conducted bathymetric surveys to map substrate elevations using digital elevation models and surveyed colonizing Pacific cordgrass (*Spartina foliosa*). The average elevation of Pond 3 was 0.96 ± 0.19 m (mean ± SD; meters NAVD88) in 2005. In 2008–2009, aver-age pond elevations were 1.05 ± 0.25 m in Pond 3, 0.81 ± 0.26 m in Pond 4, and 0.84 ± 0.24 m in Pond 5 (means ± SD; meters NAVD88). The largest site (Pond 3; 508 ha) accreted 9.5 ± 0.2 cm (mean ± SD) over 4 years, but accretion varied spatially and ranged from sediment loss in borrow ditches and adjacent to an unplanned, early breach to sediment gains up to 33 cm in more sheltered regions. The mean elevation of colonizing *S. foliosa* varied by pond ($F = 71.20$, $df = 84$, $P < 0.0001$) and was significantly lower in Ponds 4 and 5 compared with Pond 3 which corresponded with greater tidal muting in those ponds. We estimated 16% of Pond 3, 13% of Pond 4, and 24% of Pond 5 were greater than or equal to the median elevation of *S. foliosa*. Our results suggest that sedimentation to elevations that enable vegetation colonization is feasible in large sites with sufficient sediment loads although may occur more slowly compared with smaller sites.

Keywords: bathymetry, elevation, marshplain development, salt marsh, salt pond, *Spartina foliosa*

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Monitoring and Supporting Listed, Ground Nesting Birds in a Environment

Karen Taylor, California Department Fish and Game, kctaylor@dfg.ca.gov

California Least Tern (LETE) have been sited periodically in the Napa-Sonoma Marshes Wildlife Area (NSMWA) since 2006 (via USGS bird data). Confirmation of LETE nesting in NSMWA, was first identified in 2008 at the NPS in the South Unit. Passive, detailed nesting surveys began in 2009 for the NSMWA LETE colony. The colony is considered a loose colony where the majority of the nests occur at the Napa Plant Site, but a small portion of the colony also nest on the internal levee of Ponds 7/7A in the Huichica Creek Unit of the NSMWA two miles away. To date, three detailed nesting surveys have been conducted:

Pre-construction in 2009 (salt ponds)

During construction in 2010 (where habitat islands were formed, but construction outside the buffer area was active and the area not tidal), and

Post-construction in 2011(fully tidal)

A fourth survey will be conducted in 2012.

In addition to LETE, a small number of Western Snowy Plover (SNPL) have also utilized the NSMWA for breeding. The four years of detailed nesting surveys have provided surveyors with valuable observations about LETE, SNPL, and associated species.

Keywords: Habitat Restoration, Nesting, DFG lands, Least Tern, Snowy Plover,

Thursday, October 18, 2012: Room 306, Napa-Sonoma Marshes Wildlife Area Restoration–Order 4

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Progression of Fisheries Use in Restored Salt Ponds at Napa Plant Site

Francesca Demgen, URS Corp., francesca.demgen@urs.com
Michael Carbiener, URS Corp., michael.carbiener@urs.com
David Pecora, URS Corp., david.pecora@urs.com
Renee Spenst, Ducks Unlimited, rspenst@du.org

California Fish and Game's goal was to restore a mosaic of wetland habitats for estuarine fish, waterbirds, and small mammals on 1,460-acres of former salt ponds in the Napa River floodplain. Three sequentially restored units breached in 2008, '09 and '10 were monitored to answer questions regarding the progression of fish use on the newly constructed site. Beach seine and otter trawl surveys were conducted seasonally in 2010 and 2011. Less than a month after the August 2010 South Unit breach, topsmelt were collected a mile inland from the breach, using a beach seine in the former crystallizer beds where salinities had exceeded 350 ppt prior to breaching. Topsmelt are planktovores, water column foragers, 7 months later, staghorn sculpin a demersal (bottom) foraging fish was collected, after benthic invertebrates had time to establish; potentially related to dissolution or silt deposition on the salt crust. Twenty-six species: 16 natives and 14 of those were listed in Goals Report as "Key Fish Species" representing the complexity of the San Francisco Baylands Ecosystem. Inland silversides was most abundant, Sacramento splittail population doubled between years, perhaps due to water year or vegetation growth facilitated spawning. Chinook salmon smolts came in for rearing. This monitoring frequency shows immediate and diverse fish use of restored high salinity salt ponds.

Keywords: fish, restoration, salt ponds, Napa River

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Thermal Implications of an Unimpaired Hydrograph on Managing Declining Salmonid Populations in a Delta Tributary

Chris Hammersmark, CBEC Eco Engineering, Inc., c.hammersmark@cbecoeng.com
Chris Bowles, CBEC Eco Engineering, Inc., c.bowles@cbecoeng.com
Chris Campbell, CBEC Eco Engineering, Inc., c.campbell@cbecoeng.com
Tom Gohring, Water Forum, tgohring@waterforum.org

Current efforts to rehabilitate the Bay-Delta Ecosystem have identified the ecological importance of the natural flow regime, and this recognition has led to the consideration of a prescription of some proportion of unimpaired inflow for the delta. However, this framework may yield unintended impacts to declining anadromous salmonid species. In most major Central Valley Rivers, these cold-water dependent populations are relegated to the valley floor by rim dams, and as such are required to complete some of their freshwater life stages in environments that differ from those in which they evolved (i.e., on the valley floor rather than higher in the watershed). The understanding that we are trying to promote and improve a cold-water fishery in an environment that is not thermally suitable needs to be considered when scenarios prescribing some proportion of the unimpaired flow are evaluated. To quantify the potential impact to the cold-water fisheries components of the ecosystem, a suite of water supply, hydrodynamic and water quality models are used in concert to simulate long term series of water temperature in the lower American River. In this effort, existing water supply and water quality models (CALSIM II and USBR Temperature Model) are used to develop flow and temperature boundary conditions for a sub-daily hydrodynamic and water quality model (HEC-RAS). These models are used to simulate water temperatures for current and proposed flow management scenarios, allowing a quantitative assessment of potential differences. The results show that a flow prescription which uses a proportion of unimpaired runoff results in elevated temperature conditions particularly in the late summer and early fall, exposing salmonids to less-tolerable and in many cases unsuitable thermal conditions. Using this knowledge, the impacts to cold-water dependent fisheries in delta tributaries must be considered simultaneously and not serially when determining the flow needs for the delta.

Keywords: salmon, water temperature, flow objective, American River, flow management

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 1

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Analyzing Spatial Patterns of Groundwater-Surface Water Interactions at the Meander-Bend Scale in a Gravel-Bed Lowland River during a Large-Scale Flow Experiment

Erin Bray*, Bren School of Environmental Science and Management, University of California, Santa Barbara, California, USA, ebray@bren.ucsb.edu
Thomas Dunne, Bren School of Environmental Science and Management, University of California, Santa Barbara, California, USA, tdunne@bren.ucsb.edu

We measured the effects of a large-scale flow experiment on near-bed and subsurface temperature throughout three meander bends using fiber optic distributed temperature sensing (DTS) as a means to investigate groundwater-surface water exchange in a gravel-bed lowland river. We deployed 2 km of fiber-optic cable directly on top of the riverbed over three pool-riffle sequences each with a different degree of bed mobility. DTS data were collected in Reach 1A of the San Joaquin River, CA (1.5 days at 10 cms, 10 days at 20 cms, 16 days at 10 cms, and 4.5 days at 2-4 cms). Three installations of six hyporheic zone sensors recorded interstitial pore water temperature at depths of 46 cm. Measured channel bed elevation, flow depth, velocity, and bed-material grain size were used to develop a two-dimensional numerical model of the flow field as boundary conditions for a model of the hyporheic flow field.

The initial flow of 10 cms showed relatively uniform temperature over the 2-km reach. Near-bed temperatures averaged 15.6°C while pore water temperatures at 46 cm averaged 15.4°C. The 20 cms flow decreased average near-bed temperatures to 14.9°C and pore water temperatures to 14.7°C. During the 20 cms flow, the bed became mobile causing local scour and deposition at three locations and buried the DTS cable with sand/gravel. Our DTS results allowed us to record the transition from near-bed temperatures to shallow subsurface temperatures during a sediment-mobilizing flow. Shallow pore water temperatures were increasingly buffered and lagged with 1) distance downstream over the length of a point bar and 2) duration of the high flow event. We aim to generalize spatial patterns of groundwater exchange, intra-gravel, and near-bed temperatures at the meander-bend scale over a range of restoration flow releases in determination of suitable salmonid spawning habitat below Friant Dam.

Keywords: groundwater, surface water, river, hydrology, geomorphology, instream flow

Thursday, October 18, 2012: Room 306, Modeling (I)– Order 2

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Forecasting Delta Turbidity Conditions with Artificial Neural Networks

Paul Hutton, Metropolitan Water District of Southern California, phutton@mwdh2o.com
Sujoy Roy, Tetra Tech, Sujoy.Roy@tetratech.com
Limin Chen, Tetra Tech, limin.chen@tetratech.com

Significant salvage of adult Delta smelt at the south Delta export facilities has been observed to coincide with the formation of a turbidity "bridge" between the central and south Delta. The remanded 2008 USFWS biological opinion restricts reverse flows from the central to south Delta along Old and Middle Rivers when turbidity conditions reach pre-defined threshold levels. Understanding the influence of export operations on prevailing turbidity conditions is necessary to develop management strategies that promote cost-effective protection of adult Delta smelt.

Metropolitan Water District, in collaboration with its consulting team, has developed and piloted a decision support system over the past three years to forecast turbidity conditions in the Delta. The system integrates hydrology and operations forecasts, computer simulation models, and real-time data to generate Delta turbidity forecasts on a weekly basis during the winter when Delta smelt are preparing to spawn. To compliment this decision support system, a fast and easy-to-use tool with a spreadsheet-based interface was developed for scenario analysis as well as for long-term water supply planning. Employing artificial neural network technology, this tool was successfully designed and calibrated to mimic flow-turbidity relationships as modeled in DSM2, the Department of Water Resources' Delta hydrodynamic and water quality transport model. This tool, by allowing for rapid evaluation of turbidity response under alternative export and watershed loading scenarios, can provide scientists, regulators and operators insights for developing cost-effective management strategies for fishery protection.

Keywords: Delta smelt, biological opinion, turbidity, modeling, management strategies, hydrodynamics

Thursday, October 18, 2012: Room 306, Modeling (I)– Order 3

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The Devil is in the Details: Why the Representation of the Flow Field, Especially at Junctions, Matters in Order to Simulate Dispersion in the Delta

Nancy Monsen, Stanford University; Dept. of Civil and Environmental Engineering; Environmental Fluid Mechanics Laboratory, winter@stanford.edu
Phillip Wolfram, Stanford University; Dept. of Civil and Environmental Engineering; Environmental Fluid Mechanics Laboratory, pwolfram@stanford.edu
Karla Gleichauf, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, kgleich@stanford.edu
Oliver Fringer, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, fringer@stanford.edu
Stephen Monismith, Stanford University, Dept. of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory, monismith@stanford.edu

The Bay Delta Conservation Plan Effects Analysis in many cases represents the hydrodynamic flow field as an Eulerian tidally-averaged flow as the basis for many other ecological models. In addition, the Effects Analysis includes particle tracking to simulate migration patterns and entrainment of fish using a 1-dimensional hydrodynamic representation the Delta.We will present results from hydrodynamic simulations utilizing the newly developed SUNTANS multi-dimensional hydrodynamic model of the Delta to discuss why tidal flow and physical representation of junctions are essential to represent dispersion in the Delta.

We are extending the SUNTANS Bay hydrodynamic model to include the Sacramento- San Joaquin Delta region. This development includes the addition of river inflows as well as gate, pump, and temporary barrier operations. Using a particle tracking method, we will discuss circulation patterns and dispersion at key junctions in the Western and Central Delta. We will also identify regions where the length of tidal excursion is longer than the distance between junctions.

In the Delta, the characteristics of the channel junctions and a Lagrangian framework are important to understand mixing. The representation of mixing at junctions in hydrodynamic models is critical in order to use these foundational models to assess ecosystem stability in the near and long term.

Keywords: hydrodynamic models; dispersion; junctions; Lagrangian transport; circulation patterns; tidal flow

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 4

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Investigating the Retention of Planktonic Organisms in the Low-Salinity Zone Using a Particle Tracking Model

Edward Gross, Resource Management Associates, ed@rmanet.com
Wim Kimmerer, Romberg Tiburon Center, San Francisco State University, kimmerer@sfsu.edu
Michael MacWilliams, Delta Modeling Associates, michael@deltamodeling.com

A major challenge for estuarine plankton is to maintain populations within an estuary against tidal mixing and continuous seaward movement due to river flow. The Entrapment Zone study in 1994-1996 examined how vertical movements of plankton might result in retention in the Low-Salinity Zone of the San Francisco Estuary, generally in Suisun Bay. Copepods and larval fish appeared to move vertically in synchrony with the tidal currents, a pattern that should aid in retention of these organisms. However, retention calculated with observed vertical velocity profiles in the Suisun Bay channel was negligible, implying a need to represent the three-dimensional flow field. We have examined the influence of vertical movement on retention using the UnTRIM three-dimensional hydrodynamic model and the Fish-PTM particle tracking model. Particles were assigned various behaviors including passive drifting, tidal vertical migration, and constant downward swimming. We first determined the tidal patterns of vertical distribution of particles that resulted from each behavior, then selected behaviors that gave similar vertical profiles of abundance to those observed. We released particles distributed in salinity space similar to the distribution of *Eurytemora affinis* and compared retention of vertically migrating particles to retention of passive particles. Passive particles shifted seaward with the net flow. Downward movement, either tidally synchronized or continuous, reduced or eliminated seaward movement. Thus, the time-varying three-dimensional flow field determines how behaviors influence retention. By inference, the horizontal spatial distributions of organisms that move vertically would be difficult to predict without a particle tracking model operating at a suitably fine spatial scale.

This work is part of a project whose goal is to develop an understanding of the pelagic food web that accounts for hydrodynamic influences. We will incorporate this understanding into an individual-based model to explore the influence of management actions on the food web supporting pelagic fish species.

Keywords: modeling, hydrodynamic,s three-dimensional particle, copepod, pelagic, salinity, Suisun

Thursday, October 18, 2012: Room 306, Modeling (I) – Order 5

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Water Quality Model Framework to Support Resource Management Planning for the Sacramento San Joaquin Delta

Silong Lu, Dynamic Solutions LLC, slu@dsllc.com
Paul Craig, Dynamic Solutions-International, pmcraig@ds-intl.biz
Christopher Wallen, Dynamic Solutions LLC, cmwallen@dsllc.com
Zhijun Liu, Dynamic Solutions LLC, zliu@dsllc.com
Andrew Stoddard, Dynamic Solutions LLC, astoddard@dsllc.com
William McAnally, Dynamic Solutions LLC, whmcanally@dsllc.com
Eugene Maak, US Army Corps of Engineers, Sacramento District, Eugene.C.Maak@usace.army.mil

The Sacramento San Joaquin Delta is a unique estuarine resource that supports water supply, navigation, and recreation while maintaining a complex but fragile ecosystem. Ecosystem restoration and maintenance of an abundant supply of clean water to support agricultural and public needs have been deemed co-equal goals for planning efforts in the Delta. Long-term trends in nutrient availability have triggered questions about the sources and effects of nutrients on algal production and other ecological processes. Ecosystem models are needed to provide a scientifically credible framework to understand the complex interactions of natural conditions, regulatory controls, and resource management efforts on water quality and ecological resources. A three-dimensional water quality model – from Carquinez Strait, through Suisun Bay and the Delta to Verona on the Sacramento River and Vernalis on the San Joaquin River – has been developed by the USACE, Sacramento District using the Environmental Fluid Dynamics Code (EFDC). The model is a fully-coupled representation of Delta hydrodynamics, sediment transport, water quality and sediment diagenesis calibrated and validated to data from 2003 and 2004. Selected model results for nutrients, algae biomass (chlorophyll), and dissolved oxygen will be presented as (a) station time series and (b) for specific times along profiles running from Suisun Bay up the Sacramento and San Joaquin River channels. The Delta EFDC model provides a robust numerical modeling tool that can be used for Delta management to (a) support evaluations of proposed regulatory controls on nutrient sources and (b) provide a load-response model for a nutrient numeric endpoint framework. The results from this model have also been linked to a process-based lower trophic level ecological model to understand the effects of environmental conditions on the food web in the lower salinity zone.

Keywords: EFDC, water quality, model, nutrients, algae, oxygen, Suisun Bay Delta

Thursday, October 18, 2012: Room 306, Modeling (II)– Order 6

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Assessment and Comparison of One- and Two-Dimensional Models for Predicting Flow and Salinity in the Delta

Fabian Bombardelli, University of California, Davis, Department of Civil and Environmental Engineering, fabianbombardelli2@gmail.com
Swetcha Reddy, Northwest Hydraulics Consultants and UC Davis, svreddy@ucdavis.edu
James Kohne, University of California, Davis, jrkohne@ucdavis.edu
Mark Gowdy, California Water Resources Control Board, MGowdy@waterboards.ca.gov

The social, environmental, and economic importance of the Sacramento-San Joaquin Delta has led to the development, application and validation of several numerical models to address hydrodynamic and water quality conditions. Those models range from one-dimensional (1-D) approaches in channel networks, to 2-D and, recently, 3-D models. In the last 20 years, the Delta has been the subject of at least 10 independent modeling efforts using codes such as DSM2 (1-D), WAM (1-D), RMA2 (2-D), TRIM (2-D and 3-D), UnTRIM (3-D), Delft3D (3-D), EFDC (3-D), SUNTANS (3-D), etc., which provide a wealth of information about the system. No systematic comparisons of results of these efforts have been attempted. Yet future physical, biological and social 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 assessment and comparison of Delta-specific models developed by Resource Management Associates (RMA), RMA2 and WAM, and the Department of Water Resources (DWR), DSM2. This work starts with a thorough analysis of the models from the theoretical and numerical points of view, and highlights differences and similarities in the approaches. Subsequently, it discusses scenario-driven comparisons of performance of each model to historical data, and investigates model "accuracy" and sensitivity to varying levels of export pumping values, each within dry and wet water years. For the first time to the best of our knowledge, this work evaluates ranges of differences among model predictions and data for the Delta.

