ORAL ABSTRACTS

2016 Bay-Delta Science Conference

Abstracts for oral sessions presented at the 2016 State of the Bay-Delta Science Conference are compiled in this document. Abstracts are listed by topic in the order that they appear in the program and are sorted by day, room, and time. In the abstracts, names of presenting authors are underlined. Asterisks (*) indicate the abstract is submitted by a student and eligible for the student presentation awards competition.

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Lessons from the Ocean for Integrating Science in Policy Decisions

Steve Gaines, Dean, Bren School of Environmental Science and Management at UCSB, gaines@ucsb.edu

The Bay Delta poses a complicated array of environmental and social challenges. Science has a lot to add to the discussion, but as in many complex, contentious situations, science often gets relegated to a small role. This challenge is equally true in other systems, and my work in the ocean has many parallels. I will draw on my experience from a variety of marine policy discussions with strong conflict between stakeholder groups to share lessons learned about how to make science play a more effective role in these discussions. Some of these lessons emerged from successes, others emerged from failures. I will highlight four major lessons – focus on the science of solutions as much as on defining the problems, build new teams to enhance your impact, embrace the fact that different people value different things, and choose pretty good over perfection if it helps scale solutions. I believe all of these lessons transcend the systems we work in and the problems we tackle, so I hope that they can stimulate interesting dialogue on how science can play a more impactful role in enhancing solutions for the complex challenges in the Bay Delta.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

The Scientific Challenges of Establishing Appropriate Baselines for Watershed Restoration

Daniel Schindler, Harriet Bullitt Endowed Chair in Conservation, School of Aquatic and Fishery Sciences, University of Washington, deschind@uw.edu

Ecological restoration seeks to reestablish ecological structures and processes in ecosystems that have been degraded by human activities. Success is typically assessed by comparing prevailing conditions to restoration targets chosen to reflect desired ecosystem states. Restoration targets are often assumed to be an approximation of the ecosystem under superficial human influence. While such comparisons are convenient for developing restoration strategies and measuring success, they often lead to the assumption that there is a single stable state that the ecosystem should exist in. Long-term analyses of watersheds in coastal Alaska emphasize that ecosystems are continuously changing and re-organizing as they are subjected to a range of environmental perturbations. The observed degree of stasis and turnover in ecosystem properties depends critically on the spatial and temporal perspective taken. I will argue that restoration targets should be established that emphasize turnover and restructuring of ecosystem functions rather than the more typical approach that assumes there is a single desirable configuration of an ecosystem.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

Academic Research, Delta Smelt, and Public Policy

Peter Moyle, Center for Watershed Sciences and Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, pbmoyle@ucdavis.edu

The current ecological crisis in the Delta, first came to major public attention with the listing of the delta smelt. It was met with an unprecedented research effort, especially in academia. The result has been a vastly improved knowledge of the Delta. But the Delta ecosystem has continued to undergo rapid change despite the new knowledge. Science-based policy studies, such as those of the joint efforts of the UCD Center for Watershed Sciences and the Public Policy Institute of California, have shown alternative pathways to the future other than the status quo. So far, the status quo continues to be the pathway of choice. The extinction of delta smelt may become the symbol of the result of taking that pathway as the 'easy way out'. Nevertheless, it possible to be optimistic that academic and other research endeavors will eventually allow for switching pathways, although at increasing ecological and economic cost.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

Use of Science in Complex Public Policy Decision-Making

Felicia Marcus, Chair, State Water Resources Control Board, Felicia.Marcus@waterboards.ca.gov

This talk will focus on the way that the State Water Board incorporates science into decision-making in various types of decisions, particularly regarding the San Francisco Bay-Delta. The State Water Board employs science in a variety of ways, through the retention of expert panels, the use of peer review, the publishing of scientific basis reports, the convening of workshops, the use of the Delta Science Program, and in listening to the invocation of "science" on behalf of wildly differing points of view in a very public policy making process. Different examples will be shared, as well as the view from the perch of a public policy maker trying to incorporate science into complex decisions that are about balancing different beneficial uses of water in an arena in which few want to share.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

A Guide for the Perplexed[1]

Phil Isenberg, former Chair and Vice-Chair, Delta Stewardship Council

Our panel is asked to explain "how we use science and data to develop solutions and support decisions in the Bay Delta". Implicit in the question is the belief that a lot of good science is being ignored by policy-makers. We look to possible answers from Winston Churchill, C.P. Snow, Jeff Kightlinger, Dr. John A. Wiens and John Fleck to provide guidance to those of us perplexed by how to connect science and policy.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

[1] With apologies to Moshe ben Maimon (aka Maimonides), who wrote *The Guide for the Perplexed* about the year 1190. And apologies to E.F. Schumacher, who penned his own version in 1973. No, *Small is Beautiful: A Study of Economics as if People Mattered* is a different Schumacher book Governor Jerry Brown used to cite approvingly in his first stint as Governor; not so much now.

Data, Decisions, Delta Science, and Delta Directions

Cliff Dahm, Independent Lead Scientist, Delta Science Program, cliff.dahm@deltacouncil.ca.gov

The lead scientist talk by Peter Goodwin during the 2014 Delta Science Conference focused on six things that the Delta Science Community had learned in the previous two years. One-Delta and one-science, sustaining science mentors, the role of technology, key science discoveries, climate change and communication, and no magic bullet were key themes for his talk. Now, in 2016, the theme of this conference is "Science for Solutions: Linking Data and Decisions." How have we done in addressing some of these themes? Some important progress has been made. First, the white paper on "Enhancing the Vision for Managing California's Environmental Information" was issued in 2015, and data and data management are being highlighted throughout this conference. Second, the synthesis paper "Challenges Facing the Sacramento-San Joaquin Delta: Complex, Chaotic, or Simply Cantankerous" was published in 2015 and provided an overview of Delta issues from the perspectives of four former lead scientists. Third, an "Integrated Modeling of Estuarine Systems" workshop was held at UC Davis to emphasize the importance of data, modeling, and decision-making, and a summary document for policymakers prepared. Fourth, the State of Bay-Delta Science 2016 update is are being published as peer-reviewed papers by *San Francisco Estuary and Watershed Science* in the June, September, and December issues, and a summary for policymakers document was recently issued. Fifth, the Science Action Agenda for 2017 is an ongoing effort called out by the Delta Science Plan and drawing upon the input and knowledge of participants attending this conference. Sixth, the Science Enterprises workshop brought together scientists from coastal ecosystems throughout the US to learn about how science has developed and is conducted. Important progress is being made. What directions should Delta science take in the coming years? I will share my ideas on some fruitful scientific endeavors for the coming years.

Session Title: Plenary Speaker
Session Time: Tuesday Morning, Rooms 308-313

Regional Selenium Exposures of Adult Sacramento Splittail in the San Francisco Estuary

A. Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Rachel C. Johnson, National Marine Fisheries Service, rachel.johnson@noaa.gov
Frederick Feyrer, U.S. Geological Survey, ffeyrer@usgs.gov

Selenium (Se) is a dietary contaminant that has the potential to threaten fish and birds and thus impede restoration efforts throughout the San Francisco Bay and Delta. A byproduct of oil refining and agricultural irrigation, Se bioaccumulation in benthic invertebrate prey (i.e. *Potamocorbula amurensis*) has been shown to vary spatially in the northern estuary, based on proximity to Se sources, and temporally in response to freshwater inflow, with unclear consequences for migratory predators. Leveraging samples collected from an earlier study to evaluate metapopulations of the native minnow Sacramento splittail, we analyzed the liver, muscle and ovaries of 80 individual adult splittail collected from 5 distinct regions (Petaluma River, Napa River, Suisun Cut, Pacheco Creek and Confluence) during the fall of 2010 and 2011. Our objective was to evaluate how Se exposures in adult splittail vary relative to their site collection site, foraging range (using stable isotopes), and morophometric characteristics (age, sex), to better understand spatiotemporal variation of Se exposures in predators and the potential risk to the splittail population overall. Preliminary results indicate strong regional differences with Se concentrations in liver tissue (range: 3 to 29 µg/g dry weight) being more elevated in Pacheco Creek samples and lower in the Napa or Petaluma samples. Elevated Se concentrations in splittail from Pacheco Creek near Carquinez Strait were consistent with those spatial patterns in Se concentrations previously observed in *P. amurensis*. The consequences for maternal transfer of Se to offspring in this migratory species will be discussed.

Keywords: Selenium, Sacramento splittail, exposure, fish populations, bioaccumulation, toxicity
Session Title: Estuarine Ecology
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 306

Unraveling Sources and Pathways of Se Exposure in Wild Sacramento Splittail with Spinal Deformities

Rachel Johnson, NOAA Fisheries, Rachel.Johnson@noaa.gov
Robin Stewart, USGS, arstewar@usgs.gov
Karin Limburg, State University of New York, klimburg@esf.edu
Rong Huang, Cornell University, rh66@cornell.edu
Frederick Feyrer, USGS, ffeyrer@usgs.gov

Selenium (Se) is an essential nutrient required for oxidative and enzymatic processes, but at elevated levels it can disrupt protein synthesis resulting in deformities in developing offspring of fish and birds. Incidences of individuals with deformities consistent with Se toxicity (e.g., S-shaped spines) have been observed in Sacramento splittail (splittail) *Pogonichthys macrolepidotus, a cyprinid endemic to the San Francisco Estuary and its watershed.* Juvenile splittail can be exposed to elevated Se through direct ingestion of prey or through maternally-derived yolk. Here, we use scanning X-ray fluorescence microscopy (SXFM) at Cornell's High Energy Synchrotron Source to detect Se and quantify the chronology of Se in otoliths of wild-caught juvenile splittail that display spinal deformities. We evaluate the spatio-temporal distribution of Se in the otoliths and compare the core (maternal) and edge (environmental) to test the pathway of Se exposure. Results of this study demonstrate the utility of otolith tools in ecotoxicology to differentiate among multiple human-mediated sources of elevated Se in the ecosystem that can influence native fishes.

Keywords: Sacramento splittail, contaminant, otolith, Selenium, isotope, San Joaquin
Session Title: Estuarine Ecology
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 306

Fish Nursery Areas and Migratory Corridors in Suisun Marsh

Denise De Carion*, Center for Watershed Sciences and Wildlife, Fish and Conservation Biology, UC Davis, dpdecarion@ucdavis.edu
Amber Manfree, Center for Watershed Sciences, UC Davis, admanfree@ucdavis.edu
John Durand, Center for Watershed Sciences, UC Davis, jrdurand@ucdavis.edu
Teejay O'Rear, Center for Watershed Sciences and Wildlife, Fish and Conservation Biology, UC Davis, taorear@ucdavis.edu
Brian Williamson, Center for Watershed Sciences, UC Davis, bowilliamson@ucdavis.edu
Peter Moyle, Center for Watershed Sciences and Wildlife, Fish and Conservation Biology, UC Davis, pbmoyle@ucdavis.edu

Tidal wetland restoration is hypothesized to improve conditions for juvenile fish in the San Francisco Estuary. To address this issue, we investigated the roles of tidal wetlands and large distributary sloughs as juvenile fish habitat in Suisun Marsh over the last decade. We identified fish nursery areas based on the hypothesis that a tidal wetland supports disproportionately greater density, biomass and/or growth of juvenile fishes in comparison to other habitats. To further investigate juvenile fish associations with environmental conditions, we used generalized linear mixed models to assess relative influences of structural habitat and water quality parameters on juvenile biomass. A number of species were investigated, both individually and by freshwater or marine preference: Sacramento splittail (*Pogonichthys macrolepidotus*), striped bass (*Morone saxatilis*), tule perch (*Hysterocarpus traski*), Pacific staghorn sculpin (*Leptocottus armatus*) and starry flounder (*Platichthys stellatus*). Marine and freshwater species varied with respect to specific conductivity, demonstrating the ecological value of Suisun Marsh as a brackish transition zone in the geographic center of the San Francisco Estuary. Individual species varied with respect to emergent vegetation area, channel area, channel sinuosity and channel depth, suggesting that habitat heterogeneity supports a diverse suite of juvenile fishes across Suisun Marsh. In general, our findings indicate that restoration of shallow, vegetated, meandering channels is likely a successful strategy for improving conditions for several key juvenile fishes, while large distributary sloughs likely provide important migratory corridors from tidal wetlands to the greater estuary.

Keywords: Fish nursery, tidal wetland, habitat complexity, migratory corridor, Suisun Marsh
Session Title: Estuarine Ecology
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 306

Rearing Habitat of Larval Pacific Herring (*Clupea pallasi*) in Shallow Open Water and Tidal Marsh Habitats of San Pablo Bay and the Western Delta

Jillian Burns, ICF, jillian.burns@icfi.com
LeAnne Rojas, ICF, leanne.rojas@icfi.com
Donna Maniscalco, ICF, donna.maniscalco@icfi.com
Lenny Grimaldo, ICF, lenny.grimaldo@icfi.com

Pacific Herring in the San Francisco Estuary previously supported a substantial fishery and play an important role as a marine-derived food source. Recently, however, the population has declined, possibly as a result of poor ocean conditions. Previous adult Pacific Herring surveys indicate that spawning is typically concentrated throughout western San Pablo Bay and around Tiburon. We investigated larval Pacific Herring populations in the San Francisco Estuary to better understand factors that may contribute to enhanced survival and recruitment. In this study, we examined larval herring data collected from our own targeted shallow water studies (SWS) using a zooplankton net and the California Department of Fish and Wildlife Smelt Larval Survey (CDFW SLS) from three water years (2013, 2014, and 2016) to determine how physical and biological factors affected larval herring abundance and distribution in the upper estuary. Overall, larval Pacific Herring were most abundant during the CDFW SLS survey in 2014, which appears to be consistent with adult spawning biomass estimates in San Francisco Bay (CDFW Pacific Herring Spawning Summary 2014). During our SWS, densities were highest in 2016. The difference between the two surveys could reflect differences in targeted sample depths. In the SWS, larval Pacific Herring densities were not significantly different between open water and tidal slough habitats and were generally higher in cooler water (5-8 °C) and lower salinities (1-8 PPT). Information from our study indicates that warming waters associated with climate change may affect future distribution and abundance. Our findings highlight the importance of shallow open water and tidal marsh habitats for Pacific Herring and other key species of management interest, which could be used to guide future restoration in the area.