Keywords: DSM2, RMA2, WAM, model performance, data, Delta, salinity, numerics

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 7

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Flood Modeling in the Yolo Bypass to Support Habitat Evaluation

Chris Bowles, CBEC Eco Engineering, Inc., c.bowles@cbecoeng.com
April Sawyer, CBEC Eco Engineering, Inc., a.sawyer@cbecoeng.com
Chris Campbell, CBEC Eco Engineering, Inc., c.campbell@cbecoeng.com
Ray McDowell, DWR - FESSRO, rmcdowel@water.ca.gov
Marianne Kirkland, DWR-Division of Environmental Services, marianne@water.ca.gov

The Yolo Bypass is a major seasonal floodplain in the Central Valley and the Delta that provides rearing habitat and serves as a migratory pathway for juvenile Chinook salmon and splittail. In support of the Central Valley Flood Protection Plan (CVFPP) Restoration Opportunity Analysis (ROA), two-dimensional (2D) hydrodynamic modeling was performed using MIKE 21 FM to evaluate seasonal inundation patterns in the Yolo Bypass under a range of historical flows to understand habitat conditions for juvenile Chinook salmon and splittail. Inundation patterns are complex in the Yolo Bypass given the variability and timing of the source hydrology. Prior habitat use studies in the Yolo Bypass (e.g., Sommer et. al., 2005) have shown the importance of sustained inundation in the Yolo Bypass on fish success. As such, the objective of this study was to investigate habitat conditions in the Yolo Bypass under a range of flow conditions in years when spatial and temporal trends in juvenile Chinook salmon use were monitored. Historical hydrology for two high performing years and two low performing years for juvenile Chinook salmon and splittail were simulated in addition to two flood events (i.e., 2-year and 10-year) and used to assess habitat suitability and identify differences between years.

Keywords: Yolo Bypass, 2D modeling, habitat evaluation, fisheries, floodplain management

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 8

ED_000733_DD_NSF_00015174-00173

Tidal Salt Marsh Susceptibility with Sea-Level Rise: The Importance of Spatially-Explicit, Local-Scale Models to Assess Outcomes for Endangered Wildlife

Karen Thorne, USGS, kthorne@usgs.gov
Kevin Buffington, USGS, kbuffington@usgs.gov
John Takekawa, USGS, john_takekawa@usgs.gov
Deborah Elliot-Fisk, UC Davis, dlelliotfisk@ucdavis.edu

Coastal salt marshes and estuaries are projected to be disproportionately impacted by climate change and sea-level rise, according to the IPCC. Salt marshes along the west coast have been lost to urban development and landscape modification, limiting the habitat available for listed wildlife species. The maintenance and expansion of habitat is crucial to the successful recovery of these endangered species, but it remains unknown how much of an effect sea-level rise may have on the amount and quality of habitat. The focus of our interdisciplinary study is a bottom-up site-specific approach evaluating sea-level rise impacts to salt marsh habitats and wildlife by synthesizing field data and predictive modeling to develop habitat impact models. Our project has expanded to five sites along the Californian coast and is being implemented along the Washington and Oregon coasts. Elevation and sediment models, vegetation characteristics relative to elevation, and tidal inundation patterns have been established at each site to better understand potential future habitat changes. We hypothesize that a relatively small rise in sea level may result in increased drowning, nest failure, and an increase in predation pressure for many salt marsh species. Results from a new, spatially explicit sea-level rise response model for San Pablo Bay NWR will be discussed and compared with existing modeling efforts. Our model projects with 1.15 m of sea-level rise by 2100 that 80% of the existing marsh at San Pablo Bay refuge will transition to mudflat by 2060 with the remaining 20% converting by 2080. Our work illustrates the variable risk to wildlife species and identifies critical sea-level rise thresholds for salt marsh species.

Keywords: sea-level rise, salt marsh, response modeling, sediment, endangered species

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 9

ED_000733_DD_NSF_00015174-00174

Investigating the Influence of Tides, Inflows, and Exports on Sub-Daily Flows at Junctions in the Sacramento-San Joaquin Delta

Phil Gaskill, Cramer Fish Sciences, pgaskill@fishsciences.net
Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Jenny Melgo, Cramer Fish Sciences, jennym@fishsciences.net

The relative influence of tides, inflows, and exports on flow patterns in California's Sacramento-San Joaquin Delta continues to be a source of confusion and uncertainty for resource managers. The potential for impacts to sensitive fish species from export pumping remains highly contentious and has been the focus of recent Endangered Species Act Section 7 biological opinions. Particle tracking models (PTM) have been used to assess Delta flow patterns and entrainment risk of fish. PTM results are sensitive to net water movement within Delta channels and have not been used to describe daily and sub-daily variations in flow due to the interaction of tides with river inflows and exports. Yet, tidally-driven variations are known to influence salmon migration, and recent studies have pointed out that the interaction of complex fish behaviors and sub-daily changes in flow is the key to understanding migration and entrainment, particularly at junctions. We take a new approach to analyzing water movement in the Delta; one that is potentially more useful in describing water movement relevant to migrating salmon than PTM. Informed by recent acoustic tagging studies, and starting with inflow and export scenarios from Kimmerer and Nobriga (2008), we used flow data taken at 15-minute intervals from a Delta Simulation Model-2 Hydrodynamics model simulation to analyze sub-daily flow patterns in nine key Delta junctions. We obtained a detailed description of how tides, river inflows, and exports interact to influence juvenile salmon route selection. We found that tidal flow and stage are the primary influence on flow patterns, as well as on the proportion of water which enters the interior Delta, and that river inflow and export levels have a minor influence on flow patterns at most junctions. These findings sharply contrast with the results of PTM studies, and provide new insights for Delta water management.

Keywords: salmon; DSM2 Hydro; flow; junctions; migration; entrainment; tides; inflows; exports

Thursday, October 18, 2012: Room 306, Modeling (II) – Order 10

ED_000733_DD_NSF_00015174-00175

Transitions in the Delta Economy

Josue Medellin-Azuara, Center for Watershed Sciences, UC Davis, jmedellin@ucdavis.edu
Ellen Hanak, Public Policy Institute of California, hanak@ppic.org
Richard Howitt, Agricultural and Resource Economics UC Davis, howitt@primal.ucdavis.edu
Jay Lund, Center for Watershed Sciences, UC Davis, jrlund@ucdavis.edu

The future of the Sacramento- San Joaquin Delta is characterized by change from physical forces and water management decisions. More permanently flooding of subsided areas, changes in water quality and habitat expansion may reshape the Delta we know today. In this study we explore how these changes may affect the Delta regional economy. Most changes in the Delta are likely to occur in the inner Delta or the primary zone, a heavily agricultural area. However, most of the business activity and population growth occurs on the secondary zone. Changes in salinity from either water exports or permanent flooding are relatively minor and may not affect agricultural production overall. Areas of natural habitat development were considered based on a prioritization of ecosystem investments study. A cost-benefit analysis for repairing levees after flooding was conducted to determine worthwhile areas to maintain in the event of levee failures. Most losses to agriculture are due to permanently flooded areas or habitat expansion, whereas water quality effects are marginal. About 1800 jobs and 130 million dollars in value added could be lost every year as a result of combined flooding and water quality effects. Water-based recreation has the potential of reducing job and value added losses from flooding and water quality. A better levee policy, mitigation programs for affected parties and research on hydrodynamics and levee prioritization may benefit the future of the Delta economy.

Keywords: Sacramento-San Joaquin Delta, water quality, modeling, multiplier effects, flooding, habitat

Thursday, October 18, 2012: Room 307, Delta People: Residents, Workers, and Recreationists–Order 1

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Economy of the Sacramento-San Joaquin Delta

Jeffrey Michael, University of the Pacific, Business Forcasting Center, jmichael@pacific.edu
Thomas Pogue, University of the Pacific, Business Forecasting Center, tpogue@pacific.edu
Pete Dangermond, The Dangermond Group,
Ben Sigman, Economic & Planning Systems,
Jesse Walker, Economic & Planning Systems,
Karen Winters, The Dangermond Group,

Current long-term Bay-Delta management planning seeks to achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem…in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Through an analysis of the Delta's economy this presentation aims to inform management of the Delta.

The presentation draws on the Delta Protection Commission's recently completed *Economic Sustainability Plan*, which compiled a broad set of indicators and information about the Delta's economy. In addition, the presentation utilizes information from the *Delta Sustainability Scoreboard* that the University of the Pacific's Business Forecasting Center is developing to monitor and evaluate economic sustainability in the Delta.

These analyses indicate that there are approximately 200,000 jobs in the Delta, the vast majority of these (approximately 97%) are in the Secondary Zone. Overall, the Delta appears to have a relatively balanced employment composition typical of suburban areas with four sectors accounting for about 44% of employment: retail (13%), education (12%), health care and social services (10%). In contrast employment in the Primary Zone is heavily concentrated in the agriculture sector, which accounts for 44% of all jobs. Recreation-related industries: retail, arts/entertainment, and accommodation/food services, account for roughly 9% of jobs in the Primary Zone. Location quotient analysis of gross regional product shows the Delta has high relative concentrations of economic activity in three areas: agriculture; transportation, warehousing and utilities; construction, housing and real estate. The Delta is also a diverse and critical infrastructure hub for the regional and state economy. Besides the state water system it hosts extensive energy, transportation, and in-Delta municipal and industrial water supplies.

Keywords: Primary zone economy, employment, industry clusters, agriculture, recreation, infrastructure

Thursday, October 18, 2012: Room 307, Delta People: Residents, Workers, and Recreationists–Order 2

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People of the Sacramento-San Joaquin Delta

Thomas Pogue, University of the Pacific, Business Forecasting Center, tpogue@pacific.edu
Jeffrey Michael, University of the Pacific, Business Forecasting Center, jmichael@pacific.edu
Ben Sigman, Economic & Planning Systems,
Jason Moody, Economic & Planning Systems,

Current Bay-Delta management planning seeks to achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem…in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Through an analysis of the Delta's residents this presentation aims to inform management of the Delta.

The presentation draws on the Delta Protection Commission's *Economic Sustainability Plan*, which compiled indicators and information about the Delta's economy. In addition, the presentation utilizes the *Delta Sustainability Scoreboard* that the University of the Pacific's Business Forecasting Center is developing to monitor and evaluate economic sustainability in the Delta.

It is estimated that in 2010 the Delta had 570,000 residents, but only about 12,000 of these individuals lived in the Primary Zone. While the more suburban Secondary Zone grew by 56% between 1990 and 2010, the relatively rural Primary Zone has about the same population as 20 years ago. Taken as a whole, the Delta's age and household composition is similar to California, but with slightly younger and larger families. However, the Primary Zone had a notably older population, fewer children and relatively small households. In terms of race, 56% of residents identified themselves as being White in the Secondary Zone and 75% in the Primary Zone. Between 1990 and 2010, the Delta's Secondary Zone saw a 50% net increase in new housing units, while the Primary Zone saw 10% growth despite its stagnant population. Across the Delta workers have relatively complex commute patterns typical of areas where residents generally work elsewhere. The Delta also has a better educated population than California as a whole, but it is nuanced with fewer high school drop-outs but also a smaller share of residents with higher education.

Keywords: Primary Zone residents, demographics, housing, education, commuting

Thursday, October 18, 2012: Room 307, Delta People: Residents, Workers, and Recreationists–Order 3

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Recreational Opportunities in the Delta and Suisun Marsh

Cheryl Essex, California State Parks, cessex@parks.ca.gov

Problem Statement: Five million people live within a 20-minute drive of the Sacramento-San Joaquin Delta and Suisun Marsh, with many drawn to enjoy the region's waterways, parks, wildlife refuges, historic communities and pleasant country roads. What does the future hold for recreation and tourism in this dynamic landscape?

Approach: The Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh carries out the Delta Reform Act's guidance to California State Parks. This proposal informs both the Delta Protection Commission's Economic Sustainability Plan and the Delta Stewardship Council's Delta Plan by:

- Assessing recreation demand and opportunities
- Describing issues that may affect recreation
- Recommending additions and/or improvements to state-managed lands and programs to increase recreational opportunities

Results: This study describes the types of recreation that residents and visitors desire and describes the State's role in protecting and enhancing recreational opportunities. Research suggests there is significant and increasing demand for recreation and tourism development in the region, but Delta and Suisun Marsh recreation providers face substantial barriers. Encouraging more residents and visitors to enjoy and appreciate the unique, inherent values of the Delta and Suisun Marsh will require strong partnerships between the region's communities and the State.

Relevance: A better understanding of the Delta and Suisun Marsh's recreation potential will assist water resource and ecosystem restoration specialists support and implement policies and projects that will increase recreational opportunities, business income, local and state tax revenues and jobs in the region.

Keywords: Human demographics, culture

Thursday, October 18, 2012: Room 307, Delta People: Residents, Workers, and Recreationists–Order 4

ED_000733_DD_NSF_00015174-00179

Modeling the Hydraulics of Expanded Floodways on the Lower San Joaquin River

Paul Frank, NewFields, pfrank@newfields.com
Mark Tompkins, NewFields, mtompkins@newfields.com

Past efforts to plan flood corridor improvements on a large-scale basis in the central valley have often relied on gross estimations of water surfaces outside of current levees rather than true hydraulic modeling. Modeling the hydraulics of the lower San Joaquin River and its floodplain is complicated by multiple distributary channels, built infrastructure affecting flow routing, and its multiple parallel channels. We conducted one-dimensional numerical modeling of river and floodplain hydraulics on the lower San Joaquin River using a newly updated and modified version of the Hydrologic Engineering Center - River Analysis System (HEC-RAS) model originally created for the Comprehensive Study. Novel modifications to the original model now allow predictions of floodplain hydraulics and the model has been extended longitudinally downstream in key areas. We developed an "existing conditions" configuration and multiple "expanded floodway conditions" that included modifications of levees, weirs, and flood bypasses. Output from this hydraulic modeling provided input to evaluations of ecosystem benefit, flood risk reduction, and water supply improvement associated with expanded lower San Joaquin floodways and allowed us to iteratively evaluate a range of alternative configurations to improve flood routing performance and restore critical habitat types.

Keywords: San Joaquin, Flood Management, Ecosystem Restoration

Thursday, October 18, 2012: Room 307, Multiple Benefits of Flood Corridors on the Lower San Joaquin River– Order 1

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Developing Alternate Hydrologies for the Lower San Joaquin River

Rich Walkling, Restoration Design Group, rich@rdgmail.com

We selected and designed multiple hydrologies to evaluate the sensitivity of ecosystem and flood risk performance of alternate floodway topographies to changes in flow. Hydrologies included 1) a post-Friant dam period record (1970-2011); 2) a hot and dry climate change scenario (2001-2099); and 3) an augmented flow scenario (60% unimpaired 1929-2011 flows). We developed the post-dam flow record using publicly available daily flow data for the Vernalis USGS gage, and for the hot and dry climate change scenario we used the Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE) data. We created the augmented flow scenario by disaggregating March, April, and May monthly flood volumes equal to 60% of the unimpaired flows into hypothetical daily hydrographs that would maximize 7, 14, 21, and 28-day inundation on the floodplains of the proposed bypass. In any given year, we limited peak flows in the augmented flow scenario to the existing peak flows in the historical record (or 20,000 cfs, whichever was greater) so that the new hydrologic regime would not increase flood risk. We examined the plausibility of delivering 60% unimpaired flows for floodplain inundation at Vernalis without impairing water deliveries using a Water Evaluation and Planning (WEAP) model designed for the Stanislaus, Tuolumne, Merced and San Joaquin River systems. This presentation will focus on the development of the augmented flow record as this record showed the most significant improvements in ecosystem conditions.

Keywords: San Joaquin River Flood Corridors Hydrology

Thursday, October 18, 2012: Room 307, Multiple Benefits of Flood Corridors on the Lower San Joaquin River– Order 2

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Quantifying the Ecosystem Benefits of Restored Floodplain Habitat Connectivity on the Lower San Joaquin River

Mary Matella, UC Berkeley, mmatella@berkeley.edu
Katie Jagt, American Rivers, katiejagt@gmail.com

California's Sacramento-San Joaquin Delta was once a dynamic ecosystem that flooded seasonally, but topographic and hydrologic alterations for water supply and flood control have severed hydraulic connections, leading to habitat loss and declines in aquatic biodiversity. To evaluate the potential ecological benefits of floodplain reconnection, we used results from a one-dimensional hydraulic model of the lower San Joaquin River system with a statistical ecosystem functions model to quantify the potential habitat benefits resulting from floodplain reconnections and ecosystem friendly reservoir operations. We evaluated a range of corridor expansion alternatives and hydrologies. Our ecosystem benefit metrics quantify the potential floodplain habitat as a function of season, duration, and frequency in Area-Duration-Frequency (ADF) curves and as annualized expected habitat (AEH). We summarize the development and implementation of these metrics and present results for an expanded floodway that includes levee setbacks along the San Joaquin River, Paradise Cut, and Fabian Tract with historical, climate change-influenced, and augmented hydrologies. Under climate change, we see substantial floodplain habitat loss in a no-action scenario. The historical and augmented hydrologies show how the potential benefit of floodway expansion depends on available flows. This project presents a method for quantifying the impact of floodplain reconnection, bounding the range of benefits that a large-scale floodplain reconnection could provide along the lower San Joaquin River, and can help managers evaluate floodplain restoration projects as part of flood management planning.

Keywords: river-floodplain restoration; ecosystem functions model

Thursday, October 18, 2012: Room 307, Multiple Benefits of Flood Corridors on the Lower San Joaquin River– Order 3

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Evaluating Changes in Flood Risk with Changes in Floodway Size and Hydrology Along the Lower San Joaquin River

Katie Jagt, Consulting Engineer to American Rivers, katiejagt@gmail.com

We developed a method that uses output from a hydraulic model of the lower San Joaquin River, hydrologic statistics, levee failure curves, and GIS modeling to evaluate the potential flood-risk benefits of floodplain reconnection projects. We examined two physical configurations of the lower San Joaquin River in this analysis: the existing system with levees that closely follow the mainstem channel alignment, and an expanded floodway that would reconnect approximately 20,000 acres of historical floodplain. To quantify flood risk benefits we established metrics that describe the annualized probability of levee failure though the reach. This number represents the probability of a levee failure, within each reach of the project, in any given year. Starting with hydraulic model outputs and high resolution DEMs of the project area, we calculated the freeboard for each 10foot section of levee throughout the reach. Using previously published levee fragility curves we then correlated freeboard to a levee failure probability that accounts for geotechnical failures as well as overtopping. We found that the annualized probability of levee failure decreases by approximately 50 percent with an expanded floodway. Through this analysis we also were able to show substantial water surface elevation reductions and flood risk benefits to vulnerable areas such as the City of Stockton.

Keywords: Flood risk, levee failure, multiple benefits, hydraulic modeling.

Thursday, October 18, 2012: Room 307, Multiple Benefits of Flood Corridors on the Lower San Joaquin River– Order 4

ED_000733_DD_NSF_00015174-00183

A Flow of Analyses to Evaluate Multiple Benefits of Floodway Expansion Along the Lower San Joaquin River

John Cain, American Rivers, jcain@americanrivers.org

Major ongoing water resources planning efforts including the Delta Plan, the Bay Delta Conservation Plan (BDCP), and the Central Valley Flood Management Plan (CVFMP) identify the creation of floodplain habitat as a critical element of success. However, a clear approach to 1) defining necessary modifications to existing river corridor conditions, and 2) systematically evaluating the three primary benefits (water supply, flood management, and ecosystem) of the modified system has remained elusive. We have developed a simple flow of analyses to evaluate these three benefits and have demonstrated its use through a pilot study of an expanded floodway on the lower San Joaquin River. Several related abstracts summarize the major components of this flow of analyses. Here we summarize the development, challenges, and novel advances that we experienced in completing this study, and implications of our primary finding that an expanded lower San Joaquin floodway could measurably improve flood management, increase water supply reliability, and improve ecosystem conditions.

Keywords: San Joaquin River, flood management, floodplain reconnection, restoration, water supply

Thursday, October 18, 2012: Room 307, Multiple Benefits of Flood Corridors on the Lower San Joaquin River– Order 5

ED_000733_DD_NSF_00015174-00184

Adaptive Management in the Delta Plan

Lindsay Correa, Delta Science Program, Delta Stewardship Council, lindsay.correa@deltacouncil.ca.gov
Clifford Dahm, University of New Mexico - Albuquerque, New Mexico, cdahm@sevilleta.unm.edu

The Delta Reform Act of 2009 requires the use of adaptive management and defines adaptive management as "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives" (Water code section 85052). Inconsistent use of adaptive management for water supply management and ecosystem restoration in the Delta leads to unintended consequences such as reduced likelihood of project, plan or program success and increased likelihood of adverse environmental impact. Adaptive management provides flexibility and feedback to the management of natural resources in the face of considerable uncertainty. The Delta Stewardship Council must include in its Delta Plan "a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions" (Water code section 85308(f)). The Delta Plan puts forth a three-phase ("Plan", "Do", and "Evaluate and Respond") and nine-step adaptive management approach for ongoing ecosystem restoration and water management decisions. The Council is applying this science-based adaptive management framework to the Delta Plan and requiring its use by proponents of ecosystem restoration and water management actions seeking consistency with the Delta Plan. Intended outcomes of this approach include broader and more consistent use of adaptive management, the application and development of best scientific information, and an increased likelihood of success for water and environmental decision making under conditions of uncertainty. Proper development and application of adaptive management plans for programs and projects in the Delta will lead to an improved state of knowledge of the system and ultimately inform policy-makers and managers about California's progress toward achieving its coequal goals of "a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem" (Water code section 85054).

Keywords: adaptive management, Delta, water management, ecosystem restoration, plan, policy

Thursday, October 18, 2012: Room 307, Adaptive Management– Order 1

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The Necessary Action to Ensure the Ecological Recovery of the San Joaquin Delta

Stacy K. Li, Aquatic Systems Research, stacyli@sonic.net

The Sacramento San Joaquin Delta is a rare inverted river delta, so the Delta is actually deltas and the ecological effects from water export operations in each delta are separate. The Sacramento Delta ecology is relatively unaffected by present water export operations. In stark contrast, the San Joaquin Delta ecology has been profoundly degraded by current and historical water export operations. Large population declines of Chinook salmon, steelhead, delta smelt, longfin smelt, threadfin shad and young-of-the-year striped bass are direct adverse effects of present water export operations. All of these declines can be reversed, with improvement of other ecological conditions if the following action is taken: Allow no flow reversals to occur in the San Joaquin River.

In addition to water supply and delta ecological improvement, controlling salt intrusion during the flood tide cycle is an important political and economic consideration. The San Joaquin River is better at resisting salt intrusion than the Sacramento River, so except for in-Delta diversions, allow all San Joaquin River flow to "waste" to the sea.

Benefits from this single action include: return of emigration cues for salmonid smolts, return of attraction flows for returning anadromous adults, return of backwater habitats for delta and longfin smelts, return of longer residence time of San Joaquin River water that will facilitate an increase in abundance and diversity of planktonic communities needed by threadfin shad and young-of-the year striped bass, and an almost complete cessation of salt importation into the San Joaquin Valley, along with a decrease in water treatment costs.

Keywords: ecological recovery reverse flows POD

Thursday, October 18, 2012: Room 307, Adaptive Management– Order 2

ED_000733_DD_NSF_00015174-00186

Can Adaptive Management for the Sacramento-San Joaquin Delta be More Than Words?

Jay Lund, Department of Civil and Environmental Engineering UC Davis, Center for Watershed Sciences, jrlund@ucdavis.edu

"Adaptive management" is an almost unavoidable term in contemporary environmental planning, management, and policy. It is almost impossible to have a major environmental planning or policy effort which does not refer to or require it. Although rhetorical consensus on the desirability of adaptive management seems frequently achieved, implementation experience has been more varied and faces important impediments. This has spawned numerous learned papers and reports on the success, prospects, and pitfalls of adaptive management. Adaptive management seems to have taken on many practical meanings which differ from the original approach suggested by C.S. Holling (1978). The various schools of adaptive management thought seem to include Model, manage, monitor, and revise (Holling 1978); Experimental management (Lee); Real-time management(e.g., VAMP); Manage and revise reactively (trial and error); Manage and promise to fix later; and Just keep saying adaptive management.

The Delta's ecosystem includes a growing list of threatened and endangered species under federal and state legislation, as well as a growing number of invasive species and growing controversies over water and land management. Hundreds of federal, state, and local agencies are involved, as well as numerous non-governmental organizations and private stakeholders. Several planning processes are ongoing; all are controversial. Many invoke "adaptive management". The development of an ecologically effective adaptive management program is technically, scientifically, institutionally, and politically difficult under these circumstances. But, there seems little alternative except to try.

Some ideas are suggested for developing an effective adaptive management program under these challenging conditions. Perfection is unlikely. The rapid learning needed for adaptive management will challenge both bureaucratic and scientific cultures; mistakes from both perspectives will be made. Mistakes are important for learning.

Keywords: adaptive management

Thursday, October 18, 2012: Room 307, Adaptive Management– Order 3

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Managing Freshwater Inflows to the San Francisco Estuary to Reverse "Chronic Drought" Conditions

Christina Swanson, Natural Resources Defense Council, cswanson@nrdc.org

The amounts and variability of freshwater inflows to the San Francisco Estuary—key physical and ecological drivers that create estuarine habitat, promote productivity and influence abundance, movement and life cycles of fish and wildlife—have been highly altered by dams and water diversions. Addressing the estuary's altered hydrograph, one of the principal stressors on the ecosystem and its fish resources, is one of the most challenging issues for development of plans to meet the state-mandated co-equal goals of ecosystem restoration and water supply reliability. In this presentation, I discuss application of quantitative indicators of freshwater inflow conditions developed for the San Francisco Estuary Partnership's State of the San Francisco Bay report for exploration of alternative flow management strategies for the estuary. For the past 30 years (1982-2011), annual freshwater inflows to the estuary have been reduced by 45%, on average, compared to estimated unimpaired inflows. Proportional flow reductions are greatest in drier years, averaging 60% in the driest 40% of years. Reduced annual inflows have doubled the frequency of years in which the estuary receives inflows comparable to what it would have received in the driest 20% of years under unimpaired conditions, effectively driving the estuary into anthropogenic "chronic drought" conditions. Directed management of inflows as a percentage of unimpaired flows, a strategy under investigation by the State Water Resources Control Board, could improve conditions. For example, annual inflows at 75% of unimpaired flows restore inter-annual variability to a more natural pattern. By comparison, flows at 65% of unimpaired increase the frequency of "very dry" inflow conditions by 56%, from 9 to 14 years during the 1982-2011.These results reinforce the importance of evaluating outcomes of various proposed flow management regimens in terms of inter-annual variability as well as in terms of flow amounts.

Keywords: Estuary, freshwater inflows, flow management, indicators, water supply

Thursday, October 18, 2012: Room 307, Adaptive Management– Order 4

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Unifying the Science, Regulation and Operation of the Delta Water-Works System: A Practical Path Forward

Erwin Van Nieuwenhuyse, Bureau of Reclamation, evannieuwenhuyse@usbr.gov

Biological Opinions designed to protect listed fish populations in the Sacramento-San Joaquin catchment are poorly integrated with each other and with the coordinated operation of the Central Valley Project and State Water Project (CVP/SWP). This lack of unity stems in part from the single-species focus of the Endangered Species Act (ESA) and from the lack of unity in the science that is supposed to inform the ESA consultation process. Each Biological Opinion hinges on hundreds of hypotheses that require research and monitoring programs to test them all. Delta science is thus anchored to the regulatory process rather than the other way around. This lack of regulatory and scientific integration makes it impossible to achieve the co-equilibrium of environmentally and economically responsible water supply management mandated by federal and state law. This talk will present a practical strategy for unifying and aligning the science, regulation and operation of the CVP/SWP to help achieve this new co-equilibrium.

Keywords: unity, integration, Endangered Species Act, co-equal goals, water operations, regulations

Thursday, October 18, 2012: Room 307, Adaptive Management– Order 5

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Prioritizing Tidal Marsh Conservation and Restoration Efforts Given High Uncertainty due to Future Environmental Change

Sam Veloz, PRBO Conservation Science, sveloz@prbo.org
Nadav Nur, PRBO Conservation Science, nnur@prbo.org
Leonardo Salas, PRBO Conservation Science, lsalas@prbo.org
Diana Stralberg, University of Alberta, Canada, stralber@ualberta.ca
Dennis Jongsomjit, PRBO Conservation Science, djongsomjit@prbo.org
Julian Wood, PRBO Conservation Science, jwood@prbo.org
Leonard Liu, PRBO Conservation Science, lliu@prbo.org
Grant Ballard, PRBO Conservation Science, gballard@prbo.org

Uncertainty surrounding the effects of sea-level rise and climate change on tidal marsh habitats, and the species that depend on them, exacerbates the difficulty in planning effective conservation and restoration efforts. To help conservation practitioners address this uncertainty, we projected the distribution and abundance of tidal marsh bird species in the San Francisco Estuary in twenty-year intervals, from 2010 to 2110. To assess the sensitivity of models to uncertainty in future conditions, we considered four future scenarios, with assumptions of low or high suspended sediment concentrations and two rates of sea-level rise (0.52 m or 1.65 m/100 yr). We used the projections of bird populations to prioritize current and future marsh sites for conservation and restoration using Zonation conservation planning software. We evaluated whether the ranking of the top 25% of proposed restoration projects changed based on which future scenario we used in the prioritization. We ranked the potential restoration projects under six scenarios: the four future scenarios, one scenario representing current conditions, and one scenario including all future scenarios. We found that ranking restoration projects based on current conditions only consistently resulted in fewer tidal marsh birds protected under all scenarios, suggesting that ignoring future forecasts because of high uncertainty can lead to inefficient use of resources and high biological costs. Ranking the restoration sites based on only one of the four future scenarios showed variable performance depending on which future scenario was used. Ranking restoration projects using the combined scenario consistently performed as well as or better than rankings using individual scenarios regardless of what future scenario was used to assess performance. Our results demonstrate the value of using models of different scenarios to ensure that climate change adaptation plans are robust to the uncertainty in future conditions.

Keywords: Uncertainty, Conservation Prioritization, Tidal Marsh Birds, Sea Level Rise

Thursday, October 18, 2012: Room 307, Integrated Science and Management– Order 1

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Restoration in the North Delta

Amy Merrill, Stillwater Sciences, amy@stillwatersci.com
Anitra Pawley, Department of Water Resources, apawley@water.ca.gov
Megan Keever, Stillwater Sciences, megan@stillwatersci.com

In the north-eastern Delta, where sea level rise, increased frequency of large flow events, and the potential to remove or set back levees are at hand, restoration needs to proceed in the face of uncertain and likely changing hydrologic conditions. Using a case study from Grizzly Slough near Thornton California, we discuss how restoration can be implemented in the face of environmental and funding uncertainties. The DWR-owned land parcel is located between Grizzly and Bear Sloughs, near the confluence of the Cosumnes, Mokelumne and Sacramento rivers, which historically hosted distributary channels in a landscape of emergent wetland and mixed riparian vegetation. Currently leveed and farmed, the parcel floods approximately every 10 years. Our restoration design, being implemented in 2011 and 2012, accommodates future variable hydrologic conditions while incorporating existing volunteer riparian vegetation and addressing weed control. We took advantage of 'natures' gifts' by developing a unique swale design and supplying water using an innovative method of puncturing an aquiclude and using the release in hydrostatic pressure to flood historic low elevation distributary channel surfaces. We also took advantage of existing volunteer riparian cottonwood and willow cohorts and local seed sources for natural recruitment. In addition, the planted vegetation types include species with wide hydrologic tolerance ranges that can accommodate future changes in conditions (e.g. sea level rise, full or partial levee removal). Results from two monitoring seasons indicate the viability of this design and suggest maintenance approaches. Vigorous growth of native woody and herbaceous plants was observed (>85% survival in most instances) but extensive control of invasives was necessary. This project is part of a broader planning effort to link multiple high quality riparian forests and wetlands throughout the northeast Sacramento-San Joaquin Delta in order to create a landscape scale corridor for anadromous fish, migratory birds, and other wildlife.

Keywords: riparian, restoration, recruitment, landscape ecology, north Delta, monitoring, weed control

Thursday, October 18, 2012: Room 307, Integrated Science and Management– Order 2

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Scaling Restoration Strategies to Ecosystem Processes

Michael C. Vasey, Department of Biology, San Francisco State University, mcvasey@gmail.com
V. Thomas Parker, Department of Biology, San Francisco State University, parker@sfsu.edu
John C. Callaway, Department of Environmental Science, University of San Francisco, callaway@usfca.edu
Lisa M. Schile, Department of Environmental Science, Management, and Policy, University of California Berkeley, lmschile@gmail.com

Recent empirical studies have demonstrated that, at a regional scale, strong environmental filters limit species diversity in more stressful, less productive ends of a gradient whereas stochastic processes (such as dispersal limitation and priority effects) are more important in less physically stressful, more productive environments. To test this theoretical premise, we investigated within- and among-tidal wetland plant species diversity patterns along a broad gradient from freshwater to salt marshes. Our six study sites focused on remnant tidal wetlands with minimal anthropogenic influence: China Camp, Petaluma Marsh, Coon Island, Rush Ranch, Browns Island, and Sand Mound Slough. We found that, as predicted, salt marshes with high salinity levels have significantly reduced species diversity compared to species diversity in brackish and freshwater marshes. Similarly, we found fewer differences among plots at the stressful end of the gradient (using multivariate analysis of dispersion) compared to the Delta site. These findings suggest that restoration strategies based on predictable, deterministic responses of species in salt marshes may be relatively successful in restoring Bay wetlands, but a strategy attuned to more stochastic processes is critical for restoration of biodiversity in the Delta. This implies that assisted migration and other restoration methods emulating random processes will be necessary to sustain diversity in the upper portion of the Estuary. In reality, deterministic and stochastic processes are inherent in community assembly mechanisms throughout the estuary but differ in degree of importance at any particular site. In the Bay, specialized habitats such as brackish upland-wetland transition zones probably require a similar stochastic approach to restoration. Ultimately, the key is to incorporate the appropriate ecosystem processes to match the restoration strategy that best takes into account these different scales of community dynamics.

Keywords: Deterministic, Stochastic, Environmental Filters, Dispersal Limitation, Tidal Wetland, Salinity Gradient

Thursday, October 18, 2012: Room 307, Integrated Science and Management– Order 3

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Communicating Bay-Delta Science to the Public: Envisioning the Delta as it Was

Jon Christensen, Stanford University, Bill Lane Center for the American West, jonchristensen@stanford.edu

Earlier this year KQED's science program "Quest" collaborated with the San Francisco Estuary Institute and Stanford University's Bill Lane Center for the American West to produce an interactive, multimedia online application based on SFEI's research on the historical ecology of the Sacramento-San Joaquin Delta. The online feature enabled the public to explore the sources, methods, and findings of the scientific and historical research in a compelling, user-friendly format enriched by narratives, maps, photographs, and historical documents. The online application accompanies a radio feature story that aired on Morning Edition on KQED and on the California Report statewide and was part of a series of stories exploring the history, science, and future of the Delta. The entire effort was based on a deep collaboration between scientists, scholars, and journalists. This special oral presentation will feature a panel that will tell the story of this collaboration, discuss its significance and the necessary ingredients for success in such collaborations, and explore the lessons learned for future efforts to enrich public understanding of science and its implications for the Bay-Delta.

Keywords: Multimedia online application, Public, Quest

Thursday, October 18, 2012: Room 307, Integrated Science and Management– Order 4 & 5

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Preliminary Analysis of Suspended-Sediment Concentration and Turbidity in the Fall Low Salinity Zone of the San Francisco Estuary

David Schoellhamer, U.S. Geological Survey, dschoell@usgs.gov
Tara Morgan-King, U.S. Geological Survey, tamorgan@usgs.gov
Maureen Downing-Kunz, U.S. Geological Survey, mokunz@usgs.gov
Scott Wright, U.S. Geological Survey, sawright@usgs.gov
Greg Shellenbarger, U.S. Geological Survey, gshellen@usgs.gov

During fall, delta smelt occupy the low salinity zone (salinity 1-6) of the San Francisco Estuary which is located in eastern Suisun Bay or landward at the confluence of the Sacramento and San Joaquin Rivers. Delta smelt also occupy the freshwater Cache Slough complex. Delta smelt favor more turbid water and turbidity is primarily a function of suspended-sediment concentration (SSC) in the Estuary. The USGS California Water Science Center has continuously monitored turbidity and SSC in the Cache Slough complex since 2008 and SSC in eastern Suisun Bay at Mallard Island since 1994. In fall 2011, we deployed instruments to measure hydrodynamics, turbidity, and SSC at two Suisun Bay sites, Grizzly Bay and Suisun Cutoff, where we made similar measurements in fall 1995. Preliminary findings are that 1) the position of the salinity 2 isohaline (X2) does not affect fall SSC at Mallard Island, 2) mean fall SSC at Mallard Island decreased by about one-half from 1994 to 2011 and in Grizzly Bay and Suisun Cutoff it was 45% and 9% less in 2011 than in 1995, 3) Suisun Bay was usually more turbid than the confluence in fall 1994-2011, 4) Suisun Bay was usually more turbid than the Cache Slough complex in fall 2011, and 5) turbidity at Mallard Island was greater in fall 2011 than 2010 but in the Cache Slough complex the opposite was observed with turbidity being greater in fall 2010 than 2011. Factors affecting the fall turbidity may include wind, salinity, clearing of estuarine waters, tides, and prior wet season flow and sediment supply.