Keywords: Pacific Herring, larval, rearing, survival, recruitment, shallow water habitat, marsh
Session Title: Estuarine Ecology
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 306

Native Submerged Aquatic Vegetation in the San Francisco Estuary: Causes and Implications of Morphological Variation and Phenotypic Plasticity

Melissa Patten*, San Francisco State University, Romberg Tiburon Center, mvpatten@mail.sfsu.edu
Katharyn Boyer, San Francisco State University, Romberg Tiburon Center, katboyer@sfsu.edu

Submerged aquatic vegetation provides valuable habitat in estuary ecosystems. In San Francisco Estuary (SFE), the native pondweeds *Stuckenia* spp*.,* are widespread in the ecologically important low-salinity zone, covering over 500 hectares and spanning more than 25 kilometers from east to west. We have been conducting a series of studies on these pondweeds since 2011, but some basic questions such as species identity have been unanswered until now.

In the field, we observe patches with distinctly different plant architecture and morphological complexity, which may be due to phenotypic plasticity, or genetic differences. Individuals most closely resemble *S. filiformis* and sometimes *S. pectinata*. We hypothesized that both species and/or hybrid individuals may be present, and have addressed that question with a combination of common garden experiments and genotyping. Further, we investigated the effects of plant morphology on the food web by quantifying the relationship between plant complexity and associated invertebrate communities. Our surprising genetic findings show that all plants in the study area are *S. pectinata,* with no evidence of hybrids present. The morphology of the population is anomalously robust for the species. We are currently utilizing microsatellite loci to further study the relationship between and among regional *S. pectinata* populations.

Common garden results show that plants are morphologically plastic in response to flow conditions. Using paired mesocosm treatments with genetically identical shoots, we found that flow conditions significantly altered multiple morphological traits. Finally, we found a significant positive relationship between plant complexity and invertebrate abundance and diversity. The results from these experiments will allow us to predict how these plants may respond to changing conditions in the SFE, including changes in flow dynamics that could result from different management scenarios. Further, conservation and restoration actions might be informed by an understanding how species identity and plasticity relate to habitat values.

Keywords: Potamogeton, Pondweeds, SAV, Stuckenia, Flow, Plasticity, Mesocosm, Invertebrate, Low-salinity zone
Session Title: Estuarine Ecology
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 306

Differences in Salinity Tolerance in Two populations of Sacramento Splittail

Nann Fangue, Wildlife, Fish & Conservation Biology, UC Davis, nafangue@ucdavis.edu
Ken Jeffries, Anatomy, Physiology & Cell Biology, School of Veterinary Medicine, University of California, kenmjeffries@gmail.com
Christine Verhille, Wildlife, Fish & Conservation Biology, University of California, Davis, cverhille@gmail.com
Theresa Dabruzzi, Wildlife, Fish & Conservation Biology, University of California, Davis, tfdabruzzi@ucdavis.edu
Richard Connon, Anatomy, Physiology & Cell Biology, School of Veterinary Medicine, University of California, Davis, reconnon@ucdavis.edu

Differences in physiological responses to environmental stressors between populations of fishes may be attributed to phenotypic plasticity and/or genetic differences associated with local adaptation. Using a common-garden experimental design, we examined the effects of salt water on two populations of wild-caught Sacramento splittail (*Pogonichthys macrolepidotus*), the Central Valley population and the San Pablo population. Previous work suggests that the San Pablo population is relatively tolerant to salt water while the Central Valley population is more sensitive. We observed higher mortality in the Central Valley population after 7 d exposure to 16 ppt salt water compared with no mortality in the San Pablo population. Additionally, the Central Valley population showed evidence of osmoregulatory disturbance after 7 d of exposure to 14 ppt salt water relative to the San Pablo population. We then used RNA-sequencing to compare the cellular responses in both populations after exposure for 72 hrs and 168 hrs to 14 ppt salt water. We compared these responses to a fresh water control group for each population. We found evidence of a conserved general response to salt water in the two populations suggestive of phenotypic plasticity. We also found distinct differences in the gene expression profiles with the saltwater tolerant population upregulating the expression of genes involved in ion regulatory mechanisms and gill tissue remodeling at 168 hrs suggesting an enhanced ability to acclimate to higher salinities, patterns not observed in the saltwater sensitive population. These differences in the cellular response to salinity, in addition to genetic variation between the populations, suggest that the populations have adapted to their local environmental conditions. Understanding how populations respond to environmental conditions is critical for the conservation of native species in California.

Keywords: fish, salinity, intraspecific variation, splittail
Session Title: Fish Biology and Ecology
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 306

The Highs and Lows of Twenty Years of Juvenile Winter-run Chinook Salmon Abundance Monitoring at Red Bluff Diversion Dam

William R. Poytress, USFWS Red Bluff Fish and Wildlife Office, bill_poytress@fws.gov

Quantitative assessments of juvenile Chinook salmon passage and estimates of fry production using rotary traps have been conducted at the Red Bluff Diversion Dam by the US Fish and Wildlife Service since 1995. Four runs of Chinook salmon spawn upstream of this sample site in various subwatersheds and at very different levels of abundance. Endangered winter-run Chinook salmon spawn exclusively in the mainstem Sacramento River upstream of Red Bluff Diversion Dam and our monitoring work has, and continues to be, of great importance for evaluating the effects of fishery and water management actions as well as ecological fluctuations. Trends in juvenile winter-run Chinook abundance, estimates of egg-to-fry survival rates, and comparisons to adult spawner abundance estimates will be presented highlighting the variability observed over twenty years of fish monitoring at the Red Bluff Diversion Dam. Declines in juvenile winter-run Chinook production estimates during a period of increasing adult returns in recent low water runoff years will be discussed with potential explanatory environmental and biological variables.

Keywords: Chinook, salmon, drought, monitoring, rotary traps, management
Session Title: Fish Biology and Ecology
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 306

Life on the Edge: Temperature and Flow Restrict Steelhead Productivity in a Large Central Valley, California River

Whitney Thorpe, California Department of Fish and Wildlife, and Sacramento State University, Whitney.Thorpe@wildlife.ca.gov
Rob Titus, California Department of Fish and Wildlife, Rob.Titus@wildlife.ca.gov

Steelhead trout (*Oncorhynchus mykiss*) are native to the American River in California's Central Valley, but are restricted to the lowermost 37 km of the river below Folsom Dam. The lower American River provides a limited amount of moderate gradient habitat for steelhead spawning and rearing, the quality of which is mediated by flow. Potentially a more critical limitation to steelhead production is water temperature above the optimum for juvenile steelhead during the summer-to-early-fall rearing period. California Department of Fish and Wildlife (CDFW) has worked with U.S. Bureau of Reclamation and other collaborators since 2001 on specific questions regarding steelhead oversummering relative to temperature, flow, and other manageable habitat attributes on the American River. The objectives of this work are to measure changes in distribution, relative abundance, growth, and condition of juvenile steelhead in response to temperature and flow conditions over time. Associated hypotheses are that as temperature becomes supraoptimal: steelhead distribution downstream from Folsom Dam will become more restricted; growth and condition of steelhead will decrease; and, consequently, steelhead relative abundance will decrease. Results to date suggest high site fidelity of juvenile steelhead such that no upstream shift in distribution occurs in response to worsening thermal conditions. As predicted under extreme drought conditions (2014-2015), results indicate reduced spawning and rearing distribution in downstream habitat areas previously supporting these functions, and lower juvenile steelhead abundance was evidenced through low catch rates and loss of steelhead at specific sites over a season. Unexpectedly, juvenile steelhead condition remained high, and we hypothesize that the effect of low steelhead abundance, by reducing density-dependent effects on individual growth, may have been more influential on steelhead condition than temperature. These results demonstrate threshold ecosystem conditions at which the lower American River no longer provides suitable flow and thermal conditions for natural steelhead production.

Keywords: Steelhead trout, American River, temperature, flow
Session Title: Fish Biology and Ecology
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 306

Larval Fish Assemblage Structure and Prey Availability in Liberty Island

Lori Smith, US Fish and Wildlife Service, lori_smith@fws.gov
Todd Miller, US Fish and Wildlife Service, todd_miller@fws.gov

Liberty Island is a restoring (levee breached) wetland in the northern Delta that demonstrates potential processes and outcomes of tidal freshwater restoration. It provides important habitat for native species and is occupied by larval Delta Smelt, Longfin Smelt, and Sacramento Splittail when they occupy brackish and tidal freshwater regions of the northern Delta. However, the extent to which vegetation colonization, habitat complexity, habitat patchiness and landscape position influences larval fish assemblages, their prey resources, and food web support is largely unknown. From February to June of 2015, we focused on the dichotomy between open water and vegetated marsh habitats in Liberty Island and the greater Cache Slough Complex. Our goals were to establish the temporal and spatial structure of larval fish assemblages in these contrasting habitats and determine the prey availability and selection of larval fish species in flooded shallow water habitats, tidal marsh channels, and submerged aquatic vegetation. Emerging results indicated that under the severe drought conditions in 2015, the larval fish assemblage in Liberty Island was largely composed of nonnative species (80%). Diets among all species analyzed showed little variability in prey selection and were dominated by *Pseudodiaptomus forbesi*. We will present how the larval fish assemblage structure differed between vegetated and non-vegetated habitats and whether prey availability explained the variation in assemblage structure relative to abiotic variables in Liberty Island and the greater Cache Slough Complex. This study will advance our understanding about how complex estuarine landscapes, and particularly restoring wetlands, support ecologically sensitive organisms in the Cache Slough Complex.

Keywords: Liberty Island, larval fish, food web, abundance, abiotic
Session Title: Fish Biology and Ecology
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 306

Physics to Fish: Linking Stationary and Dynamic Habitat Features to Small-Scale Fish Distribution in the Sacramento-San Joaquin Delta

Fred Feyrer, USGS, ffeyrer@usgs.gov
Jon Burau, USGS, jburau@usgs.gov
Leah Kammel, USGS, lkammel@usgs.gov
Paul Stumpner, USGS, pstump@usgs.gov
Dave Ayers, USGS, dayers@usgs.gov
Larry Brown, USGS, lrbrown@usgs.gov

A better understanding of the processes influencing the distribution and movements of fishes, such as the endangered Delta Smelt, is needed to guide water project operations to improve water supply reliability while conserving imperiled species. This information is especially needed as drought conditions and very low Delta Smelt population abundances interact to limit operational flexibility and water deliveries. Here, we report on interdisciplinary studies linking stationary (i.e., bathymetry and channel junctions and configuration) and dynamic (i.e., hydrodynamics, water quality, food availability) habitat features to small-scale (within site) fish distribution in the Sacramento-San Joaquin Delta. High frequency physical and biological sampling in the San Joaquin River at its junction with False River has been conducted to learn how habitat features drive the vertical and lateral distribution of small pelagic fishes and their movements through channel junctions, the configurations of which may have important implications for movement into unfavorable habitats.

Keywords: fish, hydrodynamics, habitat, delta smelt, smeltcam
Session Title: Fish Biology and Ecology
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 306

Blue Carbon in the Delta: Its History and the Prospects for Increased Carbon Storage through Wetland Restoration

Judith Drexler, US Geological Survey, California Water Science Center, jdrexler@usgs.gov
Shruti Khanna, Center for Spatial Technology and Remote Sensing, UC Davis, shrkhanna@ucdavis.edu
David Schoellhamer, US Geological Survey, California Water Science Center, dschoell@usgs.gov
James Orlando, US Geological Survey, California Water Science Center, jorlando@usgs.gov

In this presentation, I will summarize an analysis we carried out on the history and future prospects for "blue carbon" storage in the Sacramento-San Joaquin Delta. Blue carbon is defined as the organic carbon stored in coastal ecosystems. Based on calculations using our data as well as the literature, we estimate that before conversion to agriculture began (~1850), the Delta contained between 150 to 210 Tg C (Tg = 1 x 10^{12} g, C = organic carbon) in its highly organic, peat soils. By 2005-2010, we estimate that ~100 Tg C of this blue carbon sink was lost, mainly due to microbial oxidation of the peat. The loss of this extensive wetland region contributed to the collapse of the Delta ecosystem, leading to a series of tidal wetland restoration projects beginning in the 1960s. Such efforts are continuing, yet success hinges strongly on overcoming challenges such as the shortage of suitable lands, the declining availability of sediment, invasive aquatic vegetation, and sea-level rise. The total area of wetland restoration (both managed and tidal) is slated to reach ~7600 ha by 2020. Our calculations show that the amount of carbon, which will accumulate in these restored wetlands over 100 years is ~1 Tg. This represents about 1% of the carbon lost from the Delta following conversion to agriculture. Although this amount of carbon is modest, the co-benefits that come along with wetland restoration, including retarding land-surface subsidence, expanding critical wildlife habitat, and recovering some of the historic detrital food web are highly important in and of themselves. This analysis of blue carbon shows that, although current projections for wetland restoration may not have a large carbon benefit (especially if methane emissions are considered), wetland restoration is still essential for recovering some basic ecosystem functions.