Keywords: delta smelt, habitat, turbidity, suspended sediment, low salinity zone,

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (I) – Order 1

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Comparison of Seston Composition and Sources in the Delta during Two High-Flow Falls, 2006 and 2011

Carol Kendall, U. S. Geological Survey, ckendall@usgs.gov
Steve Silva, U. S. Geological Survey, srsilva@usgs.gov
Megan Young, U. S. Geological Survey, mbyoung@usgs.gov
Jennifer Lehman, U. S. Geological Survey, jlehman@usgs.gov
Calla Schmidt, U. S. Geological Survey & UCSC, callaschmidt@gmail.com
Marianne Guerin, Resource Management Associates, maguerin@rmanet.com

We have been using a multi-tracer, multi-isotope approach to assess biogeochemical processes and sources of organic matter, nutrients, and water at several score main-channel and tributary sites in the Delta 2005-2012. Since this large dataset overlaps the three main fall habitats of delta smelt, we are evaluating whether the additional biogeochemical insights provided by a multi-fingerprinting approach might explain more of the variance in smelt presence-absence than the X2-habitat curve approach. For this comparison, we analyzed bulk seston (POM) for $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, and C:N. Samples were also analyzed for ammonium, nitrate, DOC, and water isotopes to further evaluate habitat conditions; these latter analyses for 2011 are in progress. Splits of all samples were analyzed for nutrients, chlorophyll, and other constituents.

Sacramento River flow was relatively high in the falls of both 2006 and 2011 as a result of the preceding wet springs, with fall 2011 having slightly higher flow. These two high-flow falls had very different biological, chemical, and isotopic responses; in specific, 2011 had lower nutrient concentrations, higher NO3/NH4, and much more frequent and larger phytoplankton blooms. POM composition is sensitive to changes in salinity, nutrient sources, extent and type of C-N-S cycling, geographic sources of the POM, and quality of the organic matter. The two years showed huge differences in POM sources and quality, and biogeochemical processing of C-N-S. For example, POM in 2011 had a much lower percent of terrestrial POM and showed a steeper downstream gradient of C cycling, less uptake of marine SO4, and N that was more affected by nitrification. The POM in 2011 was higher-quality than in 2006, and was derived in part from the Cache/Yolo region. Therefore, small differences in flow between fall 2006 and 2011 resulted in huge changes in the sources and quality of organic matter.

Keywords: isotopes, POM, seston, habitat-quality, nutrients, organic-matter-quality

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (I) – Order 2

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Modeling Fall LSZ Habitat Using the UnTRIM Bay-Delta Model

Michael MacWilliams, Delta Modeling Associates, Inc., michael@deltamodeling.com

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.

The UnTRIM Bay-Delta model was applied to characterize the areal and volumetric extent of estuarine habitat in the Low Salinity Zone (LSZ) over a range of historic conditions between 1994 and 2011. The area, volume, and average depth of the LSZ was related to the position of the 2 psu isohaline (X2) on each simulation day to establish relationships between the position of X2 and the location and extent of the LSZ. The percentage of time per day the LSZ resides in a given location of the Bay-Delta was also evaluated. This approach unifies the 1-D approach employed by the State Water Resources Control Board since 1995 to manage the location of X2 with a 3-D characterization of LSZ habitat, and demonstrates how the physical characteristics of the LSZ are influenced by the distribution of shallow habitats along the axis of the estuary.

Keywords: Low Salinity Zone, UnTRIM, X2, hydrodynamic modeling

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FLaSH: Health Status of Delta Smelt, *Hypomesus transpacificus*

Shawn Acuña, Aquatic Health Program, University of California, Davis, scacuna@ucdavis.edu
James Hobbs, Wildlife and Fisheries Conservation Biology, University of California, Davis, jahobbs@ucdavis.edu
Dolores Baxa, Aquatic Health Program, University of California, Davis, dvbaxa@ucdavis.edu
Saikrithika Gandhi, Aquatic Health Program, University of California, Davis, saikrithi@gmail.com
Alireza Javidmehr, Aquatic Health Program, University of California, Davis, ajavidmehr@ucdavis.edu
Tomofumi Kurobe, Aquatic Health Program, University of California, Davis, tkurobe@ucdavis.edu
Michael Park, Aquatic Health Program, University of California, Davis, mopark@ucdavis.edu
Swee Teh, Aquatic Health Program, University of California, Davis, sjteh@ucdavis.edu

The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with California Department of Fish and Game (CDFG) long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl, the FLaSH has been investigating delta smelt health occupying the SFE. This study examined the potential effects of habitat quality on the growth, nutritional, and reproductive status of delta smelt. We compared the effect of habitat quality on morphometric indices, otolith analyses and nutritional status of the 2011-2012 delta smelt year class and the indices relationship with reproductive status. Preliminary results indicate that the 2011 was a 'good' habitat year when examining growth rates and condition indices. RNA/DNA ratios increased from fall to winter while triglyceride concentrations were variable. Indications for reproductive performance will be discussed in regards to growth, condition, and nutritional status. Preliminary results show that gonadosomatic and hepatosomatic indices increased from fall 2011 to spring 2012.
Relevance: Information presented in this study examines the concepts outlined by the FLaSH to determine the effect of habitat quality on the health of delta smelt and potentially other species of management concern in the upper San Francisco Estuary.

Keywords: Delta smelt, nutrition, otolith, habitat

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (I) – Order 4

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Water and Particle Properties as Measures of Habitat Quality

Brian Bergamaschi, US Geological Survey, bbergama@usgs.gov
Bryan Downing, US Geological Survey, bdowning@usgs.gov
Michael Sauer, US Geological Survey, msauer@usgs.gov

Aquatic habitat quality in the Delta is determined by interactions between nutrients, suspended sediment, water, and light. Together, these habitat attributes affect the food supply by controlling algal production and species distribution; affect the food web structure by influencing energy transfer and grazer community composition; and affect fish distributions by altering foraging behavior and predation. The variation in these attributes across the Delta is commonly observed as variations in, for example, chlorophyll, turbidity, and secchi depth, which have been related to algal, zooplankton, and fish abundance. Our project examines these relationships in greater detail using a suite of new optical techniques that directly measure light transmission properties as well as algal and particle size and abundance. One purpose of the study is to identify the simplest optical water quality measurements that may best be used in a continuous real-time in-situ monitoring network of habitat quality.

We conducted profile measurements and collected samples at 25 stations from Suisun Bay to Cache Slough in conjunction with the2011 Fall Mid-Water Trawl and Spring Kodiak Trawl programs, sampling at the same time and location as the fish collection activities. We found a large tidal dependency and large spatial variability for the parameters measured. For example, the chlorophyll concentration and median size of large suspended particles (including algae and flocs) increased upstream, in contrast to turbidity and salinity which showed the opposite trend. Distributions and interactions between measured parameters will be presented in combination with results of more traditional water quality measurements and from analysis of discrete water samples. The optical measurements will be used as part of an effort to establish relationships between readily-measured habitat quality indices and direct measurements of fish and community structure.

Keywords: Habitat Quality, Particles, Algae, Sediment, Turbidity, Phytoplankton

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (I) – Order 5

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Response of the Delta Smelt Population to the Fall Outflow Conditions in 2011: Insights from Qualitative Modeling

Gonzalo Castillo, U.S. Fish and Wildlife Service, gonzalo_castillo@fws.gov

The role the low salinity habitat (LSH) to the ecology of the Sacramento-San Joaquin Delta (Delta) and the biological response of the LSH to the high outflows in 2011 is an area of active research and management interest, mainly in terms of the likely benefits to the delta smelt (*Hypomesus transpacificus*) population. How the hypothesized flow-induced responses in the LSH are integrated at community level remains a central ecological question. Signed digraph qualitative modeling was used to evaluate potential ecological interactions and underlying feedback mechanisms operating in the LSH delta smelt subsystem. The objectives of this research were: 1) to develop alternative models for the delta smelt subsystem during the fall 2011 and 2) compare the observed patterns in the fall 2011 with the hypothesized and predicted changes in the delta smelt subsystem. The modeled subsystem was composed of 5 community variables, including species (sub-adult delta smelt and the introduced overbite clam *Potamocorbula amurensis*), trophic groups (phytoplankton, zooplankton and delta smelt predators) and fall outflow. Models assumed negative effect of outflow on overbite clam and either positive or no direct effect of outflow on phytoplankton, zooplankton and delta smelt. The predictions of FLaSH hypotheses and qualitative models were compared to the 2011 field results for the Fall Low Salinity Habitat Program (FLaSH). Model predictions showed: 1) A consistently positive influence of outflow on the delta smelt population and zooplankton under all scenarios, 2) a generally positive influence of flow on phytoplankton and 3) a generally negative influence of outflow on the overbite clam. The consistency of model predictions and observed field patterns points out the coherence of FLaSH hypotheses and inherent ecological interactions. Model predictions support the adaptive management of fall outflows to enhance the quality of the LSH for sub-adult delta smelt.

Keywords: Primary zone economy, employment, industry clusters, agriculture, recreation, infrastructure

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (II) – Order 6

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FLaSH: Enzymatic Biomarkers and Pathogens as Stress Indicators on the Health of Delta Smelt, *Hypomesus transpacificus*

Saikrithika Gandhi, Aquatic Health Program, UC Davis, saikrithi@gmail.com
Dolores Baxa, Aquatic Health Program, UC Davis, dvbaxa@ucdavis.edu
Shawn Acuña, Aquatic Health Program, UC Davis, scacuna@ucdavis.edu
James Hobbs, Wildlife Fisheries and Conservation Biology, UC Davis, jahobbs@ucdavis.edu
Alireza Javidmehr, Aquatic Health Program, UC Davis, ajavidmehr@ucdavis.edu
Tomofumi Kurobe, Aquatic Health Program, UC Davis, tkurobe@ucdavis.edu
Michael Park, Aquatic Health Program, UC Davis, mopark@ucdavis.edu
Swee Teh, Aquatic Health Program, UC Davis, sjteh@ucdavis.edu

The Fall Low Salinity Habitat (FLaSH) study examined the potential effects of habitat quality on the health, nutrition, and reproductive status of delta smelt, *Hypomesus transpacificus*, in the San Francisco Estuary (SFE). In collaboration with California Department of Fish and Game (CDFG) long-term fish monitoring surveys, the Summer Tow Net, Fall Midwater Trawl and the Spring Kodiak Trawl, the FLaSH has been investigating delta smelt health occupying the SFE. The main goal is to investigate the effects of habitat quality on the general health status of delta smelt. Fish health in this context is broadly defined and measured in terms of growth, reproduction, and survival from the adverse effects of multiple stressors (biological, environmental, and chemical) present in the estuary.

Delta smelt and other species were collected in collaboration with various Interagency Ecological Program (IEP) fish monitoring surveys including the Summer Tow Net, Fall Midwater Trawl, and the Spring Kodiak Trawl. Fish health measurements are in progress and results will be analyzed within and across data sets. The presence of xenobiotics (OP pesticides, carbamates, metal contamination, PAH, and PCBs) was determined for the 2011-2012 delta smelt year class by using several biochemical biomarkers such as Acetylcholinesterase (AChE), Sodium Potassium Adenosine Triphosphatase (Na^+/K^+ ATPase), and Ethoxyresorufin O-Deethylase (EROD). The potential relationships among the biomarkers, presence of pathogens/disease, and reproductive status are being examined. Preliminary results showed that there were significant depression in AChE and Na^+/K^+ ATPase for some of the fishes collected at certain regions. Pathogen analysis showed a significant interaction of water temperature, location, and surface conductivity to cause *Mycobacterium* DNA presence in delta smelt.

Relevance: Contaminants and pathogens are important stressors affecting fish health in the SFE. These findings will provide management protocols for delta smelt and other species of concern in the upper San Francisco Estuary.

Keywords: Delta smelt, contaminants, enzymes, disease, habitat Quality

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (II) – Order 7

ED_000733_DD_NSF_00015174-00200

Opposing Seasonal Biomass Cycles Influence the Grazing Effects of Corbicula and Potamocorbula.

Janet Thompson, U.S. Geological Survey, jthompso@usgs.gov
Karen Gehrts, California Department of Water Resources, Kagehrts@water.ca.gov
Francis Parchaso, U.S. Geologcal Survey, parchaso@usgs.gov
Heather Fuller, California Department of Water Resources, hlfuller@water.ca.gov
Jeff Crauder, U.S. Geological Survey, jcrauder@usgs.gov

Potamocorbula amurensis and *Corbicula fluminea* have both been shown to be capable of reducing phytoplankton biomass in San Francisco Bay and the Delta. Therefore both bivalves have the potential for further stressing the base of an already strained foodweb and for derailing restoration plans that include increased phytoplankton production. Our goals are to understand the population dynamics of both bivalves in the system and to uncover environmental factors that might limit their success. Here, we use the California Department of Water Resources spatially intensive benthic sampling program (GRTS) to examine the grazing rate distribution of both bivalves in spring and fall of 2009 through 2011.

Population distributions of *Potamocorbula*, an estuarine clam, and *Corbicula*, a freshwater clam, overlapped in the ecologically sensitive X2 region except in the wet year, 2011, when they overlapped upstream of the X2 region, particularly in spring. Maximum grazing rate occurred in October of all years in Suisun and Grizzly Bays, due to *Potamocorbula* populations that peak in biomass in fall and drop to a minimum in spring. The confluence region and most of the Delta had higher grazing rates in May than in October in all years. The spring dominance was strongest in regions most influenced by the Sacramento River. A consistent exception to this pattern was observed in Mildred Island and the historic Sacramento River where *Corbicula* had higher grazing rates in fall than in spring.

Bivalve grazing rates were sufficiently high in fall of 2009 and 2010 to potentially limit phytoplankton biomass accumulation in the low salinity zone. Grazing rates were low enough in spring of all years and in fall 2011 that bivalve grazing alone could not account for observed phytoplankton biomass levels. The increased freshwater flow in 2011 is likely the cause of the reduced bivalve grazing impact in 2011.

Keywords: bivalve, grazing, foodweb, *Corbicula potamocorbula*, biomass

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (II)– Order 8

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The Food Environment for Delta Smelt in Fall: A Synthesis of Recent Findings

Wim Kimmerer, SFSU, kimmerer@sfsu.edu

The low-salinity zone (LSZ) of the San Francisco Estuary provides habitat for juvenile delta smelt and several other fish species. Decades of monitoring coupled with several intensive studies of this region have yielded important insights that provide a context for the ongoing fall habitat studies. The aim of these studies is to determine how freshwater flow influences this habitat; however, because of the myriad influences of flow on the estuary, this effect is elusive. I summarize some of the key findings that have emerged from our studies of the LSZ, particularly in the last several years. The LSZ is not a production hot-spot as once believed; rather, in many years grazing by clams depresses abundance of phytoplankton, the copepod *Pseudodiaptomus forbesi*, and probably microzooplankton. Populations of these organisms must be subsidized by transport from other parts of the estuary. I show evidence of this transport from the deficit in production within the LSZ and from measurements of chlorophyll and zooplankton abundance made during transects across the LSZ. Elevated freshwater flow increases the transport of phytoplankton and zooplankton into the LSZ, but to some extent it also uncouples the plankton from benthic grazing. The result is higher copepod abundance in the LSZ when flow is high during spring and sometimes into fall, whereas abundance in the freshwater source region is nearly invariant with flow. As these results are developed further using coupled hydrodynamic-ecological models, they will prove useful for understanding and predicting how feeding conditions for delta smelt in their fall habitat may vary with flow.

Keywords: delta smelt; low-salinity zone; copepod; foodweb; hydrodynamics;

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (II) – Order 9

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The Rise in Fall of Northern Estuary Phytoplankton During the FLaSH Study

Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Alex Parker, Romberg Tiburon Center, San Francisco State University, aeparker@sfsu.edu
Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Sarah Blaser, Romberg Tiburon Center, San Francisco State University, sarahblaser@gmail.com
Adam Pimenta, Romberg Tiburon Center, San Francisco State University, pimenta.adam@gmail.com
Christina Buck, Romberg Tiburon Center, San Francisco State University, christina.buck@gmail.com
Erica Kress, Romberg Tiburon Center, San Francisco State University, ericakress@yahoo.com

Most efforts to understand the delta smelt ecosystem have focused on studies in spring. We have been measuring conditions in the low salinity zone (LSZ) and the Sacramento and San Joaquin Rivers during fall since 2010. Fall blooms are rare. In 2010 chlorophyll in all regions was low (< 4 µg/L) compared to spring. In Fall 2011 there was excess freshwater and the fall low salinity habitat (FLaSH) program was put into place to maximize fall ecosystem studies when there was a more seaward location of X2 (or LSZ). As part of this we sampled water from Suisun Bay/confluence from September to early November 2011 to evaluate the response of nutrients and chlorophyll. A transect of nine stations within the Sacramento River and Suisun Bay between Rio Vista and Avon Pier was sampled eight times for nutrients, dissolved inorganic carbon, chlorophyll, phytoplankton community composition and rates of primary production and nutrient uptake. On 26 October and 2 November a phytoplankton bloom (chlorophyll ~30 µg/L) was observed at Sacramento River stations. The bloom was dominated by the diatom *Aulacoseira* that had long chains, typically 15-20 cells per chain. At these stations, nutrients were lower with ammonium concentrations < 2 µM and nitrate ~15 µM, and the percent nitrate uptake contributing to primary production was high. The role of light availability was unclear as Secchi depths were similar between bloom and non-bloom stations. The 2011 bloom may have been a consequence of the increased freshwater flow. The interaction of flow and nutrients, in particular anthropogenically derived ammonium, will be developed. The results could be used in adaptive management of fall outflow for delta smelt protection

Keywords: diatom, nitrate, ammonium, phytoplankton, bloom, chlorophyll, low salinity zone

Thursday, October 18, 2012: Room 308-310, Low Salinity Habitat in the San Francisco Estuary (II)– Order 10

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DNA Fingerprinting and Quantitative Assessments of Toxigenic Microcystis Assemblages and Their Environmental Drivers in the San Francisco Estuary Delta

Timothy Otten, University of North Carolina at Chapel Hill, ottentim@email.unc.edu
Hans Paerl, University of North Carolina at Chapel Hill, ottentim@email.unc.edu

Microcystis is a toxin-producing (microcystin) harmful algal bloom forming cyanobacterium that is suspected of being involved in the pelagic organism decline occurring throughout the San Francisco Estuary. In order to characterize the toxigenicity of these blooms, individual colonies of *Microcystis* were isolated and genotyped on the basis of their 16S-23S rDNA ITS and microcystin synthetase gene (*mcyB*) sequences. During the summer of 2011, *Microcystis* colonies were observed to appear as one of two morphologies; 1) densely packed and web-like, or 2) large, loosely packed flakes. Although only two morphotypes were observed, the colonies were genetically variable and comprised at least 11 unique operational taxonomic units, with both subtypes being potentially toxic (*mcyB* possessing). Quantitative PCR was utilized to enumerate the total and the toxigenic *Microcystis* populations from six unique sites that were each sampled six times during the summer of 2011. Additionally, water was collected from each sampling site and used in bioassay experiments investigating the role of temperature and light intensity on *Microcystis* growth and toxigenicity. The spatiotemporal patterns and environmental factors likely promoting *Microcystis* throughout the delta is discussed.