Keywords: carbon storage, wetland restoration, land-surface subsidence, Sacramento-San Joaquin Delta
Session Title: Food Web Foundations I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 307

Compositional drivers of dissolved organic matter utilization by microbes

Peter Hernes, University of California, pjhernes@ucdavis.edu
Jennifer Harfmann, University of California, jlharfman@ucdavis.edu
Chia-Ying Chuang, University of California, cychuang@ucdavis.edu
Karl Kaiser, Texas A&M University at Galveston, kaiserk@tamug.edu
Danielle Creeley, Texas A&M University at Galveston, greyspot@tamu.edu
Robert Spencer, Florida State University, rgspencer@fsu.edu
Francois Guillemette, Florida State University, guillemette.francois@gmail.com

Microbial assimilation is the primary means by which aquatic food webs incorporate dissolved organic matter (DOM). However, not all DOM is equally capable of assimilation, nor are all microbes equally capable of assimilating the same DOM. In an effort to better understand the relationship between microbial utilization of DOM and DOM composition, we conducted a series of incubation experiments that included source materials common to California and the Bay Delta Estuary, i.e. leachates from blue oak, loblolly pine, annual grasses from an oak savannah, and a cattail/tule mixture. Over the course of ~150 days of incubation (seven sampling time points), DOC losses ranged from 78% in the pine sample to only 45% loss in the oak sample, highlighting the impact of composition on bioavailability. These differences in bioavailability generally correspond to differences in aromaticity as indicated by carbon-specific absorbance at 254nm (SUVA254), with oak leachates containing the highest percentage of aromatic compounds. However, the strength of this study is that we measured a suite of biomarkers, including lignin, amino sugars, amino acids (totals as well as D-amino acids), carbohydrates, and utilize new data processing techniques to incorporate hundreds of compounds that are also detectable in the lignin traces. The scope of the chemical characterization is unprecedented and will lead to new insight as to timing, kinetics, and competition for various biochemicals by the microbial community. In the bigger picture, the comprehensive set of molecular tools that we are developing will enable new lines of research better equipped to capture carbon cycling dynamics in the complex and challenging Bay-Delta environment.

Keywords: Biomarkers, microbial processes, dissolved organic matter
Session Title: Food Web Foundations I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 307

Evaluation of Delta Subregions for Nutrient Monitoring and Assessment

Thomas Jabusch, SFEI-ASC, thomasj@sfei.org
Phil Bresnahan, SFEI-ASC, philb@sfei.org
Phil Trowbridge, SFEI-ASC, philt@sfei.org
David Senn, SFEI-ASC, davids@sfei.org

Previous work has documented a large degree of spatial variability in nutrient concentrations and in seasonal and long-term trends across different geographic monitoring locations the Delta (Novick et al. 2015). Dividing the Delta into subregions for use in nutrient monitoring and assessment would fulfill two important needs: 1) allow a comparison of trends and processes across subregions to gain a better understanding of the spatial variability, and 2) improve estimates of regional long-term trends. Researchers have split the Delta up into regions for various purposes, but not yet specifically to inform the design of monitoring for nutrients, which was the objective of this study. The analysis had three key components. First, we recommended subregions in the Delta that could potentially be used for monitoring and assessing nutrients. Second, we performed time-series analyses on a 40-year dataset using non-negative matrix factorization (NMF) to assess spatial variability in dominant factors driving nutrient concentrations within and across these proposed subregions. And third, we performed power analyses for long-term trend detection to compare different sampling design options for the proposed subregions. In addition, we calculated the area of different habitat types in each of the subregions and how the existing nutrient monitoring network overlapped with each habitat type.

Keywords: Delta, subregions, nutrients, monitoring network, drivers
Session Title: Food Web Foundations I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 307

Vertical Biogeochemical Variability in Sloughs Impacts Habitat Quality and Metabolic Rate Estimates

Philip Bresnahan, San Francisco Estuary Institute, philb@sfei.org
Rusty Holleman, San Francisco Estuary Institute, rustyh@sfei.org
Zephyr Sylvester, San Francisco Estuary Institute, zephyrs@sfei.org
Emily Novick, San Francisco Estuary Institute, emilyn@sfei.org
David Senn, San Francisco Estuary Institute, davids@sfei.org

The margins of estuaries have a disproportionately large impact on biogeochemical cycling despite their relatively small size. As direct conduits from land to the bay, sloughs and creeks exhibit variability in many parameters (*e.g.*, dissolved oxygen, chlorophyll, suspended sediment, in/organic carbon, nutrients) that can be much larger than in other parts of the estuarine system. In order to unravel this heterogeneity—both in time at a given site and across sites at a given time—it is necessary to observe the full four-dimensional (latitude, longitude, depth, and time) system.

Preliminary results from vertical profiling of sloughs in Lower South San Francisco Bay from the Summer of 2015 suggest that the vertical variability of multiple biogeochemical parameters is greater than is often taken into account. Vertical gradients in dissolved oxygen, even when smaller than horizontal gradients, can still have first-order effects on habitat quality assessments and biogeochemical rate estimates, for example. We will provide examples from field studies completed in 2015 and 2016 as part of the San Francisco Bay Nutrient Management Strategy. Our results characterize sloughs/creeks where both habitat volume and metabolic rate estimates potentially differ depending on whether or not the observed vertical variability is taken into account. These findings will help to inform nutrient management decisions by narrowing uncertainties around habitat volume and biogeochemical rate calculations.

Keywords: deoxygenation, vertical, biogeochemistry, habitat quality, metabolic rates, slough
Session Title: Food Web Foundations I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 307

Using Stable Isotopes to Evaluate the Effects of Seasonal and Spatial Changes in Flow and Nutrients on Biogeochemical Processes, Habitat Quality, and Ecosystem Health in the Sacramento River, northern Delta, and northern San Francisco Bay, 2006-2016

Carol Kendall, U. S. Geological Survey, ckendall@usgs.gov
Megan Young, U. S. Geological Survey, mbyoung@usgs.gov
Sara Peek, U. S. Geological Survey, speek@usgs.gov
Rachel Mixon, U. S. Geological Survey, rmixon@usgs.gov

There is increasing competition for fresh water in the San Francisco Estuary, and hence an increasing need to justify seasonal flow requirements to maintain ecosystem health in the Delta. How do we justify increased water allocations, especially during droughts? Stable isotope measurements of nutrients, particulate organic matter (POM), and water can provide unique information about the effects of flow on biogeochemical processes, nutrient and organic matter sources, and ecosystem health at different locations. Hence, isotope data can help provide managers with science-based support for models used to determine the seasonal flow and other requirements for healthy habitats for native organisms. Towards this and other long-term goals, we have piggybacked the collection of stable isotope samples onto several water quality monitoring programs in the Sacramento River, northern Delta, and northern San Francisco Bay to generate comprehensive multi-isotope datasets for most months during 10 of the 11 falls 2006-2016 and 9 of the 10 spring/summers 2007-2016. With these data, we have compared the effects of seasonal and spatial variations in flow and nutrients in wet and dry years with a wide range of flows and habitat indices, and with antecedent moisture conditions, on various habitat characteristics including organic matter quality, dominant sources of C-N-S to algal uptake, nitrification rate, locations of nitrification hotspots, etc. In specific, stable isotope measurements of nitrogen forms and bulk POM can be used to identify the dominant nitrogen sources used by primary producers over different spatial and temporal scales. The C and S isotopes of POM provide information on sources of the algae. And comparison of the downstream changes in NO3 concentrations and N/O isotopes with changes in water H/O isotopes allows quantification of seasonal and spatial changes in nitrification rate, external sources of NO3, and algal uptake.

Keywords: nutrients, flow, isotopes, habitat quality, drought, ecosystem health, uptake, nitrification
Session Title: Food Web Foundations I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 307

Using Stable Isotopes to Identify Changes in Nitrogen Sources, Processes, and Uptake Over Time in the San Joaquin River and Eastern Delta

Megan Young, U.S. Geological Survey, mbyoung@usgs.gov
Carol Kendall, U.S. Geological Survey, ckendall@usgs.gov
Marianne Guerin, Resource Management Associates, maguerin@rmanet.com
William Stringfellow, University of the Pacific, Lawrence Berkeley National Laboratory, wstringfellow@lbl.gov

Stable isotope measurements of nutrients and particulate organic matter (POM) can provide information about both the sources and processes controlling their concentrations and distribution. In the San Joaquin River (SJR) and parts of the San Francisco Bay-Delta region, POM is often composed almost entirely of phytoplankton and bacteria, and therefore stable isotope measurements of nitrogen forms and bulk POM can be used to identify the dominant nitrogen sources used by primary producers over different spatial and temporal scales. The USGS Isotope Tracers Project conducted multiple isotope studies in the San Joaquin River and eastern Delta from 2000 through the present, allowing us to examine how nutrient sources and biological cycling have varied over recent timescales, including during the period when significant upgrades were made to the Stockton Wastewater Treatment Plant (WWTP). Our results show that seasonal variations and flow conditions were the dominant controls on nitrate sources and concentrations to the lower SJR and Stockton Deep Water Ship Channel (SDWSC), but the upgrades to the Stockton WWTP had a significant impact on nitrogen sources used by the community of primary producers. In samples collected in 2002 and 2004 in the upper SDWSC, the δ^{15}N-POM suggested that there was a distinct spatial shift in nitrogen uptake dynamics, with uptake of nitrate dominating in the SJR above the WWTP, and nitrification of ammonium dominating in the area below the WWTP. Isotope samples collected in the years after the WWTP upgrade (2007 to present) did not show such a clear zone of nitrification, and instead indicated that both nutrient sources and nitrogen uptake were primarily controlled by physical mixing between Sacramento and San Joaquin River water, which have distinct nutrient concentrations and isotopic compositions.

Keywords: stable isotopes, nutrients, nitrate, ammonium, nutrient cycling
Session Title: Food Web Foundations II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 307

Spatial Variability Reveals Complex Controls on Phytoplankton Abundance and Community Structure in a Shallow Tidal Freshwater System

Elizabeth Stumpner, USGS California Water Science Center, estumpner@usgs.gov
Brian Bergamaschi, USGS California Water Science Center, bbergama@usgs.gov
Bryan Downing, USGS California Water Science Center, bdowning@usgs.gov
Alexander Parker, California State University Maritime Academy, aparker@csum.edu
Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Tamara Kraus, USGS California Water Science Center, tkraus@usgs.gov
Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Michael Murrell, US Environmental Protection Agency Gulf Ecology Division, murrell.michael@epa.gov
Kurt Carpenter, USGS Oregon Water Science Center, kdcar@usgs.gov
James Orlando, USGS California Water Science Center, jorlando@usgs.gov
Carol Kendall, USGS National Research Program, ckendall@usgs.gov

We used the marked spatial variability across zones in freshwater tidal wetlands in the North Sacramento-San Joaquin Delta to examine the effects of nutrients, light, contaminants, and residence time on phytoplankton abundance, size and taxonomic distribution. Phytoplankton abundance was quantified and the community structure evaluated using total chlorophyll-a concentration, chlorophyll-a size fractionation, pigment analyses, direct counts, and visual identification. Spatial variability was assessed using high-resolution mapping, discrete sampling, and enclosure experiments. While there was no evidence that light or contaminants affected the phytoplankton community, we found spatial variability across the region was characterized by strong gradients that corresponded to differences in residence time. Zones representing high and low residence time were characterized by differences in nutrient concentrations and phytoplankton communities. Zones characterized by higher residence times and lower ammonium concentrations (1 ± 0.8 μM) had higher chlorophyll-a concentrations (9 ± 4 μg L^{-1}) and the phytoplankton community was composed primarily of small cells < 5 μm (74 ± 8%), including picocyanobacteria. Diatom abundances, however, did not dominate the phytoplankton community even where NO_3 was available for uptake as has been observed elsewhere in in the system. Concurrently, zones characterized by lower residence time and higher ammonium concentration (13 ± 5 μM) coincided with lower chlorophyll-a abundance (5 ± 1 μg L^{-1}), but with diatoms making up a greater proportion of the phytoplankton community (27 ± 11% vs. 11 ± 5%) and showing similar percentage of small cells as the higher residence time zone but with phytoplankton nitrate uptake near zero. Our results suggest that while some tidal wetlands in the Delta support elevated phytoplankton biomass as a result of longer water residence time, the ensuing community may be composed of smaller cells that may not provide high quality food resources.

Keywords: phytoplankton abundance and community composition, freshwater tidal wetlands, residence time
Session Title: Food Web Foundations II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 307

Are Zooplankton and Clams Dining on Super Food or Junk Food? Application of a Phytoplankton Food Quality Index

Tara Schraga, U.S. Geological Survey, tschraga@usgs.gov
Melissa Peacock, U.C. Santa Cruz, mdbpeacock@gmail.com
Aaron W. E. Galloway, University of Oregon, agallow3@uoregon.edu
Monika Winder, Stockholm University, monika.winder@su.se
David Senn, San Francisco Estuary Institute, davids@sfei.org
Raphael Kudela, U.C. Santa Cruz, kudela@ucsc.edu
James Cloern, U.S. Geological Survey, jecloern@usgs.gov

Phytoplankton are the largest living component of biomass in San Francisco Bay and the primary food source upon which the Bay's consumers (e.g., zooplankton, clams, crabs, flatfish, shrimp) ultimately depend. The patterns and processes of phytoplankton biomass variability in this estuary are relatively well understood, but what about the quality of this food resource for consumers? Food quality varies with phytoplankton attributes such as cell size, palatability, and biochemical composition. We address one biochemical component, the phytoplankton derived long-chain fatty acids (LCEFA) that cannot be synthesized by animals and are essential dietary components and indicators of food quality for consumers. We used results of a new meta-analysis that indexes phytoplankton food quality based on differences in LCEFA content and omega-3:omega-6 fatty acid ratios among algal groups. This index reflects the greater nutritional value of diatoms, dinoflagellates, and cryptophytes than of chlorophytes and cyanobacteria, due to their higher LCEFA content and larger fatty acid ratios. We applied the index to a San Francisco Bay-Delta dataset of phytoplankton community composition determined by microscopy (1992-present) and HPLC pigment analysis (2011-2014) to explore patterns of phytoplankton food quality along the salinity gradient of this large nutrient-enriched estuary.

Keywords: phytoplankton; fatty acids; EFA; LCEFA; community composition; taxonomy; pigment
Session Title: Food Web Foundations II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 307

High-Throughput Genetic Sequencing Provides Novel Insight into the Cache Slough Complex Food Web

Ann Holmes*, San Francisco State/Romberg Tiburon Center, annieholmes78@gmail.com
Toni Ignoffo, San Francisco State/Romberg Tiburon Center, tignoffo@sfsu.edu
Wim Kimmerer, San Francisco State/Romberg Tiburon Center, kimmerer@sfsu.edu

The Delta's Cache Slough Complex (CSC) is considered key habitat for delta smelt and other native fish. Delta smelt are found year-round in the CSC despite high water temperature, low salinity, and contaminants. These stressors may be offset by a relatively abundant food supply, yet CSC plankton food web interactions are poorly understood compared with other areas of the estuary. In this study, we describe planktonic copepod (*Pseudodiaptomus forbesi*) feeding patterns using high-throughput genetic sequencing (HTS). This method identifies prey items with high taxonomic specificity, including rare or fragile prey. HTS does not require expertise in plankton taxonomy. The most common phytoplankton prey detected were cyanobacteria (*Dolichospermum* (=*Anabaena*) sp. and *Synechococcus* sp.) and green algae similar to *Spirogyra* sp. These results indicate that nutritionally deficient cyanobacteria may be an important energy source for copepods. Ciliate protists were the most commonly detected non-photosynthetic eukaryotic prey. Cryptophytes, diatoms and eustigmatophytes were detected frequently in water samples, but less frequently in copepod guts. Inherent biases of HTS in food web studies (primer bias, gene copy number bias, and overamplification of predator DNA) mean that HTS prey results may not be quantitative in terms of biomass. However, a quantitative analysis (qPCR) could be applied to samples after HTS has been used to identify prey items. The decreasing cost and increasing accessibility of this technology make HTS a valuable tool for food web studies in the Bay-Delta.

Relevance: Food abundance is a key bottom-up control of fish populations. A better understanding of food web interactions in the CSC may guide restoration efforts for delta smelt and other fish.

Keywords: food web; Cache Slough; delta smelt; copepods; genetics
Session Title: Food Web Foundations II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 307

Long-Term Seasonal Trends in the Prey Community of Delta Smelt (*Hypomesus transpacificus*) Within the Sacramento-San Joaquin Delta, California

Joe Merz, Cramer Fish Sciences, jmerz@fishsciences.net
Paul Bergman, Cramer Fish Sciences, pbergman@fishsciences.net
Joseph Simonis, Cramer Fish Sciences, josie.simonis@fishsciences.net
David Delaney, Cramer FIsh Sciences, dgdelaney@gmail.com
James Pierson, Horn Point Laboratory, University of Maryland Center for Environmental Science, jpierson@umces.edu
Paul Anders, Cramer Fish Sciences, anders@fishsciences.net

Abiotic factors and species introductions can alter food web timing, disrupt life cycles, and change life history expressions and the temporal scale of population dynamics in zooplankton communities. We examined physical, trophic, and zooplankton community dynamics in the San Francisco Estuary, California, a highly altered Mediterranean climate waterway, across a 43-year dataset (1972–2014). Before invasion by the suspension-feeding overbite clam (*Potamocorbula amurensis*) in the mid-1980s, the estuary demonstrated monomictic thermal mixing in which winter turbidity and cool temperatures contributed to seasonally low productivity, followed by a late-spring-summer clearing phase with warm water and peak phytoplankton blooms that continued into early winter. Following the clam invasion, we observed a shift in peak phytoplankton bloom timing, with peak productivity now occurring in May compared to June prior to the invasion. Peak abundance of several zooplankton taxa (*Eurytemora affinis*, *Pseudodiaptomus*, other calanoids, and non-copepods) also shifted to earlier in the season. We present the first evidence of a shift in the timing of peak abundance for zooplankton species that are key prey items of delta smelt (*Hypomesus transpacificus*), a federally threatened pelagic fish species. These timing shifts may have exacerbated well-documented food limitations of delta smelt due to declines in primary productivity since the invasion of the overbite clam. Future conservation efforts in the estuary should consider measures designed to restore the timing and magnitude of pre-invasion phytoplankton blooms.

Keywords: Primary productivity, Ecological succession, Pelagic Food web, Seasonality
Session Title: Food Web Foundations II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 307

Quantifying and Characterizing Bird Response to Tidal Restoration: A Multi-Species Approach

Julian Wood, Point Blue Conservation Science, jwood@pointblue.org
Nadav Nur, Point Blue Conservation Science, nnur@pointblue.org
Megan Elrod, Point Blue Conservation Science, melrod@pointblue.org
Dennis Jongsomjit, Point Blue Conservation Science, djongsomjit@pointblue.org
Sam Veloz, Point Blue Conservation Science, sveloz@pointblur.org

Restoring tidal exchange to low-lying areas in the San Francisco Bay Estuary has helped mitigate historic losses of tidal wetlands. Tidal restoration projects often seek to restore the ecological attributes and functions of tidal systems including restoring the avian community. Because most restoration projects do not assess avian community response during latter stages of restoration it is often not known how and when tidal marsh-dependent birds respond to restoration projects. Assessing restoration depends on identifying the expected trajectory of avian response to restoration, and relating the response to the associated change in habitat. Millions have been invested in restoring tens of thousands of acres throughout the Estuary yet the cumulative impact of these investments on the avian community has not been assessed. Not all restoration projects will follow the same trajectory over time: how does the ultimate outcome of a restoration project depend on conditions at the site and in the matrix of surrounding habitat? We used models of bird distribution and abundance developed using on-the-ground surveys to quantify bird response to restoration for six tidal marsh-dependent at-risk bird species: California Ridgway's Rail, California Black Rail, Salt Marsh Common Yellowthroat, and three subspecies of Song Sparrow. We characterize the timing of response to restoration and identify factors that may influence restoration outcome. We summarize the impact of restoration in terms of numbers of individuals gained, increase in species diversity and trends in density. Results confirm that, overall, restoration aids the recovery of tidal marsh-dependent bird populations. We provide recommendations for land managers and restoration practitioners to develop effective assessment programs. Information collected in this context will help improve habitat quality and accelerate tidal marsh bird recovery. Monitoring a suite of tidal marsh-dependent birds is more informative than relying on a single species, such as the Ridgway's rail.

Keywords: San Francisco Bay Estuary, restoration, monitoring, tidal marsh, salt marsh
Session Title: Habitat Restoration and Conservation
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 308-310

Avian Response to Restoration of North Bay Salt Ponds: Managed vs. Breached Ponds

Tanya Graham, U. S. Geological Survey, tgraham@usgs.gov
Susan De La Cruz, U. S. Geological Survey, sdelacruz@usgs.gov

San Francisco Bay (SFB) is important habitat for migrating and wintering waterbirds, with over a million shorebirds and 40-50% of Pacific Flyway scaup and scoter visiting San Francisco Bay each winter. As much as 15% of SFB wintering waterfowl are found in North Bay salt ponds (Richmond et al. 2014). The areas surrounding the Napa-Sonoma Marshes Wildlife Area, (including Napa Plant Site, and Cullinan Ranch) comprise over 5100 ha of wildlife habitat, and thus are the focus of intense multi-agency efforts to achieve restoration and wildlife management goals. The challenge central to the restoration is to balance the needs of marsh species with migratory shorebird and waterfowl populations. We examined the waterbird response to restoration efforts comparing use of managed ponds to breached ponds. We conducted high-tide surveys of 14 ponds in winter (Dec – Feb) from 2008 – 2016. Surveys included pre- and post-breach abundance at three ponds, including low tide surveys. Overall waterbird abundance at high tide has increased since 2008. Managed ponds supported higher waterfowl and shorebird abundances than breached ponds at high tide; however, breached ponds were important habitats for shorebirds at low tide. Prior to restoration, breached ponds served as high tide refuge for shorebirds, but were unoccupied by shorebirds at low tide. Post-restoration, high tide water levels within the breached ponds displaced roosting shorebirds; however, waterfowl densities on breached ponds have increased compared to pre-restoration values and remain on the breached ponds throughout the tidal cycle. In summary, restoration efforts have been successful at providing high and low tide habitat for waterfowl, but habitat for shorebirds at high tide appears to be limited. As the breached areas continue to transition to tidal marsh, the reduction in available habitat may present challenges for managers, particularly in maintaining migratory shorebird populations.

Keywords: salt ponds, waterfowl, shorebirds, restoration, habitat
Session Title: Habitat Restoration and Conservation
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 308-310

Salt Marsh Harvest Mouse Habitat Past, Present, and Future: Our Evolving Understanding of the Habitat Requirements of this "Habitat Specialist"

Katie Smith, UC Davis CA Department of Fish and Wildlife, ratsmith@ucdavis.edu

For decades the salt marsh harvest mouse has been managed as a habitat specialist, dependent on pickleweed dominated tidal marshes. However, more recent research and monitoring has revealed a much more adaptable rodent than previously believed. As we face an increasingly uncertain future of climate change, sea level rise and the challenges of tidal restoration, what do we need to keep in mind? In this talk I will discuss the historical state of the salt marsh harvest mouse range, how we currently perceive and manage habitat, and directions we need to consider as we manage this species in the face of future uncertainty.

Keywords: salt marsh harvest mouse, *Reithrodontomys raviventris*, marsh, wetland, habitat, pickleweed
Session Title: Habitat Restoration and Conservation
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 308-310

Restoring Saline Tidal Wetlands: 20 years of Physical and Biological Monitoring at the Sonoma Baylands Restoration

Michelle Orr, Environmental Science Associates (ESA), morr@esassoc.com
Lindsey Sheehan, ESA, LSheehan@esassoc.com
Steven Crooks, ESA, SCrooks@esassoc.com
Gavin Archbald, H.T. Harvey & Associates, GArchbald@harveyecology.com
Max Busnardo, H.T. Harvey & Associates, MBusnardo@harveyecology.com
Annie Eicher, H.T. Harvey & Associates, AEicher@harveyecology.com
Jules Evens, Avocet Research Associates, avocetra@gmail.com
Eric Jolliffe, US Army Corps of Engineers, Eric.F.Jolliffe@usace.army.mil

In 1996, a 120-ha (300-acre) site in San Francisco Bay received 1.5 M cubic meters (1.9 M CY) of dredged material, becoming one of the first to beneficially reuse dredged material to create coastal wetlands. We present 20 years of physical and biological monitoring data showing how the site, the Sonoma Baylands Restoration, has evolved and lessons learned that can be applied to current restoration efforts.

Summary of findings:

- The decision not to excavate larger outboard channels meant that tidal exchange to the site was initially very limited. Tidal scour of these channels accelerated after 4-7 years, resulting in a 50-fold increase in channel size (from approx. 2 m^2 to 100 m^2). Monitoring and adaptive management were used to identify and remove erosion-resistant barriers to outboard channel evolution.
- The site has converted from open water to intertidal flats and emergent marsh. With placement of dredged material and 0.3 – 0.6 m of estuarine sedimentation, much of the site is at elevations suitable for colonization by emergent vegetation. Marsh vegetative cover is 72% of the tidal area.
- Tidal channel erosion into the placed dredged material has resulted in an interior channel system similar in extent to natural reference marshes. Channel down-cutting into the former agricultural surface (beneath the dredged material) has been slower.
- 25 species of fish and 83 species of birds use the site; this number increased over time as tidal exchange improved. With open water converting to tidal flats over time, avian use has shifted away from waterfowl towards shorebirds (as expected), which now comprise 87% of avian use of the site.

The Sonoma Baylands Restoration was funded by the U.S. Army Corps of Engineers and the California State Coastal Conservancy.

Keywords: saline wetland, restoration, monitoring, adaptive learning, beneficial reuse, tidal channel.
Session Title: Habitat Restoration and Conservation
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 308-310

If You Build It, Will They Come? Fish Response to Hamilton Wetland Restoration Project

Christopher Fitzer, Environmental Science Associates, cfitzer@esassoc.com
Garrett Leidy, Environmental Science Associates, gleidy@esassoc.com
Damien Kunz, Environmental Science Associates, dkunz@esassoc.com
Andrew Hatch, Environmental Science Associates, ahatch@esassoc.com
Mark Bowen, Environmental Science Associates, mbowen@esassoc.com
Steve Crooks, Environmental Science Associates, scrooks@esassoc.com
Eric Jolliffe, U.S. Army Corps of Engineers, Eric.F.Jolliffe@usace.army.mil

Substantial investments are being made in large-scale restoration of tidal wetland habitats in the Bay-Delta to restore ecological processes and aid in the recovery of native plants, fish, and wildlife. Understanding species response to restoration is critical in determining whether or not goals and objectives are being met and also to provide lessons to inform the design of future projects. The Hamilton Wetland Restoration Project, located in Marin County, California, restores a former Army airfield (648 acres) to a mix of tidal and seasonal wetland, transitional ecotone and upland habitats. The project is being implemented by the USACE, San Francisco District, in partnership with the Coastal Conservancy. The site was constructed and opened to tidal inundation in the spring of 2014. Fish species assemblages were surveyed in the spring of 2015 and 2016 utilizing a combination of otter trawl and beach seine techniques at multiple sample sites to assess the distribution and relative abundance of juvenile and adult fish species in the restored marshes, mudflats, and associated unvegetated shallow water areas. Captured fish were identified to species and statistical summaries were generated to document species diversity and relative abundance by sample site. A total of 23 different fish species were captured; 70% were species native to the Bay and 30% nonnative. Additionally, Olympia oysters, at least four species of shrimp, three species of crab, and copepods were observed in the catch. These encouraging results represent the first and second year monitoring and document a robust initial fish response to the very young restoration site. Additional sampling will be carried out each year for the first five years of the restoration and then every other year for the remainder of the 13 year monitoring period to document fish response trends to the evolving site over time.

Keywords: Restoration Bay Fish, USACE Conservancy, Hamilton Wetlands, Monitoring Tidal Oyster
Session Title: Habitat Restoration and Conservation
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Addressing Sea Level Rise in the San Francisco South Bay, California

Thomas O'Neill, The Habitat Institute, habitat@nwhi.org
Steve Kohlmann, Tierra Resource Management, steve@tierrawildlife.com
Kathleen O'Neill, The Habitat Institute, kathleen@nwhi.org

With the advent of climate change the possibility of sea-level rise is very real, and it is especially disconcerting when the area(s) of interest already lies below sea level. Our talk presents the Corps of Engineers evaluation of their alternative scenarios for the San Francisco South Bay Shoreline study. The ecological evaluation incorporates local area knowledge from the US Fish and Wildlife Service along with integrating multiple species, habitats, and functions assessment. The Combined Habitat Assessment Protocols (CHAP) evaluates the baseline condition and scenarios using a habitat and biodiversity valuation that tracks the values over time. These scenarios are evaluated to determine the most cost effective management effort. The final product was also informed by the California Rapid Assessment Method.