Keywords: *Microcystis*, microcystin, toxin, cyanobacteria, management, spatiotemporal, light, temperature

Thursday, October 18, 2012: Room 308-310, Understanding Cyanobacterial Blooms in the San Francisco Estuary Delta (I) – Order 1

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Monitoring Cyanobacteria, Microcystis, and Microcystin in the San Joaquin River Estuary

William Stringfellow, Ecological Engineering Research Program, University of the Pacific, wstringfellow@lbl.gov
Mark Brunell, Department of Biological Sciences, University of the Pacific, mbrunell@pacific.edu
Teemu Koski, Turku University of Applied Sciences, Teemu.Koski@turkuamk.fi
Jeremy Hanlon, Ecological Engineering Research Program, University of the Pacific, jershanlon@gmail.com
Chelsea Spier, Ecological Engineering Research Program, University of the Pacific, cspier@pacific.edu

The Bay-Delta is experiencing a decline in pelagic fish populations, in part due to disruption of the estuarine food-web. One concern is the apparent increase in blooms of cyanobacteria, which have low food-quality and may produce toxins harmful to fish and other species. The abundance and distribution of cyanobacteria and cyanotoxins in the San Joaquin River estuary (south-east Bay-Delta) was investigated. Multiple techniques for measuring harmful cyanobacteria were tested and compared to results from direct microscopic measurements with the objective of identifying rapid methods for monitoring harmful cyanobacteria in surface waters. Using microscopic analysis, it was found that *Microcystis sp.* were the dominant cyanobacteria in all samples and cyanobacteria biomass was higher in areas of the estuary with low turbidity and soluble N:P ratios less than 10. *Microcystis sp.* are classified as harmful algal species and are associated with the production of the toxin microcystin. ELISA kits were used to measure toxin concentrations and microcystin concentrations had a linear correlation with total cyanobacteria biomass and *Microcystis* concentration. ELISA kits were found to be sensitive and reproducible and are recommended as a rapid alternative or supplement to traditional microscopic enumeration. Sondes for the *in-situ* measurement of phycocyanin from two different manufacturers were also tested and compared to results from microscopy. Phycocyanin is a pigment produced by cyanobacteria and sondes for the *in-situ* measurement of this pigment are used in Finland and elsewhere for the monitoring of harmful algae blooms in freshwater lakes and coastal regions. In this study, we found that the sondes were not sensitive to low concentrations of cyanobacteria and are therefore not recommended for monitoring cyanobacteria in this region. In conclusion, chemical methods for measuring the cyanotoxin microcystin were found to be a reliable and rapid method for the monitoring of harmful algae in this region.

Keywords: harmful algae blooms; water quality; pelagic organism decline POD

Thursday, October 18, 2012: Room 308-310, Understanding Cyanobacterial Blooms in the San Francisco Estuary Delta (I) – Order 2

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Occurrence and Abundance of Other Toxin-Producing Cyanobacteria in the San Francisco Bay Delta

Dolores Baxa, UC Davis, dvbaxa@ucdavis.edu
Tomofumi Kurobe, UC Davis, tkurobe@ucdavis.edu
Cécile Mioni, Institute of Marine Sciences, University of California, Santa Cruz, cmioni@ucsc.edu
Peggy Lehman, Department of Environmental Science, California Department of Water Resources, plehman@water.ca.gov
Swee Teh, UC Davis, sjteh@ucdavis.edu

The management of blooms in the San Francisco Bay Delta (SFBD) has focused mainly on *M. aeruginosa* being the major species associated in recurring algal blooms. Due to the information gap on the occurrence of other toxigenic species in the SFBD, the relevance of the cyanotoxins that they produce has been rarely investigated particularly on the implications of overlapping blooms and life stages of zooplankton and fish. We have previously demonstrated variations on the abundance of toxic and nontoxic *Microcystis* across sites in the San Francisco Bay Delta during the 2007 blooms. Although water and algal samples that were examined showed the persistence of microcystins, their concentrations did not correlate with the frequency of toxin-producing *Microcystis*. These results may be due to the 1) potential occurrence of other microcystin-producing genera in addition to *Microcystis*, and 2) difficulty of detecting other toxin-producing cyanobacterial species using traditional morphological identification.

To address the disparity in microcystin levels and the abundance of toxin-producing *Microcystis*, molecular techniques (16S rDNA sequencing and qPCR) were employed to determine the presence of other toxin-producing species on archived genomic DNA from the 2007 algal samples and compared to species present in the 2011 blooms. Our findings will show the identification, quantification, and variations on the abundance of other toxin producing cyanobacteria such as *Anabaena, Aphanizomenon,* and *Lyngbya* in addition to *Microcystis* as determined from selected sampling sites and dates from the 2007 and 2011 blooms.

Relevance: Knowledge on the shift in bloom composition and abundance will help promote the sustainability of the delta ecosystem and its resident fisheries by regulating the key environmental factors that may alter the toxicity of local cyanobacterial harmful algal blooms (CyanoHABs).

Keywords: toxin-producing, microcystin, qPCR, CyanoHABs, San Francisco Bay delta, taxon shift

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Determining Environmental Controls and Ecological Impacts of CyanoHABs in the San Joaquin-Sacramento Delta – A Multidisciplinary Approach

Cécile Mioni, UCSC, cmioni@ucsc.edu
Dolores Baxa, UCD, dvbaxa@ucdavis.edu
Lenny Grimaldo, USBR, LGrimaldo@usbr.gov
Kendra Hayashi, UCSC, khayashi@ucsc.edu
Wim Kimmerer, SFSU, kimmerer@sfsu.edu
Raphael Kudela, UCSC, kudela@ucsc.edu
Tomofumi Kurobe, UCD, tkurobe@ucdavis.edu
Lisa Lucas, USGS, llucas@usgs.gov
Hans Paerl, UNC, hans_paerl@unc.edu
Alex Parker, SFSU, aeparker@sfsu.edu
Scott Waller, DWR, swaller@water.ca.gov
Frances Wilkerson, SFSU, fwilkers@sfsu.edu

Harmful cyanobacteria (CyanoHABs), such as *Microcystis aeruginosa*, and the toxins they produce are a growing concern as a source of impairment in California water bodies. CyanoHAB distribution, abundance and environmental conditions promoting their proliferation and toxin production are not well characterized.

Total cyanobacteria biomass has increased since 1975 throughout the San Joaquin-Sacramento Delta coincident with a decline in diatom biomass. Recurrence of seasonal CyanoHABs in the Delta since 2000 coincided with the decline of various pelagic organisms and their copepod prey, suggesting that these cyanoHABs may at least in part be responsible for this decline. The increase in CyanoHABs in the Delta coincided with several environmental changes that are known to favor their growth including increasing temperature. These environmental changes also appear to correlate with the decline of pelagic fish species.

Since 2008, we have conducted multidisciplinary, multi-agencies collaborative monitoring programs in the Delta with the goal of gaining a better understanding of the environmental drivers controlling cyanoHAB occurrence and toxicity. Here, we will present results from our multiannual seasonal monitoring of spatial and temporal distribution of cyanoHAB species and associated toxins throughout the Delta. Our preliminary results indicate that cyanoHAB abundance and toxicity in the Delta are controlled by several interacting environmental factors. Surface water temperature and nutrient availability, especially nitrogen sources, appear to be key drivers of cyanoHAB composition and toxicity, but additional environmental stressors specific to individual cyanoHAB taxa may also play a significant role. Our results also indicate that in addition to *Microcystis*, other potentially toxigenic cyanobacteria such *Aphanizomenon, Anabaena* and *Synechococcus*, may contribute to bloom toxicity in the Delta. Furthermore, we find evidence for microbial consortia which may mediate toxin production within the cyanoHAB assemblage.

Keywords: Cyanobacteria, *Microcystis*, *Aphanizomenon*, CyanoHABs, toxins,

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Carbon and Nitrogen Uptake Rates Associated with Cyanobacterial Blooms in the San Francisco Delta

Alexander Parker, Romberg Tiburon Center, SFSU, aeparker@sfsu.edu
Allison Johnson, Romberg Tiburon Center, SFSU, allison95376@gmail.com
Jamie Lee, Romberg Tiburon Center, SFSU, jamielee00@gmail.com
Adam Pimenta, Romberg Tiburon Center, SFSU, pimenta.adam@gmail.com
Cecile Mioni, University of Californa, Santa Cruz, cmioni@ucsc.edu
Frances WIlkerson, Romberg Tiburon Center, SFSU, fwilkers@sfsu.edu

Blooms of cyanobacteria have been observed during the summer in the San Francisco Estuary Delta (Delta). These blooms have the potential to disrupt estuarine food webs and may pose a risk for human health through the production of toxins. During this study, depth-integrated measurements of carbon and nitrogen uptake were made at several sites within the central Delta where cyanobacteria were present in high abundances. It was hypothesized that both light and nutrient concentrations were drivers of cyanobacterial blooms. Because these cyanobacteria form blooms that are concentrated at the water surface, measurements were made using water collected at the surface (cyanobacteria-dominated) and at a depth of 3m (where other phytoplankton taxa-dominated) to allow comparison between cyanobacteria and other autotrophs. Stable isotope tracers of ^{13}C and ^{15}N (NH_4, NO_3 and urea) were added to bottles incubated at irradiances of 5 to 50% of surface photosynthetically active radiation. Results show a strong positive response of light on C and N uptake rates for communities in both surface and 3m samples. NH_4, NO_3 and urea uptake were observed in incubations suggesting that all N substrates were potentially important in these habitats. This work provides insight into light and nutrient controls on cyanobacterial blooms that may guide management strategies in the future.

Keywords: *Microcystis*, Cyanobacteria, primary production, nitrogen uptake, ammonia, nitrate, flooded island

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Stable Nitrate Isotopes Reveal Different Nitrate Dynamics in the San Joaquin River under Changing Flow Conditions

Megan Young, U.S. Geological Survey, Menlo Park, CA, mbyoung@usgs.gov
Carol Kendall, U.S. Geological Survey, Menlo Park, CA, ckendall@usgs.gov
William Stringfellow, University of the Pacific, Stockton, CA, wstringfellow@lbl.gov
Randy Dahlgren, U.C. Davis, Davis, CA, radahlgren@ucdavis.edu
Steve Silva, U.S. Geological Survey, Menlo Park, CA, srsilva@usgs.gov

The dual nitrate isotope composition ($\delta^{15}N$ and $\delta^{18}O$-NO_3) of water from the San Joaquin River (SJR) and tributaries was measured approximately monthly between March 2005 and December 2007 in order to trace dominant nitrate sources and processes under different flow conditions. 2007 was a dry year in comparison to both 2005 and 2006. In the SJR, $\delta^{15}N$-NO_3 and nitrate concentrations showed similar patterns related to flow during 2005- 2006, and distinctly different behavior during the summer and fall of 2007, indicating a shift in the processes controlling nitrate sources and cycling. Higher flows in the SJR were associated with lower nitrate concentrations and lower $\delta^{15}N$-NO_3, while periods of lower flows showed higher nitrate concentrations and higher $\delta^{15}N$-NO_3. The changes in $\delta^{15}N$-NO_3 indicate shifts in the dominant nitrate sources to the river associated with flow changes, since dilution with lower nitrate concentration water containing nitrate from the same source will not cause a change in isotopic composition. The higher $\delta^{15}N$-NO_3 observed during low flow conditions suggests significant inputs of human or animal waste to the river. During 2005- 2006, $\delta^{15}N$-NO_3 typically decreased downstream in the SJR, and isotope mass balance calculations showed that the nitrate isotope patterns in the SJR were primarily controlled by downstream inputs of lower nitrate concentration water from the Tuolumne and Stanislaus Rivers. During the very low flow conditions of summer and fall 2007, both $\delta^{15}N$- and $\delta^{18}O$-NO_3 showed coupled downstream increases which could not be accounted for by inputs from the monitored tributaries. In 2007, both the $\delta^{15}N$- and $\delta^{18}O$-NO_3 also increased over time as chl-a concentration increased, suggesting that in contrast to conditions in 2005- 2006, algal uptake, in addition to other inputs from high $\delta^{15}N$-NO_3 sources, significantly influenced the isotopic composition of nitrate in the mainstem SJR during the summer and fall of 2007.

Keywords: nutrients; nitrate; San Joaquin River; stable isotopes

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Using Multi-Isotope Techniques to Estimate the Relative Uptake of Ammonium and Nitrate by Phytoplankton for Sites in Sacramento River and Delta

Carol Kendall, U. S. Geological Survey, ckendall@usgs.gov
Megan Young, U. S. Geological Survey, mbyoung@usgs.gov
Steve Silva, U. S. Geological Survey, srsilva@usgs.gov
Marianne Guerin, Resource Management Associates, maguerin@rmanet.com
Calla Schmidt, U. S. Geological Survey and UCSC, callaschmidt@gmail.com
Alex Parker, Romberg Tiburon Center, SFSU, aeparker@sfsu.edu

High NH4 concentrations have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline in the San Francisco Estuary. One test of this hypothesis is to compare chlorophyll levels with the natural abundance stable isotope ratios of phytoplankton, NH4, and NO3. Isotope techniques are a useful tool for this test because we have found that the $\delta^{15}N$ of NH4, NO3, and phytoplankton (as estimated from bulk seston composition) at most sites are isotopically distinctive because of the effects of progressive downstream nitrification on the $\delta^{15}N$ of residual NH4 and new NO3.
To provide an independent test of this hypothesis, samples for isotopic analysis were collected along ~30 transects of the Estuary from March 2009 to December 2012. Many transects piggybacked on the sampling efforts of other teams and collected samples from 12-25 sites depending on transect. All samples have been analyzed for seston $\delta^{15}N$, $\delta^{15}N$, $\square^{34}S$, and C:N. Analysis for NH4-$\delta^{15}N$, NO3 $\delta^{15}N$ and $\delta^{18}O$, DOC-$\delta^{13}C$, and water $\delta^{18}O$ and $\delta^{2}H$ are in various stages of completion; we expect that the presentation will include most of the dataset. Calculations made using the subset of total samples with complete $\delta^{15}N$ data for seston, NH4, and NO3 show few sites and dates where the $\delta^{15}N$ values definitely support a single source of N to uptake. Instead, the $\delta^{15}N$ data are consistent with variations in proportions of NH4 and NO3 to uptake at different sites and dates, with strong downstream trends in relative proportions of N source to phytoplankton. One main complication is the estimation of how much of the uptake of N is actually by bacteria, not phytoplankton. Our approach shows promise as a direct measure of in-stream uptake rates that can be piggybacked onto routine monitoring programs for habitat characterization and estimating the impacts of N loads from different sources.

Keywords: nitrate, ammonium, phytoplankton, habitat-assessment, isotopes, uptake, assimilation

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Cyanobacterial Toxins, Environmental Drivers, and Watershed Connectivity: How Serious is the Threat?

Raphael Kudela, Institute of Marine Sciences, UC Santa Cruz, kudela@ucsc.edu
Cecile Mioni, Institute of Marine Sciences, UC Santa Cruz, cmioni@ucsc.edu
Corinne Gibble, UC Santa Cruz, corinnegibble@gmail.com
Kendra Hayashi, UC Santa Cruz, khayashi@ucsc.edu
Karen Worcester, Central Coast RWQCB, Kworcester@waterboards.ca.gov
Tara Schraga, United States Geological Survey, tschraga@usgs.gov

Harmful cyanobacteria (CyanoHABs), such as *Microcystis*, *Aphanizomenon, Anabaena,* and *Planktothrix* are of increasing concern in California's watersheds, estuaries, and coastal waters. While CyanoHABs are routinely monitored, there is increasing evidence that bloom formation and presence of toxins are not necessarily well correlated, in part because the toxins are environmentally stable and easily transported downstream, with or without cells.

New methods for toxin detection,such as Solid Phase Adsorption Toxin Tracking (SPATT) provide evidence for persistent, chronic environmental exposure to toxins in many water bodies. SPATT can detect both lower levels and ephemeral toxin exposure because it passively concentrates toxins and integrates over the duration of deployment (typically 7-30 days). Comparison of this integrated toxin data with environmental drivers such as nutrients and temperature suggest that previously identified correlates are tracking the seasonal occurrence of large bloom events but do not provide much information about the chronic toxin levels. Spatially extensive sampling of Central California watersheds has identified some "hotspot" locations such as the Bay Delta, but has also identified many other water bodies with easily detectable levels of toxins.

The imminent release of new guidelines from the Office of Environmental Health Hazard Assessment (OEHHA) will set lower recommended exposure levels for recreation and ecological impairment. Downstream transport of toxins coupled with spatial and temporal separation of toxins and cells strongly suggests that many potential negative consequences are unrecognized or unreported. We suggest that the OEHHA guidelines, together with the increasing evidence for chronic exposure not captured by traditional grab sampling (particularly during "non-bloom" periods) requires the scientific and management communities to re-assess the emerging threat of CyanoHABs. While hotspots are clearly an area of immediate concern, the widespread occurrence and transport of toxins from the coastal watershed to the land/sea interface could ultimately pose a greater and more difficult to mitigate threat.

Keywords: CyanoHAB, *Microcystis*, microcystin, blue-green algae, toxin, harmful algal bloom

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Are Nutrients a Driver of Cyanobacterial Abundance in the San Francisco Estuary Delta?