CHAP has been used in impact, mitigation, ecosystem restoration, flood risk management, and cumulative impact assessments and is viewed as a habitat and biodiversity crediting tool. The output metric from a CHAP assessment is a functional redundancy index that is spatially explicit and gives insight into the ecological integrity of a site or area. CHAP has undergone a number of independent scientific reviews and is a tool that can be consistently applied to produce a deterministic and unbasis value, which in turn helps organizations meet the intent of the President's Memo on Mitigation and the Draft Mitigation Policy of the US Fish and Wildlife Service. The CHAP approach has also been used for regional conservation strategies.

Keywords: climate change, functional assessment, habitat, value, tool, CHAP
Session Title: Sea Level Rise
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 308-310

Emerging Conflicts in Sea Level Rise Adaptation at the Local Scale: Three Bay Area Case Studies

Pedro Pinto, UC Berkeley, Instituto Superior Técnico, pedropinto@berkeley.edu
G. Mathias Kondolf, UC Berkeley, kondolf@berkeley.edu
Raymond Wong, UC Berkeley, City of Mountain View, raymondwong.e@gmail.com

Urban development has heavily encroached upon the the San Francisco Bay. Much of the shoreline has been developed over landfill and at the cost of former baylands. These low-lying urban areas are very exposed to sea-level rise (SLR) and pose a challenge to the resilience of the remaining natural systems. Wetland restoration has been a staple of regional environmental protection strategies, but further action in wetland restoration now often requires articulation with the reinforcement of flood defense structures, given the level of urban encroachment. Conflictingly, urban development over former baylands is still being proposed, sparking a debate over the merits and added exposure brought about by further shoreline development.

Through interviews and in-depth analysis of three case studies around the Bay (Redwood City Salt Ponds, Charleston Slough, and the new 'Horizontal levees' initiative) we identify emerging conflicts between stakeholders (public vs. public, public vs. private, and private vs. private). Among the region's stakeholders, awareness of the risks related to SLR is increasing, but institutional arrangements are complex, and communication between public agencies/departments could be streamlined. Some agencies and departments need to adapt their procedures in order to remove institutional barriers to adaptation, but path dependence is an obstacle.

Conflicts involving private landowners and developers may be much complicated by the threat of litigation. Limited planning mandates and imperfect environmental protection standards is a major obstacle to shoreline planning, and this is highlighted by the extreme caution of some public agencies in upholding their jurisdictions over private property. Environmental NGOs have, in the case of California, a big role to play, as they are able to resort to the same legal and lobbying instruments as the developers, and may help even-out the field between public stakeholders with limited legal and economic resources, and powerful private developers with nothing to lose.

Keywords: Sea-level rise adaptation, Flood management, Wetland restoration, Urban development, Conflict
Session Title: Sea Level Rise
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 308-310

A Novel Approach to Sea Level Rise in the Baylands and Delta: Taking the "Habitat-Friendly" Levee to the Next Level

Carlos Diaz, Environmental Science Associates (ESA), cdiaz@esassoc.com
Mark Lindley, Environmental Science Associates, mlindley@esassoc.com
Jeremy Lowe, SFEI, jeremyl@sfei.org
Jason Warner, Oro Loma Sanitary District, jwarner@oroloma.org
Peter Baye, Coastal Ecologist, baye@earthlink.net
Donna Ball, Save the Bay, dball@savesfbay.org
David Sedlak, U.C. Berkeley, sedlak@berkeley.edu

The role of vegetation on flood protection levees has long been a hotly debated issue in the Delta. While vegetation near the levee core continues to be studied, there is increased support of "habitat-friendly" levees that incorporate a wide, vegetated gentle slope on the outboard levee face – also referred to as an ecotone slope. These slopes can provide additional benefits for flood protection by reducing wind or wave-driven extreme water levels and have the potential to increase habitat and provide transgression pathways for habitats to migrate as sea levels rise.

Where space allows, a vegetated ecotone slope can be sufficiently distanced to not compromise levee integrity. The "habitat-friendly" levee provides increased habitat value, reduced erosion potential and sea level rise resiliency compared to traditional prismatic levees. Habitat-friendly levees with ecotone slopes have been constructed in San Francisco Bay, and are being incorporated into many planned tidal marsh restorations in the Delta, including McCormack-Williamson Tract and Dutch Slough.

In the San Francisco Bay, the Oro Loma Sanitary District, in cooperation with the East Bay Dischargers Authority, U.C. Berkeley and several other stakeholders, has recently constructed the first Ecotone Demonstration Project that will use treated wastewater to irrigate the ecotone slope via the subsurface. This concept could provide water quality benefits by polishing treated wastewater while restoring natural freshwater inputs to the shoreline. This pilot project will help improve our understanding of how an ecotone slope could be utilized to adapt to sea level rise by building organic soils while improving water quality potentially leading to significant changes in flood protection and sea level rise adaptation in the San Francisco Bay-Delta. This talk will present the various design approaches being tested for the demonstration project, and consider potential implication of favorable results in the Delta.

Keywords: Levee, Vegetation, Sea Level Rise, habitat, transgression, wastewater, ecotone slope
Session Title: Sea Level Rise
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 308-310

Planning for Transportation and Ecosystem Adaptation to Sea Level Rise

Fraser Shilling, University of California, Davis, fmshilling@ucdavis.edu

I describe a generalizable planning and assessment process for adaptive co-management of transportation infrastructure and tidal-marshes to sea level rise (SLR). Sea level has risen in CA by >20 cm and by 2100 may be 1 to 1.7 m higher. Infrastructural and living systems adaptations will need to occur to avoid a wholesale change in the marshes, estuarine systems, low-lying urban areas, and exposed highway infrastructure along global coastlines. A single coastal California highway, State Route 37 (SR 37) in the North San Francisco Bay, and surrounding tidal and terrestrial ecosystems were used as the laboratory in a stakeholder-advised process because it is the California highway that may be most vulnerable to SLR. Like many other coastal highways in the US, SR 37 is adjacent to protected coastal ecosystems (e.g., beaches, tidal wetlands), meaning that any activity on the highway is subject to regulatory oversight. In order to understand vulnerability to SLR, and to what degree, a model of potential inundation was developed by a contractor (AECOM) using a recent, high-resolution elevation assessment conducted using LiDAR. The cost and (dis)benefits of adaptive structures varied between US$0.8 (berm option) to $4 (causeway option) billion. The tidal ecosystems in the North Bay both buffer infrastructure from wave and tidal energy and are vulnerable to impacts from SLR. In order to monitor SLR impacts at a timescale relevant to transportation and conservation planning. I developed a combined time-lapse camera and image analysis technique to monitor changes in tidal inundation and shoreline resulting from SLR and storm events. The technique is very sensitive to small vertical changes in SLR (<10 cm) because of the large horizontal changes in shoreline resulting from small vertical changes. This technique is high-resolution and scale-able from local to national extents. Early results from this system will be presented.

Keywords: Sea level rise, climate adaptation, monitoring, adaptive management
Session Title: Sea Level Rise
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 308-310

Strategic Decision-Making for Adaptation Using New Ways of Describing the Bay Edge

Kristina Hill, UC Berkeley, kzhill@berkeley.edu
Daniella Hirschfeld, UC Berkeley, daniellah@berkeley.edu

This paper presents a method for and results of characterizing the San Francisco Bay edge into simplified categories that allow planners and decision-makers to compare strategies that employ the "building blocks" of coastal adaptation. We developed a simple classification system for shorelines that is based on historical strategies for allowing humans to live near marine waterbodies. This typology classifies all shorelines as either walls or landforms, and as either static or dynamic. Examples of static walls include seawalls; dynamic walls include tide gates; static landforms include levees; and dynamic landforms include wetlands and beaches. By re-categorizing spatial data mapped by the San Francisco Estuary Institute, we have developed a map of where the Bay edge has walls or landforms (static or dynamic). The advantage of this simplified classification is that it allows planners to see their current shoreline paired with different costs for vertical expansion. Replacing 2000 linear feet of concrete-and-steel walls has a much larger fiscal cost than raising wetland elevations along 2000 feet of shore. The typology also highlights the opportunity for local governments to expand the use of dynamic landforms that create multiple benefits, versus single-purpose walls. Simplifying the number of qualities represented allows a more detailed focus on the costs of replacing or adding to shoreline structures over time, and on the timing of investments that are intended to establish a new baseline as the process of sea level rise continues. Our results show that only a few communities in the Bay Area currently have walls, and that most of the edge is comprised of static landforms. These results can be used to help local communities manage a more diverse edge by focusing on the long-term lower costs of dynamic landforms, rather than move towards the greater long-term expense of building and replacing additional walls.

Keywords: adaptation, coastal development, sea level rise, decision-support, typology, big data
Session Title: Sea Level Rise
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 308-310

The Delta Restoration Hub: Demonstration Projects Proving the Potential of Open Data and Advanced Data Tools for Ecosystem Restoration Decisions in the Cache Slough Complex and McCormack-Williamson Tract

Mark Tompkins, FlowWest, mtompkins@flowwest.com
Tony Hale, San Francisco Estuary Institute, tonyh@sfei.or
Campbell Ingram, Delta Conservancy, Campbell.Ingram@deltaconservancy.ca.org

The Sacramento-San Joaquin Delta is a place of state and national importance for its rich farm economy and natural heritage values. It is also the front line of California water issues where societal goals for ecosystem protection and reliable water supply seek a durable balance. The Delta Restoration Network (DRN) was created out of recognition that restoration efforts will require high levels of coordination and integration to be ecologically successful and broadly acceptable. For the past two years, the DRN has worked to develop a Delta Restoration Hub that would provide advanced open data management along with modern analytical and visualization tools to help advance ecosystem restoration projects in the Delta. The Hub would provide best available data and information to all stakeholders in real-time to accelerate project planning and facilitate adaptive management of implemented projects. The Hub is currently applying these open data principles and tools to demonstration projects in the Cache Slough Complex and the McCormack-Williamson Tract. The purpose of these projects is to develop restoration strategies that optimize habitat restoration opportunities, while preserving agriculture, other land uses and infrastructure, flood objectives, and the operation and maintenance of existing water resources infrastructure. This presentation will provide a status report on these two demonstration projects and illustrate the benefits of open data principles and modern analytical and visualization tools for multi-objective ecosystem restoration.

Keywords: Open data, analytics, visualization, ecosystem restoration, adaptive management
Session Title: Data Management and Tools
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 311-313

Connecting Scientific Research Projects and Data Through Computer Science: An Opportunity for Collaboration and Data Synthesis

Amye Osti, 34 North, amye@34north.com
Nathan Hemenway, 34 North, nathan@34north.com
Karly Wagner, 34 North, karly@34north.com

The decline of fish populations and related regulatory response to this decline has increased the number of scientific research studies in the Sacramento-San Francisco Bay Delta. Connecting research in environmental science is difficult and often at the mercy of a variety of entities. In the Delta, most data are collected and stored within the origination organization (i.e. University, Government Agency, Consulting Company etc). This data is shared at quarterly meetings, after publication, added to state databases or accessible only by request. Consequently, delays sharing data between these entities is too late and no longer current or useful for real time and adaptive management actions.

In an effort to provide solutions to this issue SFCWA has funded four unique but interconnected research projects in the Cache Slough Complex. As part of the effort 34 North has extended the California Estuary and Bay-Delta Live Data Platforms to support these studies and provide a lens into each project as well as try to provide connections using computer science. Each study will collect extensive information including databases, images, reports, presentations and manuscripts focused on specific research questions. Near real time data collected during the study will inform decisions about the future of this region. Through the timely sharing of data, it will be possible to link and compare data collected in the different studies, avoid duplication of data, allow for near real time data analysis and provide updates outside of the normal quarterly report format.

This presentation will explore the process of developing this connected view of the Cache Slough Complex from data collection to data visualization and scientific collaboration. We will share lessons learned and hurdles overcome.

Keywords: Adaptive Management, Data, Food web, Research, Cache Slough Complex, Software, Synthesis
Session Title: Data Management and Tools
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 311-313

California Estuary Monitoring Workgroup – Using Web Portals to Improve Scientific Understanding

Kristopher Jones, California Water Quality Monitoring Council, kristopher.jones@water.ca.gov

The California Water Quality Monitoring Council was mandated to improve the efficiency of California's water quality and associated ecosystem monitoring, assessment, and reporting through increasing collaboration between the numerous governmental agencies and non-governmental organizations that monitor California's waters. Under the guidance of the Monitoring Council, the Estuary Monitoring Workgroup is beginning to answer stakeholder questions with a collaborative toolset that brings together peer-reviewed datasets with tools to help practitioners tell their stories. This process has resulted in the development of the California Estuaries Portal, an interactive website that strives to provide data and information for decision makers and the public regarding water quality, living resources, habitat, ecosystem processes, and stewardship for California's estuaries. While there is a current focus on the San Francisco Bay-Delta Estuary, content relating to California's remaining estuaries will be added in future portal updates. Through a partnership with Bay-Delta Live, the Estuary Workgroup is currently developing a series of data dashboards to directly inform real-time resource management decision making, drawing data from a variety of state and federal governmental partners. This collaborative effort involves multiple governmental and non-governmental organizations, working toward improved estuarine science, restoration, and protection of beneficial uses of California's water resources.

Keywords: California Water Quality Monitoring Council, Estuary Monitoring Workgroup, Estuaries Portal
Session Title: Data Management and Tools
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Hatch: Moving towards Seamless Database Protocols for Ecological Data

Alex Fremier, Washington State University, alex.fremier@wsu.edu
Colby Blair, Washington State University, colby.blair@gmail.com

Re-use of data is important for estimating change over time or over larger spatial scales. Despite the enormous amount of data being collected annually, many government agencies are only now beginning to build coordinated data management systems. With efficient data and metadata capture protocols and coded analysis tools, researchers will be better prepared to answer more effectively key ecological questions across datasets.