Adam Pimenta, San Francisco State University - Romberg Tiburon Center for Environmental Studies, pimenta.adam@gmail.com
Cecile Mioni, Institute of Marine Science University of California at Santa Cruz, cmioni@ucsc.edu
Alex Parker, San Francisco State University - Romberg Tiburon Center for Environmental Studies, aeparker@sfsu.edu
Frances Wilkerson, San Francisco State University - Romberg Tiburon Center for Environmental Studies, fwilkers@sfsu.edu

The San Francisco Estuary Delta is a complex system characterized by a variety of chemical and hydrodynamic inputs from the Sacramento and San Joaquin rivers and Suisun Bay. Blooms of cyanobacteria have been increasingly common in this system with *Microcystis aeruginosa* observed starting in 1999 and *Aphanizomenon sp.* observed starting in 2011. The relationship between cyanobacteria and nutrient concentrations has been observed in many freshwater and estuarine systems, with high concentrations of dissolved inorganic nitrogen (N) and phosphorus (P) and relatively high N : P ratios (~30:1) associated with bloom development. During the July-September period in 2011 and 2012, 3 paired sets of stations, selected to represent the different environments common in the Delta (small tributary, major river and flooded island) were sampled to test the hypothesis that nutrients were important drivers of cyanobacterial blooms. Observed N concentrations were greater than 6 µM and observed P concentrations were above 1 µM at all stations, sufficient to support cyanobacterial blooms. Sites associated with *Microcystis* had relatively low (~1µM) ammonium-N concentrations, compared to non-*Microcystis* sites (except at flooded island sites where ammonium-N concentrations were uniformly low). Water column nutrient N:P was lower than the Redfield ratio (16:1) at all of the sites. These results are contrary to the conditions hypothesized to promote cyanobacteria requiring an evaluation of nutrient impacts. Characterizing the nutrient conditions associated with cyanobacteria in the Delta are critical to develop strategies to prevent or control future blooms.

Keywords: Cyanobacteria, Nutrients, Delta, Flooded Island

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Monitoring Toxin-Producing Cyanobacteria in Clear Lake and Sacramento-San Joaquin Delta by DNA Barcoding and Development of Quantitative PCR Assays

Tomofumi Kurobe, University of California, Davis, tkurobe@ucdavis.edu
Dolores Baxa, University of California, Davis, dvbaxa@ucdavis.edu
Cécile Mioni, University of California, Santa Cruz, cmioni@ucsc.edu
Raphael Kudela, University of California, Santa Cruz, kudela@ucsc.edu
Thomas Smythe, Lake County Water Resources Department, Tom.Smythe@lakecountyca.gov
Scott Waller, California Department of Water Resources, swaller@water.ca.gov
Swee Teh, University of California, Davis, sjteh@ucdavis.edu

Accurate and consistent identification and monitoring of harmful cyanobacteria using traditional morphological taxonomy are challenging tasks due to their sizes and high degree of phenotypic plasticity in natural assemblages. To overcome the limitations associated with microscopic identification, we utilized DNA barcoding for identification of potentially toxin producing cyanobacteria in Clear Lake and in the Sacramento San Joaquin Delta in Northern California. Species specific DNA fragments, also known as "DNA barcodes" were successfully obtained and showed high similarity to major toxin producers: *Anabaena, Aphanizomenon, Lyngbya, Microcystis* and *Synechococcus*. The DNA barcodes for *Anabaena, Aphanizomenon, Lyngbya,* and *Microcystis* were also used to develop high-throughput quantitative PCR assays. Sensitivities and specificities of the assays were evaluated and all the assays showed high amplification efficiency (>98%) with excellent analytical sensitivity, as low as 10 copies of the target DNA in a single reaction. The assays showed good analytical specificities and no evidence of cross-reaction was observed among other genera obtained through DNA barcoding.

Relevance: DNA barcodes and specific qPCR assays for toxin producing cyanobacteria are useful tools for identifying the species composition of blooms. These techniques may be incorporated in monitoring recurring blooms and for determining the environmental drivers triggering bloom toxicity in the Sacramento San Joaquin delta and Clear Lake.

Keywords: Cyanobacteria, DNA barcoding, quantitative PCR

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Do Hatchery Chinook Salmon Supplement Naturally Produced Fish, or Replace Them?

John Williams, jgwill@frontiernet.net

Hatcheries are intended to increase populations. To the extent that hatchery fish replace rather than supplement naturally reproducing fish, hatcheries are at best ineffective. Data on adult returns of fall Chinook salmon to the upper Sacramento River and Battle Creek, and to the Yuba River, show that populations have varied strongly over time, but returns before the recent population collapse were about the same as half a century ago. However,the spatial distribution of spawning (Sacramento River v. Battle Creek) and recent coded-wire tag data show that many of the fish spawning in the upper Sacramento and Yuba rivers are now hatchery fish (about 50 and 70% respectively in 2010, estimated from fresh carcasses only). This strongly suggests that hatchery Chinook have replaced rather than supplemented naturally produced fish in these streams, as has been suggested elsewhere. Moreover, naturally produced fall Chinook in these rivers seem not to be reproducing themselves, or barely doing so, despite the recent reduction in fishing pressure and overall increase in returns. These results raise questions regarding the effectiveness of hatchery production of fall Chinook in the Central Valley, and whether the existing hatchery programs are consistent with the objectives of the Central Valley Project Improvement Act.

Keywords: Chinook, hatcheries, hatchery effects

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (I) – Order 1

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Key Uncertainties Surrounding Predation at Diversion Structures

David Swank, NOAA-Fisheries, david.swank@noaa.gov
Michael Tucker, NOAA-Fisheries, michael.tucker@noaa.gov

Large-scale water diversions have made possible the development of much of the arid western United States. Regulatory agencies now routinely require the screening of large diversion structures, which has greatly reduced direct entrainment mortality of listed fish species, but concerns remain over the potential they have for increasing juvenile mortality by congregating predators and increasing predation efficiency. We reviewed the literature on survival and predation at large diversion structures such as GCID and Red Bluff Diversion Dam, and found that significant mortality has been documented to occur at diversion structures, much of which is likely due to predation. However, major questions remain about the impact of this mortality, and how it can be managed. Acoustic technology allows for accurate measurements of both prey fish survival and the behavior of piscivorous fish at diversion structures. Key questions that need to be examined include:

Do predators congregate around diversion structures?

Do structures create more predation or just re-distribute predators?

Are there indirect effects from reduced flows below the diversions? E.g., reduced velocity and turbidity may impact predation efficiency. Studies have shown that river turbidity is strongly related to predation rate.

How can structures be designed to minimize predation? Recent screen designs include refuges for fish built into the screen at specific intervals, but no field studies have been conducted on their success.

Can predator numbers at a structure be suppressed enough to reduce overall predation rates?

Studies are underway to help answer these questions, including a NMFS study of predation at diversion structures in the Sacramento River at Sacramento and Freeport, but more focused studies and intensive monitoring will be needed.

Keywords: water diversion structures, predation, survival, uncertainty, monitoring

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (I) – Order 2

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The History of the Spawners: Juvenile Delta Use by Adult Winter- and Spring-Run Chinook Salmon

Peter K. Weber, Lawrence Livermore National Laboratory and University of California, Berkeley, weber21@llnl.gov
Corey C. Phillis, Simon Frasier University, cphillis@sfu.ca
George Whitman, University of California, Santa Cruz, gewhitman@gmail.com
Rachel C. Johnson, U.S. Bureau of Reclamation and University of California, Santa Cruz, RBarnettJohnson@usbr.gov
Brice X. Semmens, University of California, Santa Barbara, semmens@ucsd.edu
Eric J. Ward, National Marine Fisheries Service, Eric.Ward@noaa.gov
Jonathan W. Moore, Simon Frasier University, jwmoore@sfu.ca
B. Lynn Ingram, University of California, Berkeley, ingram@eps.berkeley.edu

Out migrating juvenile Chinook salmon are observed throughout the Sacramento-San Joaquin Delta, but little is known about the extent of Delta use as a rearing habitat for juveniles that successfully return as adults to spawn. In this study, we use Sr isotopes in otoliths to reconstruct Delta use as juveniles by the 2007-2009 Sacramento River Winter-andSpring-run Chinook salmon spawning adults. The Sr isotope history of the juvenile period of an adult salmon can be reconstructed with ~2 week resolution, presenting the potential to reconstruct the juvenile rearing history for the fish that successfully return to spawn. Inferring patterns of movement from isotopic data necessitates comparing the isotope of the fish with an isoscape, a map of the isotope signatures of the area through which an animal might move. To specifically enable Delta use reconstruction, we have identified a downstream gradient in Sacramento River Sr isotopes that allows the northern Delta (Freeport to Decker Island) to bedelineated from the upstream Sacramento River. From the northern Delta, Sr isotopes change rapidly with salinity, enabling departure from the Delta to be easily identified. Use of the South Delta can also be inferred, though it has not been observed. We compare otolith Sr isotopes to those of the Sr isoscape to infer the patterns of habitat use. Initial results show a range of outmigration strategies for Winter-run, with more limited behavior for Spring-run, but most fish spend the majority of their juvenile rearing period in the Sacramento mainstem. We observe little indication of outmigration as yearlings in either group. Finally, we show how this qualitative approach commonly used for inferring movement of animals across isoscapes can be improved by implementing a state-space model to quantify the movement and the uncertainty about those movements to recreate probabilistic migration scenarios.

Keywords: Chinook salmon; otoliths; Delta; strontium; juvenile habitat use

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ED_000733_DD_NSF_00015174-00216

Using Size, Growth Rate and Rearing Origin to Evaluate Selective Mortality of Juvenile Chinook Salmon across Years of Varying Ocean Productivity

Rachel Johnson, US Bureau of Reclamation and UC Santa Cruz, rbarnettjohnson@usbr.gov
Lindsay Woodson, National Marine Fisheries Service, Lindsay.Woodson@noaa.gov
Brian Wells, National Marine Fisheries Service, Brian.Wells@noaa.gov
George Whitman, University of California Santa Cruz, gewhitman@gmail.com
Peter Weber, Lawrence Livermore National Laboratory and UC Santa Cruz, Weber21@llnl.gov
R. Bruce MacFarlane, UC Santa Cruz and NMFS, Bruce.MacFarlane@noaa.gov

One of the most challenging aspects in understanding population declines of anadromous fish species is determining how processes occurring in freshwater, estuarine, and marine habitats influence growth, survival and reproductive success. Individual variation in growth rates and body size during early life history stages can have significant population level consequences. For example, an elevation in size-selective mortality due to poor ocean conditions is believed to be the driver behind the collapse of Central Valley fall-run Chinook salmon in 2007. However, empirical data quantifying where within the life stage smaller individuals may have greater mortality, and under what environmental conditions, are difficult to obtain.

Here we provide trends in reconstructed growth rates (otolith increment widths), fish condition (K factor), fork length, triacylglycerol lipid content (TAG), and the proportion of hatchery and wild individuals (otolith sulfur isotopes) for salmon collected in the San Francisco Bay and coastal ocean. We compare sub-yearlings that emigrated in 2000and 2001 (years of good ocean productivity) with the cohort in 2005 (a year of poor ocean productivity). Preliminary findings show that significant size and growth rate selective mortality occurred in the spring of 2005 when juvenile salmon first entered the coastal ocean to feed. Fish that were larger upon exit from the San Francisco Bay survived more than the smaller, slower growing fish during this same time. The findings in 2005 were in stark contrast to fish in 2000 and 2001where no significant size or growth rate selective mortality was detected. Although hatcheries generally release larger juveniles, our study did not find preferential selection for hatchery fish. Our data suggest that size selective mortality can be strong, favoring larger juveniles when food is limiting in the ocean and may be one of the mechanisms that contributed to the low number of returning adults in 2007.

Keywords: size selective mortality, growth rates, ocean conditions, otoliths

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (I) – Order 4

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Did San Francisco Bay Previously Provide Rearing Habitat for Juvenile Salmonids?

John Largier, UC Davis / Bodega Marine Laboratory, jlargier@ucdavis.edu

In May we held a symposium entitled: "Beyond Suisun - estuarine ecology of juvenile salmonids". Through a review of the ecology of juvenile salmonids in estuaries, the traditional wisdom was questioned that juveniles of Central Valley salmon populations do not use San Francisco Bay proper as rearing habitat (the majority of the estuary lies west of Carquinez Strait). Although data are surprisingly limited for such a critical issue, studies to-date support the idea that juvenile salmonids do not dwell long in the middle and outer estuary, moving quickly between Suisun Bay and the ocean. This poses the question whether juvenile salmonids ever used the Bay for rearing and, if so, what restoration options should be considered. Changes in the last two centuries may have shifted suitable habitat from west of Carquinez to east - specifically the landward intrusion of salinity associated with lower levels of freshwater flow and the loss of marshes west of Carquinez. The counter view is that juveniles always moved rapidly from the vegetated refuges and food-rich waters of the delta and Suisun Bay to the deep, food-rich waters west of Golden Gate and in the northern Gulf of Farallones (a region fueled by upwelling and replete in planktonic food). The Gulf thus provides habitat typical of estuaries, allowing rapid growth of juveniles to sizes that can access typical ocean prey. Nevertheless, the Bay remains a habitat for passage between river and ocean. Juvenile tagging studies will inform on the rate and pattern of migration and thus help define questions relating to survival and growth during migration through the Bay and Gulf. Understanding the current and historic estuary are critical for choosing future management scenarios, but it is not sensible and probably not possible to try to go back to a prior ecological state.

Keywords: salmonid, San Francisco Bay, juvenile migration, Gulf of Farallones, management

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (I) – Order 5

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Flow, Gates, Trucks, and Chinook salmon: Collaborative Approaches to Adaptive Management in the Lower Mokelumne River

Jose Setka, East Bay Municipal Utility District, jsetka@ebmud.com
Robert Vincik, California Department of Fish & Game, RVINCIK@dfg.ca.gov
Joseph Johnson, California Department Fish & Game, JRJOHNSON@dfg.ca.gov
Donald Ratcliff, USFWS AFRP, Donald_Ratcliff@fws.gov
Joshua Israel, USBR, jaisrael@usbr.gov

The lower Mokelumne River (LMR) produces a substantial Chinook salmon return that significantly contributes to the Central Valley salmon population and associated commercial and sport fisheries. In fall 2008 ocean conditions were identified as being one of the key factors in the decline of fall-run Chinook salmon escapement. However, an additional factor contributing to low returns in the LMR appears to be high straying rates to other rivers. During 2008 and 2009, over 50% of the total number of Mokelumne River origin Chinook salmon returning to Central Valley tributaries strayed into the American River.

The Lower Mokelumne River Partnership (Partnership) is made up of representatives from CDFG, USFWS and EBMUD. The Partnership identified several factors that can influence straying including flow operations, Delta water management (including Delta Cross Channel operations), temperature, and planting practices for hatchery fingerlings and smolts. Working with operators from EBMUD, DWR, and USBR the Partnership has developed a number of adaptive management actions to test their effect on stray rates and total escapement. These actions include closures of the Delta Cross Channel gates and attraction releases from Camanche Reservoir. Additionally, CDFG and EBMUD biologists and hatchery managers reviewed historic release sites for Mokelumne River Fish Hatchery production and identified Sherman Island as a site that potentially reduces stray rates while maintaining an acceptable rate of return to the river and fisheries.

Since implementation of various adaptive management actions, straying of Mokelumne River salmon has been reduced compared to years when no actions are taken. In fall 2011 the Chinook salmon escapement to the river was the highest observed since 1940. Based on the initial results, a five-year study plan is being developed to further evaluate the multiple management actions along with developing a protocol to support decision making about actions involving Delta water management.

Keywords: Mokelumne River, Delta Cross Channel, Attraction Flows, Straying Rates, Salmon

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (II) – Order 6

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Juvenile Chinook Salmon Entrainment into Unscreened Water-Diversion Pipes: Can Behavioral Fish-Deterrent Devices Decrease Their Entrainment Rates?

Timothy Mussen, University of California, Davis, tdmussen@ucdavis.edu
Dennis Cocherell, Dept. of Wildlife, Fish, and Cons. Bio., UC Davis, decocherell@ucdavis.edu
Oliver Patton, Dept. of Wildlife, Fish, and Cons. Bio., UC Davis, ojpatton@ucdavis.edu
Denisse Jauregui, Dept. of Wildlife, Fish, and Cons. Bio., UC Davis, djauregui@ucdavis.edu
Ali Ercan, Civil and Environmental Engineering Department, UC Davis, aercan@ucdavis.edu
Hossein Bandeh, Civil and Environmental Engineering Dept., UC Davis, ghoba@ucdavis.edu
Levent Kavvas, Civil and Environmental Engineering Dept., UC Davis, mlkavvas@ucdavis.edu
Joseph Cech Dept. of Wildlife, Fish, and Cons. Bio., UC Davis, jjcech@ucdavis.edu
Nann Fangue, Dept. of Wildlife, Fish, and Cons. Bio., UC Davis, nafangue@ucdavis.edu

Emigrating, juvenile Chinook salmon risk entrainment (removal from the river) via water-diversion pipes associated with municipal water or agricultural-irrigation withdrawals from the California Central Valley. Most water-diversion pipes are unscreened, providing no entrainment protection. Fish entrainment susceptibility may vary under different river currents, water intake diversion rates or light levels. We investigated the daytime entrainment risk of Chinook salmon (length range: 7 - 15 cm) in a large-sized (24 m L x 3.3 m W x 3.3 m H; 501,000-l) outdoor flume over a range of river currents (0.15, 0.38 and 0.61 m/s) and water diversion rates (0.34, 0.42 and 0.57 m^3/s) through a 45-cm-diameter pipe during the day. We also tested the ability of behavioral fish-deterrent devices to reduce the number of fish entrained into the pipe, without decreasing the total amount of water diverted. Fish entrainment was higher at 0.15 (50%) than at 0.61 m/s (12%) river currents, due to increased fish movement at slower river speeds. Fish deterring devices were tested at 0.15 m/s river current and 0.57 m^3/s water diversion rate. Compared to control experiments, fish entrainment rates increased significantly (by 61%) with strobe lights, were unaffected by a velocity cap, and decreased significantly (by 68%) when a metal ring was vibrated at 12 Hz in front of the pipe during the night. Most strikingly, fish entrainment rates were greatly reduced using a widened box with louver bars attached to the pipe inlet (97%) and when a perforated diffusing cylinder was used (94%). Our findings suggest that unscreened water diversions may pose a significant threat to juvenile Chinook salmon in the Delta and behavioral fish-deterrent devices may decrease their entrainment risk, without disrupting water extraction practices. Research was funded by the Anadromous Fish Screen Program.

Keywords: fish, diversions, screens, louvers, guidance, swimming, entrainment, behavior, hydraulics, flume

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (II) – Order 7

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How Do Inflow, Outflow, Water Export, and Tides Affect Salmonid Loss in the Delta's Fish Facilities?

Li-Ming He, NOAA-NMFS, li-ming.he@noaa.gov

There are long-term monitoring data available for Deltain flow, outflow, OMR flow, water export, and fish loss to the SWP and CVP fish collection facilities. These data sets have been analyzed by many researchers, in an attempt to shed light on what factors control the fish loss to the fish facilities. Some suggested that OMR flow or water export was the major factor while others indicated that tide or Delta outflow exhibited more influence than other factors. While each of the analyses may not be invalid to some degree, these studies are focused on individual factors. Our analysis presented here will use a holistic approach to evaluate these factors individually and collectively. We will provide the methods and framework we have developed and present and discuss some of the preliminary results.

Keywords: fish salvage, Delta outflow, OMR, SWP, CVP, salmonids

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (II) – Order 8

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Factors Driving Variation in Salvage and Survival of Juvenile Chinook in the Delta

Steve Cramer, Cramer Fish Sciences, stevec@fishsciences.net

Fish salvage at the Delta pumps has been used as the primary index of fish losses associated with export pumping, and is also the longest term, consistent data set on fish passing through the Delta. I will present results of our newest analyses of salvage data to sort out the key factors that drive the numbers of juvenile Chinook arriving at the pumps. Correlations of salvage to catches in the Chipps trawl, both for unmarked Chinook and for CWT groups, show that salvage increases as survivorship through the Delta increases. After including Chipps trawl catches as an independent variable reflecting smolt abundance, the remaining variation in salvage rates is related to Sacramento flow, San Joaquin flow, and water temperature. Export pumping volume shows little or no relationship to salvage density. We are extending this analysis to incorporate a mechanistic accounting of route selection and route-specific survival for smolts passing through the Delta. Route specific parameters are derived from acoustic telemetry studies, which also enable quantitative linkage of smolt behavior to flow dynamics through the Delta. We combine the results of Delta hydrodynamics models with those of smolt passage models to test the relative influence of various water operations on fish salvage at the export pumps and on smolt survival through the Delta. Results can be used by managers to weigh the merits of variations to Delta operations for protecting ESA-listed Chinook smolts.

Keywords: Delta, Chinook, survival, salvage, abundance, pumping

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (II) – Order 9

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Using Acoustic Telemetry to Assess Hydrodynamic Factors Influencing the Migration Behavior and Route Selection of Juvenile Salmonids in the Interior Delta

Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Kris Jones, Cramer Fish Sciences, kjones@fishsciences.net
Jenny Meglo, Cramer Fish Sciences, jennym@fishsciences.net

In January 2012, plaintiffs, plaintiff-intervenors, and Federal defendants in the litigation relating to the Biological Opinion on long-term operations of the State Water Project (SWP) and Central Valley Project (CVP) issued entered into a joint stipulation regarding project operations during April and May 2012. Part of this stipulation agreement called for an intensive acoustic telemetry study to assess how South Delta exports may alter the behavior and route selection of juvenile salmonids (particularly steelhead smolts) migrating along the mainstem San Joaquin River. To meet this objective, more than 500acoustically tagged hatchery steelhead smolts were released downstream of Stockton and dozens of additional telemetric receivers were placed at strategic locations in the Central, South and Western Delta. Releases were conducted every two weeks at three different levels of South Delta exports (or OMR flows). Within-season analyses showed that a relatively large fraction (~25%) of acoustically tagged smotls arrived at receiver arrays located along Old and Middle River corridors just north of Woodward Island (Railroad Cut). However, subsequent analysis showed the proportion of fish arriving at Railroad Cut was consistent with survival rates observed in previous acoustic studies and with fish routing following15-minute flow proportions. The rate of acoustically tagged fish arriving at Railroad Cut did not appear related to South Delta export levels, but these results were preliminary. Detailed analysis relating fish behavior to channel specific DSM2 Hydro and particle tracking model results will provide a robust assessment of hydrodynamic factors which may influence migrating juvenile salmonids in the interior Delta. The 2012 stipulation telemetry study is the first to focus on quantification of juvenile salmonid behavior rather than on estimating survival rates. Results reported for this study are expected to strongly influence planned Delta water project operations for 2013.

Keywords: Delta, salmon, steelhead, entrainment, exports, OMR, hydrodynamics, OCAP, BiOp, behavior

Thursday, October 18, 2012: Room 311-313, Salmonid Life History and Biology (II) – Order 10

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Assessing the Survival and Behavior of Radio Tagged Chinook Smolts on the Lower Stanislaus River

Kristopher Jones, Cramer Fish Sciences, kjones@fishsciences.net
Clark Watry, Cramer Fish Sciences, clarkw@fishsciences.net
Kirsten Sellheim, Cramer Fish Sciences, kirstens@fishsciences.net
Joe Merz, Cramer Fish Sciences, joe.merz@fishsciences.net
John Wikert, AFRP, john_wikert@fws.gov

Dramatic declines in abundance have been observed in Central Valley salmonid populations over the past few decades. Despite significant study of factors influencing the survival of salmonids in the lower Stanislaus River, there is still a great deal of uncertainty regarding the specific sources of mortality for juvenile salmonids along this stretch of river, at a fine spatial scale. For example, it is unknown whether survival is constant throughout this migration corridor or whether in-channel mine pits (e.g., Oakdale Recreation Ponds) are contributing to losses. In order to assist the Anadromous Fish Restoration Program (AFRP) in planning restoration activities, it is important to understand the spatial distribution of mortality, and identify geographic areas along the migratory corridor where losses occur. During the spring of 2012, we conducted a tagging study using radio telemetry technology to determine whether there is spatial variation in survival of Chinook smolts on the lower Stanislaus River (between river miles 10-40). In addition, we tracked experimental fish using mobile radio telemetry surveys and monitored their movement and behavior during their outmigration. These data will allow us to explore whether reach specific differences in biotic and abiotic characteristics contribute to differences in survival along the Stanislaus River. Moreover, the results from this study will serve to fill a knowledge gap regarding juvenile salmonid behavior during rearing and outmigration (e.g., travel times, habitat use, diel patterns of movement), which will enhance our understanding of Stanislaus River salmonid life histories, while also further supporting the AFRP's objectives for salmon recovery in California's Central Valley.

Keywords: Chinook, Stanislaus River, survival, outmigration, radio telemetry.

Thursday, October 18, 2012: Room 311-313, Using Biotelemetry to Assess Survival and Behavior of Fishes (I)– Order 1

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Estimating Relative Survival of Feather River Fish Hatchery Steelhead, *Oncorhynchus mykiss*, Smolts under Different Release Strategies

Ryon Kurth, Department of Water Resources, rkurth@water.ca.gov
Mike Mercer, Department of Water Resources, mmercer@water.ca.gov
Andrew Hampton, Department of Water Resources, ahampton@water.ca.gov
Katie Lentz, Department of Water Resources, klentz@water.ca.gov
Anna Kastner, Department of Fish and Game, akastner@dfg.ca.gov
A.J. Dill, Department of Fish and Game, adill@dfg.ca.gov

The Department of Water Resources and the Department of Fish and Game are preparing Hatchery and Genetic Management Plans (HGMP) for the three salmonid programs at the Feather River Fish Hatchery (FRFH). A primary goal of the HGMPs is to devise biologically-based artificial propagation management strategies that reduce ecological and genetic impacts to state and federal Endangered Species Act listed salmonids. Review of the existing data has revealed many gaps in information needed to evaluate potential impacts and develop management strategies that ameliorate those impacts. For example, the FRFH annually releases up to 450,000 steelhead, *Oncorhynchus mykiss,* smolts into the lower Feather River, yet little or no data has been collected on migration behavior and survival of these fish after release.

Using acoustic telemetry we are studying migration behavior FRFH steelhead smolts and the effect of release location and time of day of release on survival through the Feather River. In cooperation with the California Fish Tracking Consortium we will also able to track fish into the Sacramento-San Joaquin Delta (SSJD) and out to the Pacific Ocean. Preliminary results comparing two release sites (river kilometer 66.8 and 35.4) and morning or evening release indicate that relative survival through the Feather River is greater for fish released at the downstream release site and in the evening. Data regarding migration behavior and survival through the SSJD to the Pacific Ocean will also be discussed. Results from this study will improve the performance of the FRFH steelhead program and provide insight about through SSJD survival for migrating *O. mykiss*.

Keywords: *Oncorhynchus mykiss*; acoustic telemetry; survival; migration behavior; hatchery management

Thursday, October 18, 2012: Room 311-313, Using Biotelemetry to Assess Survival and Behavior of Fishes (I) – Order 2

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Tracking Juvenile Salmon with Micro-Transmitter Technology: Lessons Learned from a Pilot Sacramento River Study

Sean Hayes, NOAA SWFSC Fisheries Ecology Division, sean.hayes@noaa.gov
Arnold Ammann, NOAA SWFSC Fisheries Ecology Division, arnold.ammann@noaa.gov
Eric Chapman, Dept. of Wildlife, Fish, & Cons. Biology, UC Davis, edchapman@ucdavis.edu
Jason Hassrick, NOAA SWFSC Fisheries Ecology Division, jason.hassrick@noaa.gov
Jason Kindopp, CA DWR DES Ecological Studies Branch, jkindopp@water.ca.gov
A. Peter Klimley, Dept. of Wildlife, Fish, & Cons. Biology, UC Davis, apklimley@ucdavis.edu
Ryon Kurth, CA DWR DES Ecological Studies Branch, rkurth@water.ca.gov
Steve Lindley, NOAA SWFSC Fisheries Ecology Division, steve.lindley@noaa.gov
Cyril Michel, NOAA SWFSC Fisheries Ecology Division, cyril.michel@noaa.gov
Joseph Merz, Cramer Fish Sciences & UC Santa Cruz, jmerz@fishsciences.net
Gabriel Singer, Dept. of Wildlife, Fish, & Conservation Biology, UC Davis, gsinger@ucdavis.edu
Steven Zeug, Cramer Fish Sciences, stevez@fishsciences.net

River flow, fish size and migration timing can have significant effects on juvenile Chinook salmon *Oncorhynchus tshawytscha* survival during emigration from the highly-modified Sacramento River System to the Pacific Ocean. To date, the use of telemetry technology has been constrained to relatively large, surgically implanted tags which have required the use of larger (110-160 mm FL+), hatchery-raised salmon (often post-yearling late-fall Chinook salmon) which migrate in December to February. Extensive study has revealed survival from the upper Sacramento to the Golden Gate Bridge is quite low (~7-15%). These results are frequently used as a proxy for survival of fall-, winter- and spring-run's of Chinook salmon. However because of size and migration timing differences, late fall-run smolts may be poor surrogates for smaller sub-yearling fish that migrate at different times of year, with different migration strategies.

To remedy concerns related to surrogate performance, a consortium of federal, state, university, and private scientists implemented a pilot study using the Juvenile Salmon Acoustic Telemetry System (JSATS) to evaluate on Sacramento River Chinook salmon emigrants during the spring of 2012.An array of 54 receivers was deployed from Battle Creek on the upper Sacramento and on the Feather River to the Golden Gate in April. Coleman National Fish Hatchery (CNFH) fall-run (410) and Feather River Fish Hatchery (FRFH) spring-run (139) Chinook salmon were raised to representative sizes (76-130 mm) and implanted with JSATS tags to measure relative survival from the Upper Sacramento and Feather River hatcheries to Benicia Bridge for early versus late releases (CNFH fall-run), in-river versus trucked survival (FRFH spring-run),and a delta-specific release (CNFH fall-run). Acoustic receivers will be down loaded in July 2012. We also tested detection range, post-surgery tag retention/survival, and tag failure rates. Key lessons learned as well as pilot study results will be presented.

Keywords: JSATS, juvenile Chinook salmon, movement, survival, acoustic telemetry

Thursday, October 18, 2012: Room 311-313, Using Biotelemetry to Assess Survival and Behavior of Fishes (I)– Order 3

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Applying Predator-Prey Models to Reach-Specific Survival Estimates of Juvenile Late-Fall Chinook Salmon in the Sacramento-San Joaquin River Delta

Russell Perry, US Geological Survey, rperry@usgs.gov
Tobias Kock, US Geological Survey, tkock@usgs.gov
Jason Romine, US Geological Survey, jromine@usgs.gov
Patricia Brandes, US Fish and Wildlife Service, pat_brandes@fws.gov

Understanding factors affecting the mortality rates of juvenile salmon emigrating from the Sacramento River is critical for devising water management strategies that maximize survival. Predation by non-native piscivorous fishes is widely thought to be a primary mechanism causing mortality of juvenile salmon in the Delta. Casting juvenile salmon survival in the context of predator-prey theory can therefore provide insights about how migration dynamics of juvenile salmon contribute to their mortality. Migration rates of juvenile salmon change considerably as they transition from a riverine environment to the tidally-driven environment of the Delta. In the upper reaches of the Delta, fish migrate downstream quickly whereas in tidal regions, migration rates slow considerably due to tidal forcing. When prey move quickly through a gauntlet of predators, predator-prey theory predicts that survival will depend only on distance traveled. In contrast, when prey move slowly relative to predators, theory indicates that survival will depend only on travel time. In the Delta, we hypothesize that survival transitions from distance- to time-dependence as fish migrate from the upper to lower reaches of the Delta. To understand how both travel time and travel distance affect mortality rates, we 1) quantified the effect of river flows on migration rates, and 2) fit predator-prey models to reach-specific survival estimates of juvenile salmon collected between 2007 and 2010. We then used model selection to compare alternative predator-prey models where survival depends on travel time, on travel distance, or a mixture of both time and distance. Our analysis will provide a mechanistic basis for understanding how water management actions that alter the quantity and routing of river flow influence migration of juvenile salmon, and in turn, how changes in migration dynamics influence survival.

Keywords: telemetry, juvnile chinook salmon, survival, predator-prey models, migration

Thursday, October 18, 2012: Room 311-313, Using Biotelemetry to Assess Survival and Behavior of Fishes (I)– Order 4

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Survival and Route Selection of Juvenile Chinook Salmon in the Southern Sacramento-San Joaquin River Delta, 2011

Rebecca Buchanan, University of Washington, rabuchan@u.washington.edu

Juvenile salmonids typically have low survival migrating through the Sacramento-San Joaquin River Delta. Improving survival requires knowledge about the migration routes salmon take through the Delta and on reaches with high mortality. 2011 was the final year of the Vernalis Adaptive Management Program acoustic-tagging study, with 1,899 juvenile fall Chinook salmon tagged and released in the San Joaquin River approximately 12 miles upstream of the confluence with Old River. Tagged smolts were monitored at 25 fixed-site acoustic receiver locations throughout the south Delta to Chipps Island. Acoustic-tag detections were analyzed with a release-recapture model to estimate route selection probabilities at the head of Old River and survival probabilities in key reaches of the San Joaquin and Old rivers. Results on survival, route selection, and travel time will be presented and compared to similar studies from previous years. This information is crucial for appropriate management of salmon populations through the Delta.

Keywords: Chinook, salmon, acoustic-telemetry, release-recapture, San Joaquin, route selection, survival

Thursday, October 18, 2012: Room 311-313, Using Biotelemetry to Assess Survival and Behavior of Fishes (I) – Order 5

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Napa River Steelhead Smolt Utilization of Napa Plant Site Tidal Marsh Using Acoustic Tags

Thomas Keegan, ECORP Consulting, Inc., tkeegan@ecorpconsulting.com
Renee Spenst, Ducks Unlimited, Inc., rspenst@ducks.org
Philip Sandstrom, UC Davis, psandstrom@ucdavis.edu

Funded by NMFS (ARRA) and Ducks Unlimited, the intent of this project was to tag and track wild juvenile Napa River steelhead (Central California Coast ESU) through the lower Napa River, particularly in the vicinity of the newly-restored and breached 1,600 acre Napa Plant Site (old Cargill salt ponds). The purpose of this Project is three-fold: to quantitatively assess the utilization of restored tidal marsh habitats by wild Napa River steelhead smolts that were collected via Napa County Resource Conservation District's rotary screw trap in the upper Napa River; to assess utilization of the restored marsh by other special-status Chinook salmon, steelhead and green sturgeon that were tagged by other investigators (with permission) associated with the California Fish Tagging Consortium; and to determine the regional effectiveness of tidal restoration efforts on these species.

Fourteen acoustic (VEMCO) receivers were installed in the Napa River, upstream and downstream from the Napa Plant site, and strategically within the three units (North, Central, and South units) of the site to document steelhead entrance into the units, residency time in the vicinity of each receiver/unit, and where possible, to describe habitat preference by steelhead within each of the units. VEMCO receivers were also installed in the lower Napa River and Mare Island Strait to determine distribution and timing of outmigration.

Keywords: steelhead, tidal marsh, habitat distribution, VEMCO, acoustic tag, Napa River.

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Seasonal Distribution and Habitat Usage of Juvenile Striped Bass in the San Francisco Estuary Watershed

Cynthia Le Doux-Bloom, California Department of Water Resources, cledoux@water.ca.gov
Michael Johnson, John Muir Institute of the Environment, University of California, Davis, mbjohnson@ucdavis.edu
Serge Doroshov, Department of Animal Science, University of California, Davis, sidoroshov@ucdavis.edu
J. Jeff Isely, National Oceanic and Atmospheric Administration, Southeast Fisheries Science Center, jeff.isely@noaa.gov

Several long term studies document the behavior of adult striped bass (*Morone saxatilis*) inhabiting the San Francisco Estuary Watershed, however, comparatively little is known about the distribution or pelagic habitat use of juveniles (<2 year olds). Understanding juvenile striped bass behavior can help to illuminate predator-prey interactions and guide restoration planning. To investigate seasonal distribution and pelagic habitat usage, juvenile striped bass (n=99; mean fork length= 285 mm) were surgically implanted with acoustic transmitters in June and July 2010 and tracked via stationary receivers (n=300) through October 31, 2011. Juveniles were tagged on the American (n=11), Sacramento (n=22), and San Joaquin rivers (n=33), the Sacramento Ship Channel (n=15), and Three Mile Slough (n=18). We have detections for 82% of the tagged fish totaling over one million records. Both distribution and pelagic habitat usage differed significantly between season and tagging locations. Juveniles tagged at sites within the Estuary had similar seasonal distribution patterns, while those tagged in the American River exhibited extended freshwater residency. Juveniles were distributed more closely to their tag site location or made more visits to the area than to other locations except San Pablo Bay. As day length increased, the distribution of juveniles tagged at estuarine sites shifted toward warmer (20ºC) and higher salinity (>5 ppt) waters in the west Delta and San Pablo Bay, respectively. As day length decreased, distribution shifted away from the San Pablo and Central bays and into Carquinez Strait, Central Delta, and North Delta. During the second summer, several fish migrated over 200 Km upstream into the Sacramento and Feather rivers. Habitat usage was dominated in warm (>20ºC), fresh and temperate (10-20 ºC) polyhaline waters in summer, temperate, fresh and euhaline in fall, temperate mesohaline and fresh over winter, and temperate fresh and oligohaline habitat during spring.