In this project, we designed an online platform for seamless data management, called Hatch - http://www.datahatch.org/. Our aim is to improve databasing protocols and data access to allow timely analysis of existing data, across time and space. Hatch is being developed for ecological monitoring of stream ecosystems in the Methow River basin in Washington State; however, the platform is general enough for managing multiple forms of data anywhere in the world. Hatch currently applies both a schema and schema-less database structure to link data collection events. It applies data collections standards developed and accepted across the Columbia River Basin. Initial data capture is driven by data needs for a mechanism-based model of ecosystem processes. Input data files, both past and current flows, are validated and stored along with metadata. Data search tools are being designed in accordance with data sharing agreements with appropriate security.

The goal of Hatch is to defragment the analysis workspace by making database tools general and straight forward. Hatch helps researchers capture, search and analyze data in an online, flexible platform while conforming to project specific schemas. With less fragmented database protocols, scientists will be better prepared to answer scientific questions at relevant ecological scales, and better link data to decisions, and back.

Keywords: data, database management, software, metadata, data re-use
Session Title: Data Management and Tools
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 311-313

Development of Interactive Tools for Fisheries Management

Philip Sandstrom, Washington Department of Fish & Wildlife, philip.sandstrom@dfw.wa.gov
Joseph Anderson, Washington Department of Fish & Wildlife, joseph.anderson@dfw.wa.gov
Neala Kendall, Washington Department of Fish & Wildlife, neala.kendall@dfw.wa.gov
Jeff Hard, NOAA Fisheries Northwest Science Center, jeff.hard@noaa.gov
Ken Currens, Northwest Indian Fisheries Commission, kcurrens@nwifc.org

Life cycle models often require multiple approaches and complex analyses. In an effort to increase accessibility of the life cycle models to a broad range of practitioners, we developed a graphic user interface tool accessible via the internet that will allow anyone to alter model parameterizations and examine results. Using the Shiny package in R, the web tool operates on user defined parameter inputs and projects population abundance and extinction risk. We developed a model user guide that defines each parameter and summarizes available empirical data relevant to the model, including adult abundance, smolt abundance, age structure, and marine survival data throughout Puget Sound. We anticipate that this graphic user interface will greatly enhance the ease and effectiveness of communication as well as collaboration between the model development team, the Puget Sound Steelhead Recovery Team, and biologists. The model uses stage specific survival rates to simulate successive, linked generations of spawning and recruitment over time. The model has two stages, freshwater production (smolts per spawner) and marine survival. Freshwater production was based on stock-recruit dynamics in which capacity is modeled as a function of habitat capacity and intrinsic productivity. The marine survival stage was informed by recent acoustic telemetry work completed in Puget Sound and smolt to adult return rates. A series of scenarios, including habitat restoration and harvest, have been developed to examine the potential impacts of management actions on a demographically independent population status. We present initial results of model runs using the online tool.

Keywords: Steelhead, Shiny, graphic user interface, life-cycle model, population dynamics, management
Session Title: Data Management and Tools
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 311-313

The ARM of the Central Valley Project Improvement Act: Putting Science into Decision-Making

Cesar Blanco, U.S. Fish and Wildlife Service, cesar_blanco@fws.gov

The Central Valley Project Improvement Act (CVPIA) Fish Programs are using Adaptive Resource Management (ARM), a collaborative science-based decision-making process, to help identify actions considered most important for restoring native anadromous fish in the Sacramento-San Joaquin Bay Delta ecosystem. This relatively new, science-based approach to fish management is being used to: 1) prioritize, implement, and learn from projects; 2) develop multiple Decision Support Models (DSMs) that are based on biological objectives and can be used to examine trade-offs among management actions; and 3) revise the Program's governance structure to create an integrated CVPIA fish program, and develop science-based priorities to facilitate decision-making. By using the ARM process we are improving the CVPIA Fish Program's science-based framework, increasing our transparency and accountability, and reinvigorating our collaboration with agencies and stakeholders in the Central Valley.

Keywords: Structured Decision Making, CVPIA
Session Title: Data for Decisions: Structured Decision Making Tools for Planning and Implementing CVPIA Actions
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 311-313

Providing the Fuel for a Structured Decision Making Framework: Serving up Juvenile Salmon Data Collected with Rotary Screw Traps

Trent McDonald, Western EcoSystems Technology, Inc., tmcdonald@west-inc.com
Connie Shannon, Pacific States Marine Fisheries Commission, Connie.Shannon@wildlife.ca.gov
Jason Mitchell, MS, Western EcoSystems Technology, Inc., jmitchell@west-inc.com
Douglas Threloff, U.S. Fish and Wildlife Service, doug_threloff@fws.gov

Central Valley Project Improvement Act (CVPIA) staff are developing a Structured Decision Making Framework (Framework) to guide future habitat restoration and monitoring activities in California's Central Valley. The validation of the Framework depends upon timely access to high-quality, standardized data. Historically, a substantial portion of the juvenile Fall-run Chinook Salmon (*Oncorhynchus tshawytscha*) data needed to support the Framework have commonly been stored in several, not standardized, data formats. Those formats make the recovery and analysis of data more challenging, time consuming, and less efficient.

During the past seven years, CVPIA staff worked with several partners to acquire and standardize juvenile salmon data collected with rotary screw traps in seven watersheds. Those watersheds collectively produce ~85% of the Central Valley's adult Fall-run Chinook Salmon production. The work to standardize data has led to the development of a rotary screw trap (RST) "Platform" consisting of: (1) an Access database that stores data; (2) Visual Basic programming code that supports a data entry user interface; (3) a satellite database used to look for, and correct, data quality issues; and (4) Program R programming code that conducts several analyses.

The Platform: (1) consolidates RST data from different watersheds into one standardized database structure; (2) compensates for operational conditions that affect RST data analyses, e.g. days when RSTs did not operate; (3) produces statistically robust production estimates for different combinations of juvenile life stage and temporal scale (e.g., daily, monthly, etc.); and (4) generates corresponding bootstrapped estimates of production precision. Eventually, these production estimates will form the basis of statistically powerful analyses of juvenile salmon status and trends.

The data stored in the RST Platform will serve as a fundamental source of high-quality, standardized juvenile salmon data as the Framework and its associated decision support model are validated and evolve.

Keywords: Chinook salmon, rotary screw trap, adaptive management, structured decision making
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A Structured Adaptive Approach to Prioritizing Chinook Salmon Conservation and Restoration

James Peterson, US Geological Survey, Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, jt.peterson@oregonstate.edu

Central Valley Project Improvement Act Fisheries Program used a structured decision making approach to develop a framework to allow decision-makers to identify program objectives and guide planning of broad scale fisheries activities. Using a rapid prototyping process, program stakeholders developed a coarse resolution Chinook Salmon (*Oncorhynchus tshawytscha*) model and parameterized it using a combination of expert judgment and empirical data. The coarse resolution decision support model (DSM) was built to evaluate the relative effectiveness of restoration and conservation activities across broad geographical areas. The intent is to use the DSM to identify activities and watersheds where management actions have the greatest likelihood of achieving population objectives. Evaluations of the model via sensitivity analyses indicated that it required significant refinement and improved estimates of model parameters and inputs. Here we discuss the coarse resolution fall run Chinook Salmon model and the revisions by the science integration team. We then illustrate the uses of the model for identifying fall Chinook Salmon restoration and conservation priorities using simulation and dynamic optimization.

Keywords: *Oncorhynchus tshawytscha*, restoration, decision analysis
Session Title: Data for Decisions: Structured Decision Making Tools for Planning and Implementing CVPIA Actions
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Connecting Concepts to Numbers: Visualization to Support Shared Understanding and Decisions

Mike Urkov, WRE, mike.urkov@gmail.com
Rod Wittler, US Bureau of Reclamation, rjwittler@usbr.gov
Seth Lalonde, FlowWest, slalonde@flowwest.com

In support of CVPIA fish doubling goals, a Science Integration Team (SIT) works with disparate data across disciplines to link conceptual models to numerical models. The SITs efforts support expenditures for physical improvement projects and scientific studies to build knowledge. It is often difficult to develop shared understandings of data, physical processes, and / or conceptual relationships across complex teams. Further complicating efforts, summary reports are often time consuming to produce and consume, making shared understanding and decisions more difficult to support.

Analysts and designers supported SIT efforts through iterative development of data visualizations to help explain data inputs, sub-models, concepts, and model outputs. We connected many different sources of data directly to the models to help explain conceptual relationships affecting salmon populations. Visualizations of data and analyses facilitate rapid transfer of information about complex concepts. Individuals were able to test relationships within the models through direct interaction with the visualizations. This agile workflow allowed the SIT to review interim work product and fostered a more iterative approach to improving the models.

Visualizations allowed the SIT to quickly compare, contrast and understand competing hypotheses. Where model review and revision was previously taking several years, current revisions occur monthly. The result is faster model development and better understanding of model inputs and outputs. Over the next few months we will further develop this iterative approach in support of management alternatives.

Our primary finding was improvements in time - we were able to make decisions and advance understanding more quickly by using iterative modern visualization techniques. We believe that connecting data more directly to decisions is becoming more practical every day. If decisions can be made more quickly, with appropriate feedback loops, improvements to the Bay-Delta ecosystem are certainly possible, both in terms of robust scientific support, and defensible public policy.

Keywords: salmon, adaptive management, data, visualization, CVPIA
Session Title: Data for Decisions: Structured Decision Making Tools for Planning and Implementing CVPIA Actions
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Lessons in Model Parameterization: Quantifying Floodplain Rearing Habitat for Juvenile Salmon in a Population Model

Mark Tompkins, FlowWest, mtompkins@flowwest.com

Recent research has shown increased growth and survival of juvenile salmon on floodplains, resulting in a significant increase in activity around floodplain habitat restoration in the Central Valley. A 2014 Department of Water Resources (DWR) study quantified historical, existing, and required (to satisfy the "Doubling Goal) floodplain habitat area in all twenty six of the Central Valley Improvement Act (CVPIA) watersheds, and subsequently the CVPIA Decision Support Model (DSM) used these areas to parameterize a portion of the juvenile salmon rearing calculation in the model. Initial evaluations of CVPIA restoration actions have produced results that both support and conflict with widely held conceptual models regarding floodplain rearing habitat needs in the Central Valley. This presentation will summarize the development of floodplain areas in the CVPIA watersheds, use of these areas to parameterize the DSM model, and selected case studies highlighting where floodplain area is and is not limiting to salmon population improvement as represented in the DSM model.

Keywords: Floodplains, open data, structured decision making, salmon population modeling
Session Title: Data for Decisions: Structured Decision Making Tools for Planning and Implementing CVPIA Actions
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Science-Based Strategies to Restore Key Ecosystem Processes in the Delta

Julie Beagle, San Francisco Estuary Institute, julieb@sfei.org
Scott Dusterhoff, San Francisco Estuary Institute, scottd@sfei.org
Erica Spotswood, San Francisco Estuary Institute, ericas@sfei.org
Amy Richey, San Francisco Estuary Institute, amyr@sfei.org

The Sacramento-San Joaquin Delta—an area the size of Rhode Island that drains more than 40% of California—has been dramatically transformed by human activity over the last two centuries. While regional planning efforts identify the need to restore large tracts of interconnected habitats, very little information is available to help design the complex landscapes that are likely to achieve this goal. To help fill this gap, we drew on an understanding of the Delta's historical ecology (circa 1800) and a detailed study of landscape change since the pre-development period to identify a series of strategies to help develop functional and resilient landscapes in the present and future Delta. These strategies emphasize the reestablishment of the physical processes that sustain interconnected habitats (as opposed to emphasizing the restoration of habitats themselves). Examples of strategies include 'Reestablish tidal marsh processes in areas at intertidal elevations,' 'Reestablish connection between streams and tidal floodplains,' and 'Reestablish fluvial processes along actively migrating streams.' For each strategy, we layered relevant environment data sets to identify "opportunity areas" in the Delta where the strategy might be implemented and considered how individual strategies should be arranged and combined to achieve desired ecological functions at the landscape-scale. This information can be referenced during regional and local planning processes to ensure individual, site-scale projects add up to a whole that ultimately helps to sustain healthy populations of native wildlife.

Keywords: ecosystem restoration, natural processes, landscape-scale
Session Title: Re-Envisioning the Delta with New Knowledge from the Past I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 314

Landscape-Scale Integration of Process-Based Restoration Strategies to Support Desired Ecological Functions in the Sacramento San Joaquin Delta

April Robinson, San Francisco Estuary Institute, april@sfei.org
Sam Safran, San Francisco Estuary Institute, sams@sfei.org
Julie Beagle, San Francisco Estuary Institute, julieb@sfei.org
Letitia Grenier, San Francisco Estuary Institute, letitia@sfei.org
Robin Grossinger, San Francisco Estuary Institute, robin@sfei.org
Ruth Askevold, San Francisco Estuary Institute, ruth@sfei.org
Erica Spotswood, San Francisco Estuary Institute, ericas@sfei.org
Amy Richey, San Francisco Estuary Institute, amyr@sfei.org
Scott Dusterhoff, San Francisco Estuary Institute, scottd@sfei.org

The Sacramento San Joaquin Delta has been dramatically altered over the past two centuries, severely reducing the ability of the Delta to support native wildlife. Recovering robust wildlife populations and ecological communities, and supporting their long-term resilience, will require yet another transformation in the Delta. We used our understanding of historical ecology (circa 1800) and landscape change since the pre-development period to make recommendations for how process-based restoration strategies might be implemented and combined to best support different wildlife groups at a landscape scale. We make recommendations for anadromous and non-anadromous fish, marsh wildlife, riparian wildlife, waterbirds, and wildlife associated with habitats historically on the periphery of the Delta (including vernal pools, alkali wetlands and oak savannas). We highlight the importance of appropriate levels of habitat connectivity, diversity, and redundancy, and how these levels might be achieved in the future Delta.