Keywords: juvenile striped bass, biotelemetry, seasonal distribution, pelagic habitat,

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Environment and Movement Patterns of Largemouth Bass in the Sacramento - San Joaquin Delta

Anna Steel*, University of California, Davis, aestephenson@ucdavis.edu
A. Peter Klimley, University of California, Davis, apklimley@ucdavis.edu

To successfully manage the novel ecosystem of today's Delta we must have an understanding of key interactions between organisms and their environment. Much of our knowledge about the largemouth bass, a non-native but numerically dominant species in the Delta, originates from lake studies conducted in other regions of the country. Due to the unique complexity of the Delta, it is important to examine the life history and behavior of this species in a local context. To help achieve this goal, a telemetry positioning system was deployed over 15 months in a flooded island in the south-central Delta. The array was designed to examine the daily and seasonal movement patterns of tagged largemouth bass, particularly the species' interaction with beds of submerged aquatic vegetation and open-water habitats. The positioning system was located within an existing Delta-wide array of presence/absence monitors, allowing for observations of both coarse- and fine-scale movements. Results suggest three general classes of behavior in adult largemouth bass: a) non-resident, b) wide-ranging resident, and c) localized resident. Non-resident fish showed long range movements (~4 to~20 river km from the tagging location) which generally occurred during the summer months. Resident fish remained in the study area over several months, and displayed seasonal movement patterns which appeared to be related to breeding behavior. Additional analyses will focus on impacts of local environmental factors, such as water temperature, vegetation density, and tidal cycles, on these movement patterns. This work sheds light on the population connectivity and habitat use of largemouth bass in the Delta and provides insight into how bass may colonize or use future shallow-water restorations. The information gained will be important as management decisions attempt to balance needs of both native fish and desirable sport fish, such as the largemouth bass.

Keywords: largemouth bass, telemetry positioning system, submerged aquatic vegetation

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Using Acoustic Telemetry to Determine Movements, Behavior and Critical Spawning Habitat for Green Sturgeon in the Sacramento River

Michael Thomas, UC Davis, mjthomas@ucdavis.edu
Matthew Peterson, UC Davis, mlpeterson@ucdavis.edu
Alex Hearn, UC Davis, arhearn@ucdavis.edu
A. Peter Klimley, UC Davis, apklimley@ucdavis.edu

The green sturgeon, *Acipenser medirostris*, is one of two acipenserid fishes native to the Central Valley. On April 7, 2006 the Southern DPS, which constitutes the spawning population of the Sacramento River, was listed as "threatened" under the Endangered Species Act (ESA). Recent interest in green sturgeon behavior, habitat preferences, and migratory path ways has led us to develop a series of telemetric and hydrologic studies to identify and describe potential aggregate and spawning locations. Over the past five field seasons we have tracked green sturgeon both actively and passively within the putative spawning grounds. Using this movement data as a basis for identifying fidelity to specific habitat units, we have now begun mapping and describing the physical and hydrologic characteristics of known spawning locations. These studies will provide new information about habitat preference, and the availability of preferred habitat within the Sacramento drainage.

Keywords: green sturgeon, biotelemetry, Sacramento River

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Advancements in Delta Smelt Acoustic Tagging

Kai Eder, UC Davis, kjeder@ucdavis.edu
Tien-Chieh Hung, UC Davis, thung@ucdavis.edu
Donald Thompson, UC Davis, dethompson@ucdavis.edu
Raul Piedrahita, UC Davis, rhpiedrahita@ucdavis.edu
Frank Loge, UC Davis, fjloge@ucdavis.edu

Delta smelt, previously one of the most common resident pelagic fish in the San Francisco Estuary, have dramatically declined in abundance since the 1980s. In order to develop sound management and restoration strategies, critical data gaps concerning delta smelt life history, habitat requirements, and exposure to key environmental stressors need to be addressed. Detailed resolution of fish movement and activity over spatial and temporal scales can be achieved by acoustic telemetry. The aim of this study was to assess the feasibility of tagging adult delta smelt to advance the long-term goal of establishing an estuary-wide smelt acoustic telemetry system. Cultured adult delta smelt (age-1and age-2) were injected with a low viscosity polyurethane resin in order to determine the volume and shape of the peritoneal cavity. Dimensions of adult delta smelt peritoneal cavities permitted the use of the smallest currently available acoustic transmitter as a prototype for production of dummy tags along a gradient of sizes and weights. Three differently sized transmitters and PIT (Passive Integrated Transponder) tags were surgically implanted into age-1 and age-2 delta smelt to evaluate survival, tag retention, and wound closure over 28 days. Handling and anesthesia did not affect the survival of delta smelt during the study period. Cumulative mortality of all fish implanted with tags was significantly higher than that of the untreated control group, and survival was a function of tag size/weight. However, survival in the PIT-tagged group approached 75% over the28-day period, emphasizing the potential use of a small, injectable acoustic transmitter – currently under development by the US Army Corps of Engineers - for delta smelt field studies as early as 2014.

Keywords: Delta smelt, acoustic telemetry,

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Intractable Islands in the Delta: Innovations in Polder Management for Ecosystem Restoration in the Bangladesh, California and Dutch Deltas

Philippus Wester, Assistant Professor Water Reforms, Water Resources Management Group, Department of Environmental Sciences, Wageningen University, flip.wester@wur.nl

Rising sea levels, salinity intrusion, land subsidence and higher river discharges are intractable policy issues facing the Bangladesh, California and Dutch Deltas. While very distinct, all three Deltas face similar challenges it terms of flood management and the future of land use in their polders (called islands or tracts in California). This paper explores and compares innovations in polder management in the three Deltas, to encourage mutual learning and to contribute to improved decision making on the future of the polders of the California Delta.

Strengthening and heightening embankments (Bangladesh), levees (California) and dikes (The Netherlands) is a finite and costly strategy that is increasingly questioned in the three Deltas. Innovations in polder management, such as de-poldering in the Netherlands and Tidal River Management (TRM) in Bangladesh, although highly contested, appear to provide promising opportunities for ecosystem restoration (and improved livelihood opportunities in the case of Bangladesh). To provide more room for the river and to restore ecosystems, the Dutch are experimenting with de-poldering several of their polders, by removing the protective dikes or lowering them to allow flood waters in. In Bangladesh, the creation of polders in the Southwest Delta led to the sedimentation of tidal rivers and the slow flooding of the polders due to drainage congestion. Through local initiative, people have cut their embankments to allow the tidal rivers back into the polders for a period of three to five years, leading to sedimentation in the polders and the scouring of tidal rivers. In the California Delta, the risk of levee failures are high and the future of the islands is unclear. Based on experiences with de-poldering and TRM a more pro-active policy could be developed in the California Delta to allow for the controlled flooding of selected islands for ecosystem restoration and improved recreation opportunities.

Keywords: polders, flood management, de-poldering, tidal river management, ecosystem restoration

Thursday, October 18, 2012: Room 314, Global Perspectives– Order 1

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Projected Climate Change Impacts to the San Francisco Bay-Delta Ecosystem and Region

Tom Suchanek, U.S. Geological Survey - Western Ecological Research Center, tsuchanek@usgs.gov

The San Francisco Bay region, and specifically the Bay-Delta system is being and will continue to be impacted by global climate change on a local scale. We are already experiencing extreme variability in weather and can expect further increases in air and sea temperatures, increased storm frequency and intensity resulting in greater precipitation and flooding events, increased frequency and intensity of El Niño events (which also reduce upwelling and dramatically decrease coastal ecosystem productivity), extended droughts, continued sea level rise, increased ocean acidification, and ultimately dramatic changes in and loss of shoreline habitats. This is overlain onto a system that is already impacted by ongoing land use changes, invasive species and contaminants. What will the Bay-Delta system look like in 20/50/100 years? How can we address changes that will continue to threaten endemic and listed species? What mitigation strategies can we implement to help deal with some of these risks? What timeframe do we have to start taking corrective or remedial actions? These questions and more will be addressed by referencing ongoing research by numerous organizations in the Bay Area.

Keywords: Climate change, extreme weather/variability, sea level rise, El Niño events

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Stemming the Tide of Ballast Water Invasions? Geographic Patterns of Ballast Water Exchange and Discharge to the San Francisco Bay-Delta Region

Amanda Newsom, Marine Invasive Species Program, California State Lands Commission, newsoma@slc.ca.gov
Chris Scianni, Marine Invasive Species Program, California State Lands Commission, newsoma@slc.ca.gov
Christopher Brown, Marine Invasive Species Program, California State Lands Commission, brownc@slc.ca.gov
Nicole Dobroski, Marine Invasive Species Program, California State Lands Commission, dobrosn@slc.ca.gov
Raya Nedelcheva, Marine Invasive Species Program, California State Lands Commission, nedelcr@slc.ca.gov
Maurya Falkner, Marine Invasive Species Program, California State Lands Commission, falknm@slc.ca.gov

Marine invasive species have negatively impacted public health, coastal environments, and the economy of California. To address this ongoing threat, the State of California has adopted laws and regulations aimed at controlling the influx of invasive species via ballast water discharges. Current regulations require that ships exchange waters taken up for ballast in coastal environments with open ocean waters at least 50 or 200 nautical miles off any coast, depending on where the water was sourced and where the vessel is arriving from, before discharging ballast water in California ports.

This talk will present an analysis of ballast water discharged to San Francisco Bay and the Sacramento-San Joaquin River Delta region for the past two years, in the context of a changing regulatory landscape. Under current regulations, the California State Lands Commission (Commission) collects and manages ballast water management reporting forms from vessels arriving in California. These forms contain a rich data source regarding ballast water management practices, including ballast water exchange locations, for vessels arriving to the San Francisco Bay region. Data collected from these forms will be presented regarding where and when ballast water has been taken up, exchanged, and eventually discharged within the waters of San Francisco Bay and the Delta. Patterns regarding vessel compliance with exchange requirements will also be presented. This information is a powerful tool for retrospective and predictive analyses of marine invasion patterns in the San Francisco Bay region.

Keywords: Invasive species, vector management, ballast water, open-ocean exchange

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Atmospheric Rivers, Levees and Floodplain Ecology in the Bay-Delta System

Michael Dettinger, USGS, Scripps Institution of Oceanography, mddettin@usgs.gov
Joan Florsheim, UC Davis, Dept of Geology, florsheim.geology@gmail.com
F. Martin Ralph, NOAA/Earth Systems Research Lab/Physical Sciences Division, marty.ralph@noaa.gov

Atmospheric rivers (ARs) are narrow, transient corridors of strong water-vapor transport in midlatitude winter storms, corridors of intense winds and moist air roughly 400-500 km across and thousands of km long. First recognized in 1998, ARs are increasingly understood to play crucial roles in flooding and water resources in California. ARs routinely transport water vapor at rates equivalent to 7-15 times the average daily discharge of the Mississippi River, and the half dozen or so ARs per year that make landfall in California contribute an average of one third to one half of all the State's precipitation, thereby supplying much of the State's water resources. Meanwhile, AR storms also have been the sources of many (and in some rivers, most) floods in the State. Floods arising from AR storms have been the dominant historical cause of levee breaks in the CentralValley and Delta (>80% of the breaks) since 1951. AR storms have also been the primary initiators (also about 80% of the time) of flood flows and the ecologically beneficial inundations of the Yolo Bypass floodplains in that era. Thus, ARs are an important part of the hydroclimatic variability to which the ecologies and life histories of many of the region's aquatic and riparian habitats and species are adapted. Understanding and prediction of future AR conditions could be a particularly important contribution from the climate sciences to environmental restoration activities, and to the enhancement of water-supply reliability, in the Bay-Delta system.

Keywords: Climate Climate Change Floods Floodplain ecosystems Levee Breaks Atmospheric Rivers

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Enhancement of the Sacramento-San Joaquin Delta Island Consumptive Use Estimates and Water Quality Predictions

Lucas Siegfried*, Civil & Environmental Engineering Department, University of California, Davis, ljsiegfried@ucdavis.edu
William Fleenor, Civil & Environmental Engineering Department, University of California, Davis, wefleenor@ucdavis.edu
Josue Medellin-Azuara, Civil & Environmental Engineering Department, University of California, Davis, jmedellin@ucdavis.edu

Continuous water diversions, water operations, and land-use changes in the Sacramento-San Joaquin Delta have impaired the Delta's water flows, quality, and suitability for fish species. A thorough knowledge and understanding of the flow features in Delta rivers and streams is crucial for a solution of these problems. In an on-going effort to better understand and manage the Delta, a collaborative, integrated approach was used to better predict Delta Island Consumptive Use of water (DICU) flows and water quality variables on a higher temporal resolution and actual diversion and return locations on topography rather than simple geographical approximation. The Island known as Fabian Tract was selected for this proof-of-concept study based on available data and island accessibility. A combination of historical diversion and return location data, water rights claims, and LIDAR digital elevation model data were used to predict diversion and return locations on the island. The accuracy of the predicted diversion and return locations was analyzed through ground-truthing. To calculate water requirements and runoff returns from agricultural land-use, incorporating soil and land-use characteristics as well as weather data, the IWFM Demand Calculator (IDC) was selected based on model capabilities, ease of use, applicability, and recommendations. As input to the IDC model, the Fabian Tract was divided into grid cells forming subregions, representing fields, levees, ditches, and roads. The subregions were joined to form diversion and return watersheds representing the total area supplied by a given water source or the total drainage area for a given return. Model results provide daily estimates of the volume of water diverted and returned from actual diversion and return locations, lending insight into daily agricultural diversion and return operations within the Delta that are missed in current DICU models and contributing to sustainable solutions to the problems faced by the Delta.

Keywords: Sacramento-San Joaquin Delta, Consumptive Use, DICU, IDC, IWFM, Modeling

Thursday, October 18, 2012: Room 314, Global Perspectives– Order 5

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Biological Goals and Objectives for the Bay Delta Conservation Plan: Balancing Theoretical, Practical, and Institutional Factors

Christopher Earle, ICF International, Chris.Earle@icfi.com
Chris Soncarty, ICF International, Chris.Soncarty@icfi.com

Biological goals and objectives are the principal metric by which a habitat conservation plan can demonstrate its progress in conserving protected species. Biological goals represent desired species- or population-level outcomes such as increased abundance, while the biological objectives represent quantitative metrics such as a population index or average growth measure. Despite their theoretical simplicity, the challenge in designing biological objectives comes in establishing quantitative metrics that are scientifically valid, practical and feasible to implement (e.g., cost-effective and minimize harm to the sampled species), responsive to the predicted effects of the conservation actions, and sensitive to the concerns of the many stakeholders. We review potential solutions to this conundrum for the 11 species of fish covered in the Bay-Delta Conservation Plan, illustrating how the process uses existing data and input from multiple stakeholders to craft suitable metrics.

Keywords: goals, objectives, policy, endangered, BDCP

Thursday, October 18, 2012: Room 314, Achieving Ecological Goals through the BDCP in the Face of Uncertainty– Order 1

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Tastes Great, Less Filling: Delta Smelt in a Pelagic Food Web, Past, Present, and Future

Matt Nobriga, US Fish and Wildlife Service, matt_nobriga@fws.gov

There are multiple lines of evidence that delta smelt *Hypomesus transpacificus* growth rate is food limited. Similar evidence for food limitation of growth rate has also been reported for zooplankton, overbite clam, largemouth bass, Chinook salmon, and other fishes that use the estuary's low-salinity zone as a rearing habitat. Thus, food limitation seems to be a ubiquitous feature of life in the Bay-Delta that of itself, does not explain ecological success or failure. Rather, for a particular species, the ecological outcome of food limitation depends on its severity and context. For delta smelt, food limitation is occurring in a system that (1) is near the species' thermal tolerance limits for up to several months each year, and (2) has shown other signs of habitat degradation. Nonetheless, food limitation is an issue that should be addressed as part of a comprehensive conservation plan for delta smelt. To do so, we must learn how to improve delta smelt's feeding environment, and then take actions that maximally enhance its supporting food web. This presentation will review the current scientific understanding of what limits fish production in the Bay-Delta and explore the likelihood that several proposed actions will improve the food web that supports delta smelt.

Keywords: delta smelt, *Hypomesus transpacificus*, food limitation, zooplankton

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Department of Fish and Game Perspectives on Adaptive Management in achieving the goals and objectives of the Bay Delta Conservation Plan

Carl Wilcox, Department of Fish and Game, cwilcox@dfg.ca.gov

Role of Adaptive Management: Addressing uncertainty, building understanding, and improving management to assure restoration of a healthy ecosystem and species conservation that can provide water supply reliability as part of the Co-equal goals.

The Department and associated Federal Fish and Wildlife Agencies have a long history of recognizing the importance of adaptive management in providing for the effective conservation of natural communities and associated species. The Natural Community Conservation Planning Act specifically requires inclusion of an adaptive management plan for a Natural Community Conservation Plan (NCCP) approved by the Department. Effective adaptive management is dependent on having clear and measurable goals and objectives. Additionally a clear and transparent process for evaluating and synthesizing new information developed through monitoring and research and for making management decisions is required. This process needs to incorporate the use of conceptual models which summarize our current state of knowledge about the communities, processes, stressors, and species being managed and conserved under an approved plan.

The Department and partners through the Ecosystem Restoration Program, (formerly CALFED), have developed the DRERIP conceptual models for evaluating proposed actions to identify how they should be pursued based on the certainty of the science supporting the action in addressing a stressor(s) affecting the ecosystem and the potential magnitude of effect it will have on that stressor(s). These models allow for the development of hypotheses to be tested as part of implementing an action or through research to improve our level of understanding and guide future decision making about plan implementation. These models coupled with the Logic Chain process serve to provide a framework for adaptive management decision making.

This presentation will review examples of adaptive management processes, both NCCP's and other plans, which can guide development and implementation of the adaptive management process for the Bay Delta Conservation Plan.

Keywords: Adaptive management, conceptual models, BDCP, Fish and Game, logic chain

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DWR Perspective on Collaborative Science Process for BDCP Implementation and Adaptive Management Program

Mark Cowin, DWR, mcowin@water.ca.gov

The BDCP will require a collaborative effort to advance science to meet ecological goals. While DWR is the primary applicant for the BDCP and has taken an active role in developing the conservation strategy, many other entities will need to engage in the development of information to address uncertainties, improve results, and correct our path during implementation. As part of the implementation of BDCP, the adaptive management program and collaborative science process provide opportunities for federal, state, academic and other partners to work together in the Delta to solve our collective ecological problems. In this presentation, DWR will explore potential partnership and approaches for collaborative science and how it can benefit all Delta interests in BDCP implementation. Additionally, this presentation will highlight some of the work already progressing towards better collaboration.

Keywords: collaborative science, adaptive management, BDCP

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