Keywords: Sacramento San Joaquin Delta, Ecological Function, Landscape-scale, Resilience, Historical Ecology
Session Title: Re-Envisioning the Delta with New Knowledge from the Past I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 314

Primary Production in the Delta, Then and Now

James Cloern, US Geological Survey, jecloern@usgs.gov
April Robinson, San Francisco Estuary Institute – Aquatic Science Center, april@sfei.org
Amy Richey, San Francisco Estuary Institute – Aquatic Science Center, amyr@sfei.org
Letitia Grenier, San Francisco Estuary Institute – Aquatic Science Center, Richmond, letitia@sfei.org
Robin Grossinger, San Francisco Estuary Institute – Aquatic Science Center, robin@sfei.org
Katharyn Boyer, Romberg Tiburon Center – San Francisco State University, katboyer@sfsu.edu
Jon Burau, U.S. Geological Survey, jrburau@usgs.gov
Elizabeth Canuel, Virginia Institute for Marine Science, ecanuel@vims.edu
John DeGeorge, Resource Management Associates, jfdegeorge@rmanet.com
Judith Drexler, U.S. Geological Survey, jdrexler@usgs.gov
Chris Enright, Delta Science Program (retired), Chris.Enright@deltacouncil.ca.gov
Emily Howe, Aquatic and Fishery Sciences, University of Washington, ehowe2@uw.edu

Low primary production is a constraint on meeting California's goal of protecting, restoring and enhancing the Delta ecosystem. But is low primary production an inherent attribute of the Delta, or is it largely a result of landscape changes? Recent analyses from the Historical Ecology Team and Delta Landscapes Project provide quantitative comparisons of the areal extent of 14 habitat types in the modern and historical Delta. We describe an approach for using these metrics of landscape change to: (1) produce the first quantitative estimates of how overall Delta primary production and contributions from five different producer groups have been altered by landscape transformations; (2) convert these production estimates into a common currency so the contributions of each producer group reflects its food quality and efficiency of transfer to consumers; and (3) use simple models to discover how tidal exchange between marshes and open water influences primary production and its consumption. Application of this approach would inform Delta management in two ways. First, it would measure historical losses in the Delta's capacity to produce food for native biota, providing a basis for understanding landscape change as one of multiple stressors on the Delta ecosystem. Second, it would provide restoration practitioners a new approach for establishing targets and performance measures based on the ecosystem processes that could be amplified by different restoration actions.

Keywords: ecosystem restoration, primary production, historical ecology, food quality, habitat connectivity
Session Title: Re-Envisioning the Delta with New Knowledge from the Past I
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Reinvesting in the Delta's Food Web Portfolio

Emily Howe, School of Aquatic & Fishery Sci., ehowe2@u.washington.edu
Charles Simenstad, School of Aquatic & Fishery Sci., Univ. of Washington, simenstd@u.washington.edu

Due to a century of human alterations to the Sacramento-San Joaquin Delta (Delta), the sources and magnitudes of living and detrital organic matter (OM) imported into the Delta from the watershed has changed. In concert with this change, the potential contributions of primary producers contributing to food web processes within the Delta has shifted from enormous production by marsh vascular plants to substantially less production by phytoplankton and submersed and floating aquatic vegetation. This change underlies considerable scientific debate about (1) the relative importance of production sources to consumers in the existing, relict Delta, and (2), the potential food web benefits of future tidal wetland and floodplain restoration.

Interpreting the relative significance of living (algal) and detrital sources to important consumers is complex because of differences in their quality and availability in food web pathways and processes. We utilize stable isotope analyses from the 2008-2012 BREACH III investigations of the restoring Liberty Island tidal freshwater wetlands and the on-going SFCWA Cache Slough Complex studies to provide insights into the present OM sources to food webs in a reach of the Delta with minimal tidal wetland production. Our findings indicate that larval fishes, and ecologically-important planktonic and epibenthic macroinvertebrates, are supported by a diverse mix of phytoplankton, filamentous green algae, and detrital particulate OM from macrophytic plants within the Liberty Island/Cache Slough Complex. Despite differences in the spatial and temporal variability in controls on production and the nutritional quality of these living and detrital sources, contributions of OM from tidal wetlands are non-trivial, and likely significant during periods of low algal production. Reinvesting in recovery of the Delta's historic tidal wetlands should contribute to a more diverse portfolio of widely variable quantities, qualities and timing of both living and detrital OM sources, and ultimately a more productive and resilient food web.

Keywords: food web, Delta, restoration, organic matter
Session Title: Re-Envisioning the Delta with New Knowledge from the Past I
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A Tale of Two Deltas: A Comparison of Transport Processes in the Historical and Contemporary Delta

Jon Burau, USGS, jrburau@usgs.gov
John DeGeorge, Resource Management Associates, jfdegeorge@rmanet.com

Modification of the Delta's landscape has fundamentally changed hydrodynamic and transport processes in the Delta. Here, we compare transport processes in the historical and contemporary Delta based on a scaling-up of insights gained from a handful of targeted small-scale site-specific field experiments and numerical model results. Principal among the changes are:

(1) The fortnightly (e.g. spring/neap cycle) decoupling/coupling of pelagic and marsh plain habitats that occurred on a massive scale in the historical Delta, now occurs in only a couple small-scale select locations.

(2) The historical delta was a dendritic marsh system comprised mostly of a hierarchy of independent dead-end channel systems that supported pelagic habitat diversity, unlike the homogeneous habitats created by the interconnected web of canals that exists today.

(3) Except for high flow periods, transport of the river flows through the historical Delta was mainly accomplished through a relatively few, large channels. In contrast, the contemporary Delta is fundamentally a "flow through (conveyance) system", where virtually every single channel is engaged in moving the river flows (and exports) through the system.

(4) The geomorphology of natural channels in the historical Delta created within-channel velocity gradients; these velocity gradients are largely absent in the narrow, deep, rocked, steep-sided and prismatic channels that make up the contemporary delta, possibly reducing the suitability of contemporary pelagic habitats.

The consequences of these changes, particularly the periodic fortnightly decoupling/coupling of pelagic and marsh plain habitats at the scale of the Delta on the biogeochemistry, on primary producers and on both the pelagic and marsh plain ecosystems is unknown. However, the magnitude of the differences in transport processes between these systems suggests the possibility that the historical Delta supported a radically different ecosystem at the primary producer level than the ecosystem that exists today.

Keywords: hydrodynamics, transport, historical
Session Title: Re-Envisioning the Delta with New Knowledge from the Past I
Session Time: Tuesday 1:35 PM – 3:15 PM, Room 314

A New Dimension to Historical Ecology: Insights from a 3D Hydrodynamic Model of the Pre-Development Estuary

Samuel Safran, SFEI, sams@sfei.org
Stephen Andrews, RMA, steve@rmanet.com
Letitia Grenier, SFEI, letitia@sfei.org
Robin Grossinger, SFEI, robin@sfei.org

A 3D hydrodynamic model of the pre-development (ca. 1800) upper San Francisco Estuary has been developed to help understand how changes in the geometry and hydrology of the system have altered key physical and ecological processes. This hydrodynamic model was constructed using a new digital elevation model of the pre-development upper estuary and new estimates of "natural" Delta inflows, and then calibrated using historical information on tidal characteristics. Once completed, the pre-development model was paired with a similar model of the contemporary system in order to analyze hydrodynamic changes in the upper estuary, including changes in tidal prism, isohaline position, low-salinity zone habitat, channel velocity, and source water distribution. This paper presents the results of these analyses and considers the ecological implications of the modeled differences in estuarine hydrodynamics. The models suggest that there has been a decrease in temporal variability of water salinity (with implications site-scale heterogeneity in tidal marsh plant communities), a landward movement of X2 due to changes in estuarine geometry and sea level rise (with implications for aquatic organisms and human water supply), a loss of low-velocity refugia in blind tidal sloughs (with implications for juvenile fish), and dramatic changes in the distribution of freshwater from the Delta's many tributaries (with implications for migrating adult anadromous fish). Understanding changes in these and other hydrodynamic variables can help to improve our understanding of the desirable ecosystem functions provided by the historical system and, as a result, improve our ability to recover these functions now and into the future.

Keywords: historical ecology, pre-development, Delta, Suisun, hydrodynamic modeling, X2, processes
Session Title: Re-Envisioning the Delta with New Knowledge from the Past II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 314

Time Travel in the Sacramento-San Joaquin Delta: Developing Photorealistic Images of the Historical Landscape to Inspire Restoration

Erica Spotswood, San Francisco Estuary Institute, ericas@sfei.org
David Osti, 34 North, david@34north.com
April Robinson, San Francisco Estuary Institute, april@sfei.org
Sam Safran, San Francisco Estuary Institute, sams@sfei.org
Robin Grossinger, San Francisco Estuary Institute, robin@sfei.org

The Sacramento-San Joaquin Delta has been fundamentally altered by human modification. Once an extensive tidal and freshwater emergent marsh, the Delta has been transformed by agriculture, water diversion and development. So little remains of the former Delta that it is difficult to envision what the Delta looked like historically, and few modern analogs exist. Yet, visual representations of the historical Delta can serve as a valuable tool for guiding and inspiring future restoration efforts. To fill this gap, we drew upon historical and contemporary ecology to reconstruct the Delta's many historical habitat types, including tidal and freshwater emergent wetland, riparian forests, and the transitional and upland habitats that once occurred along the margins of the Delta. By combining historical information with modern analogous habitat types from around the state, we determined the most likely dominant species composition for each habitat, as well as the likely structure and configuration of the Delta's former plant communities. Species assemblages for each habitat type and a historical digital elevation model were used as inputs into a 3D modeling and visualization tool that builds renderings of landscapes from the ground up. These renderings can be used to create seamless flyovers of the Delta at broad spatial scales, as well as detailed still imagery showing close up views of habitats and locations of interest. Visual representation of lost landscapes can help inspire future restoration, can help to create a sense of place, and can be used as a tool for public engagement and education.

Keywords: Sacramento-San Joaquin Delta, restoration, historical ecology, historical habitats, visualization
Session Title: Re-Envisioning the Delta with New Knowledge from the Past II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 314

How an Understanding of Past and Present Condition is Linked to Management and Implementation of Restoration in the Delta

Carl Wilcox, California Department of Fish and Wildlife, carl.wilcox@wildlife.ca.gov

The objectives of ongoing restoration efforts in the Delta are focused on re-establishing habitat and associated processes which have been lost or degraded during the 150 years. The Delta is a shadow of its historic past and can never be restored to its previous condition. Our challenge is to understand the physical and biological attributes of that historic condition and identify opportunities to restore and enhance those functions and processes in the context of the co-equal goals of the 2009 Delta Reform Act, providing a more reliable water supply for California and protecting, restoring and enhancing the Delta, in a manner that protects and enhances the Delta as place. As discussed in the previous presentations we have a new understanding which is critical to guiding efforts to restore important ecological attributes that are critical to supporting sensitive aquatic and terrestrial species that depend on the Delta for all or part of their life-cycle. Without this knowledge we are taking action without objective criteria against which to gauge success. Restoration efforts in the Delta will be reconciling the historic past with what is possible to achieve given the physical and social realities of today's Delta and that of the future.

Keywords: restoration, Delta, habitat, functions, processes, sensitive species, co-equal goals, historic, ecological
Session Title: Re-Envisioning the Delta with New Knowledge from the Past II
Session Time: Tuesday 3:35 PM – 5:15 PM, Room 314

Quantifying the Effects of Hatchery Management on the Portfolio Effect in Salmon

Allison Dedrick*, University of California Davis, agdedrick@ucdavis.edu
Marissa Baskett, University of California Davis, mlbaskett@ucdavis.edu
Amanda Faig, University of California Davis, afaig@ucdavis.edu
Michael Springborn, University of California Davis, mspringborn@ucdavis.edu

Diversity within populations can help buffer against collapse in a changing environment. This phenomenon, called the portfolio effect, is particularly applicable to salmon stocks because varied conditions in streams can create runs with diverse traits, such as outmigration timing. In Central Valley fall-run Chinook, which are heavily affected by humans through hatcheries, harvest, and habitat change, eroded diversity among runs could have contributed to the recent population collapse. In particular, hatchery release practices can change the amount of exchange among creeks: fish released closer to the ocean are more likely to stray and return to a non-natal creek as adults, eroding local adaptation. Using a quantitative genetic model with two creeks, one with a hatchery, we investigate the effect of hatchery management practices on the portfolio effect that arises from population dynamics and diversity across creeks. Specifically, we ask whether trucking hatchery fish downstream can drive the homogenization of outmigration timing across creeks and if so, what the consequences are for population dynamics.

We find that releasing hatchery fish closer to the ocean results in both genetic and demographic effects across the whole population, not just in the creek with the hatchery. As hatchery fish are released farther downstream, the mean traits become more similar between the two creeks and both the mean and the variance of annual total population size increase, presenting a tradeoff between average total run size and stability through time. These results indicate that hatchery release practices can drive homogenization among streams and weaken the portfolio effect, making returns larger on average but also more variable. Current management practices for the Central Valley fall-run Chinook involve hatcheries and trucking, including trucking to bypass the Bay-Delta, so the population-level tradeoffs due to trucking suggested by our study are relevant to future decisions about hatchery practices.

Keywords: hatcheries, trucking, Central Valley fall-run Chinook, outmigration, *Oncorhynchus tshawytscha*, portfolio
Session Title: Biology, Ecology and Management of Central Valley Salmonids I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 306

Salmon Strategies in the Central Valley Portfolio: Risk Spreaders vs. Risk Takers

Anna Sturrock, University of California, Berkeley, a.sturrock@berkeley.edu
Stephanie Carlson, University of California, Berkeley, smcarlson@berkeley.edu
Corey Phillis, Metropolitan Water District of Southern California, CPhillis@mwdh2o.com
Peter Weber, Lawrence Livermore National Laboratory, weber21@llnl.gov
Rachel Johnson, NOAA, Rachel.Johnson@noaa.gov

Life history diversity can buffer salmon populations over space (e.g. the use of natal and non-natal habitats for rearing) and time (e.g. variable outmigration timing resulting in a greater probability of meeting optimal ocean conditions). California Central Valley Chinook salmon display an extraordinary suite of life histories and migration strategies, but factors such as waterway channelization, modifications to the natural flow regimes, water diversions, and hatchery practices may function to truncate this diversity. For example, fall run Central Valley Chinook salmon are genetically homogeneous and exhibit correlated population dynamics that reveal a weak and deteriorating Portfolio Effect (PE), likely due, in part, to hatchery release practices. Managing for life history diversity in regulated rivers is a central element to many salmon recovery plans, yet it remains difficult to incorporate the PE into management objectives in part because it is a difficult phenomenon to quantify. Here, we have synthesized metrics of juvenile salmon life history diversity (size and time at outmigration, natal vs. non-natal rearing behaviors) from various data sources (rotary screw trap, beach seine and trawl sampling, and otolith chemistry reconstructions), rivers (Stanislaus, Tuolumne, Yuba, American and Sacramento River, Deer, Mill and Butte Creeks), and runs (spring, fall and winter run). We compare trait expression and success among years and populations, and attempt to integrate our findings with historical accounts and observations from other systems.

Keywords: Life history diversity, salmon, otolith, biocomplexity, synthesis, portfolio effect, outmigration
Session Title: Biology, Ecology and Management of Central Valley Salmonids I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 306

Identifying Hatchery Versus Wild Origin of Chinook Salmon (*Oncorhynchus tshawytscha*) on the Feather River Spawning Grounds using Otolith Strontium Isotope Ratios

Malte Willmes, Wildlife, Fish and Conservation Biology, University of California, Davis, malte.willmes@googlemail.com
Zachary Bess, Wildlife, Fish and Conservation Biology, University of California, Davis, zabess@ucdavis.edu
Anna M. Sturrock, Department of Environmental Science, University of California, Berkeley, a.sturrock@berkeley.edu
Ryon Kurth, Department of Water Resources, Division of Environmental Services, Feather River Special Studies, Ryon.Kurth@water.ca.gov
Jason Kindopp, Department of Water Resources, Division of Environmental Services, Feather River Special Studies, Jason.Kindopp@water.ca.gov
Rachel C. Johnson, NOAA Fisheries, rachel.johnson@noaa.gov
James A. Hobbs, Wildlife, Fish and Conservation Biology, University of California, Davis, jahobbs@ucdavis.edu

Chinook Salmon (*Oncorhynchus tshawytscha*) populations in California are heavily subsidized with the production of hatchery fish. However, the spawning of hatchery origin Chinook with wild fish has been found to compromise the genetic integrity of the wild origin populations through processes such as outbreeding, genetic homogenization and reduction of life history diversity. Determining the proportion of hatchery origin fish on the in-river spawning grounds is thus a direct prerequisite for the effective management of salmon populations. We used otolith strontium isotope (^{87}Sr:^{86}Sr) ratios of fish collected during carcass surveys for each year from 2002 to 2010 on the Feather River to reconstruct their life history patterns and determine their origin. Isotopically determined hatchery origin classifications were validated using otoliths of known hatchery origin from coded wire tag information and achieved an accuracy of 95%. Our results show, that a large proportion (~50-90%) of in-river spawning fish in the Feather River are of hatchery origin, with the proportion of hatchery fish dramatically increasing in 2009 and 2010. We also identified fish originating from other tributaries which contributed generally less than 10% to the spawning populations, with most strays originating from the near-by Yuba River. The high proportions of in-river spawning hatchery origin chinook salmon documented in this study indicate, that fitness of natural origin Chinook may be significantly impaired and suggest that introgression between hatchery and natural origin Chinook may be a factor contributing to the depressed status Central Valley Chinook salmon.

Keywords: Chinook Salmon, Otolith microchemistry, Feather River, Strontium isotopes
Session Title: Biology, Ecology and Management of Central Valley Salmonids I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 306

Adaptive Genetic Variation, Conservation, and Fisheries Management in the Age of Genomics

Devon Pearse, NMFS Southwest Fisheries Science Center, devon.pearse@noaa.gov

In anadromous fishes, expression of migratory life-history phenotypes is influenced by a combination of environmental, genetic, and developmental effects. Recent studies have identified specific genes and genomic regions under divergent natural selection for fitness-related phenotypes. This improved understanding of the genomic basis of life-history variation has extended our knowledge of adaptive evolution, and has the potential to provide useful data for species conservation and management decision-making, complimenting more typical conservation applications of population genetic data. However, careful consideration must be given to the implications of using marker-specific approaches to set conservation priorities. This is especially critical for hatchery supplementation programs and reintroduction projects because, unlike the practice of marker-assisted selection in captive plant and animal breeding, individuals in natural populations and hatchery broodstock programs must contend with natural selection in the environment in which they are released. Thus, marker-based selection of breeders to produce specific phenotypes in a conservation context has the potential to produce offspring with maladapted phenotypes for existing environmental conditions (e.g. anadromous migration through the delta). Here I use data on adaptive genomic variation associated with specific phenotypes in salmonids to hightlight the practical considerations and potential pitfalls of incorporating such information into conservation programs, describe conservation scenarios in which it could be misleading, and the importance of validating inferences drawn from new genomic data before applying them in conservation practice. Finally, I discuss ways to bridge the gap between newly developed genomic technologies and applied conservation practice.

Keywords: genetics, genomics, adaptation, evolution, life-history, management, hatcheries, salmon, steelhead
Session Title: Biology, Ecology and Management of Central Valley Salmonids I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 306

Selection of Donor Stock for Salmonid Reintroduction Projects

John Carlos Garza, NOAA Southwest Fisheries Science Center and the University of California Santa Cruz, carlos.garza@noaa.gov
Devon Pearse, NOAA Southwest Fisheries Science Center and the University of California Santa Cruz, devon.pearse@noaa.gov
Anthony Clemento, University of California Santa Cruz and NOAA Southwest Fisheries Science Center, anthony.clemento@noaa.gov

Much of the historically available spawning and rearing habitat for salmon and steelhead in the Sacramento/San Joaquin basin is now behind dams and reservoirs, or otherwise not suitable for successful life cycle completion. As efforts accelerate to restore fish populations to achieve ESA recovery and stabilize ecosystems, many reintroductions of salmonids are either underway or being planned. Yet, it is often not clear where to obtain fish for such reintroductions and how to go about selecting and releasing them. We describe the biological factors that need to be taken into account for such donor stock collection, including considerations of local adaptation, genetic diversity, life history and population viability. We further discuss the biological criteria and logistical issues involved in selecting individual fish for reintroductions and in release strategies. We illustrate the complex issues involved in restoring fish populations in newly available habitat with examples from the current reintroduction of Chinook salmon to the San Joaquin River and planned reintroductions of salmon to the McCloud and North Fork Yuba Rivers.

Keywords: Reintroductions, Salmon, Steelhead, Donor stock, Biological criteria
Session Title: Biology, Ecology and Management of Central Valley Salmonids I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 306

Timing of Hatchery and Wild Winter-run Chinook Salmon Caught in the Sacramento River and Chipps Island Trawls for the Implementation of Delta Management Actions.

Patricia Brandes, U.S. Fish and Wildlife Service, Pat_Brandes@fws.gov

Many management actions in the Sacramento-San Joaquin Delta are timed to be protective of juvenile winter-run Chinook salmon and use the detection of winter-run-sized fish or hatchery winter-run to trigger actions, but it is unclear how well these represent wild winter run. Winter-run-sized fish in Delta monitoring are identified using the river length-at-date-criteria (RLADC). Between 2007 and 2011, we collected tissues from juvenile Chinook salmon caught in the trawls at Sacramento and Chipps Island and determined that the RLADC over-estimated the abundance of winter-run at both locations because many fall, late-fall and spring-run Chinook salmon are designated as winter-run using the RLADC. While the winter-run RLADC does not estimate relative abundance well, it does appear to generally reflect the timing of genetic winter-run at both Sacramento and Chipps Island. In contrast, when comparing the timing of the genetic winter-run caught at Sacramento to the hatchery winter-run, we found in most cases that roughly half of the winter-run caught were caught before the hatchery fish were released, and in two of three years no winter-run hatchery fish were caught at Sacramento. This would suggest that the hatchery winter-run are poor surrogates for the early part of the wild winter-run migration into the Delta. At Chipps Island, the majority of the genetic winter-run do overlap with the hatchery winter-run catches because fewer winter-run appear to migrate past Chipps Island earlier in the season before hatchery release. Management actions that incorporate timing from both the RLADC and the winter-run hatchery fish are more likely to be successful in protecting all of the juvenile winter-run Chinook salmon in the Delta, than either method alone.

Keywords: Salmon, winter-run, migration timing, Delta
Session Title: Biology, Ecology and Management of Central Valley Salmonids II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 306

Migration and Survival of Natural Juvenile Chinook Salmon in the Delta

Li-Ming (Lee) He, NOAA Fisheries, li-ming.he@noaa.gov

Problem Statement: The Sacramento-San Joaquin Delta serves as a migration corridor and rearing place for natural juvenile winter-run and spring-run Chinook salmon that enter from the Sacramento River to the Delta each year, before migrating into the San Francisco Bay and finally to the Pacific Ocean. Many studies have been done using a limited number of hatchery-origin juveniles, but much is unknown about the migration timing, migration duration, and survival of natural juveniles migrating through the complex waterway system of the Delta.

Approach: We developed a systematic approach for compiling and analyzing 21 years (1993-2013) of juvenile fish monitoring data at Sherwood Harbor and Chipps Island. Daily juvenile catch and trawl efficiency data were used to obtain daily and annual juvenile passages at the two monitoring locations.

Results/Conclusions/Relevance: I will present results for migration timing, migration duration, and survival rates for natural winter-run and spring-run Chinook salmon juveniles migrating through the Delta. I will discuss how inflow to the Delta, Delta outflow, or water export affects migration timing, duration, or survival. The findings may shed light on how to manage the Delta for endangered or threatened salmon species.

Keywords: Chinook salmon, migration timing, duration, abundance, survival, inflow, outflow, export
Session Title: Biology, Ecology and Management of Central Valley Salmonids II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 306

Comparing In-River Survival of Coleman National Fish Hatchery- and Nimbus Fish Hatchery-Origin Steelhead Smolts Released in the Lower American River

Annie Brodsky, Cramer Fish Sciences, annieb@fishsciences.net
Steven Zeug, Cramer Fish Sciences, stevez@fishsciences.net
Jonathan Nelson, California Department of Fish and Wildlife, Jonathan.Nelson@wildlife.ca.gov
John Hannon, United States Bureau of Reclamation, jhannon@usbr.gov

Steelhead reared at Nimbus Hatchery (NH) are not part of the Central Valley evolutionary significant unit and as such, do not contribute to recovery of the native stock. The reasonable and prudent alternative in the National Marine Fisheries Service biological opinion on operation of the Central Valley Project and State Water project included direction to investigate replacement of the NH stock. In 2015 steelhead eggs from Coleman National Fish Hatchery (CNFH) were reared at NH and in-river survival was monitored for both stocks released in the Lower American River as part of an evaluation of the CNFH stock's suitability for use at NH. Smolts from both stocks were implanted with acoustic transmitters and released on two occasions into the Lower American River. Forty seven NH-origin smolts and fifty CNFH-origin smolts were released on February 11, 2016 and forty six NH-origin smolts and 57 CNFH-origin smolts were released on February 24, 2016. The minimum survival estimate from release one was 83.0% for NH -origin fish and 82% for CNFH-origin fish. Minimum survival from release two was 95.7% for Nimbus Hatchery -origin fish and 75.4% for CNFH-origin fish. The data produced to date suggest that there is no detectable difference in the proportion of NH - and CNFH -origin smolts successfully migrating out of the Lower American River. These analyses suggest further studies should be performed to assess CNFH steelhead performance at NH during other life stages.

Keywords: Lower American River, acoustic monitoring, Nimbus, Coleman, steelhead, Central Valley
Session Title: Biology, Ecology and Management of Central Valley Salmonids II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 306

Where They Go and How They Grow: Using Otoliths to Reconstruct Habitat-Specific Growth Patterns for Endangered Winter-Run Chinook

Maya Friedman*, UC Santa Cruz, mfriedma@ucsc.edu
Eric Danner, NOAA fisheries, eric.danner@noaa.gov
Rachel Johnson, NOAA Fisheries, rachel.johnson@noaa.gov

As juvenile winter-run Chinook salmon migrate from the Sacramento River through the San Francisco Estuary into the Pacific Ocean, their growth, migration, and survival are heavily affected by water temperature and flow dynamics. Yet the relative importance and use of habitats within the winter-run migration corridor is poorly understood. Salmon otoliths provide an ideal tool to reconstruct fish condition and movement. Paired with unique chemical markers within the watershed, they are able to provide insight into the habitat use, migratory behavior, and growth patterns of juvenile salmonids. We used otolith strontium isotopes ($^{87}Sr/^{86}Sr$) in adult Central Valley Winter-run Chinook salmon that successfully returned to spawn, in order to determine how river conditions influence (1) freshwater growth, (2) migration behavior, and (3) habitat use of individuals that outmigrated during 2009-2011 and successfully returned to spawn. For each successfully spawned adult, analysis of otolith increment widths and strontium isotope ratios were used to reconstruct early life growth rates and duration of riverine and delta rearing. Otolith microchemistry was paired with a high-resolution model of water temperature and flow to generate isotopic landscapes (isoscapes) of strontium for the entire range of Winter-run habitat from the Sacramento River. Size distributions and phenotype contributions were compared between juvenile emigrants and adults that returned to spawn, and used to identify patterns in selective mortality. Our study years examined juvenile cohorts emigrating over a period of contrasting flow regimes as a result of differences in precipitation patterns and water operations. Outmigration behavior (size and phenology) varied primarily as a function of hydrologic regime, with important growth differences among habitats within the migration corridor. This information will provide valuable insights to aid future management decisions aimed at minimizing drought impacts to winter run, and to improving water supply reliability.

Keywords: Chinook salmon, life history diversity, juvenile outmigration, otolith strontium isotopes
Session Title: Biology, Ecology and Management of Central Valley Salmonids II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 306

Survival and Movement Rates of Wild Chinook Salmon Smolts from Mill Creek through the Sacramento River, Sacramento-San Joaquin River Delta and San Francisco Bay, 2013-2016

Jeremy Notch*, University of California, Santa Cruz, jeremy.notch@noaa.gov
Arnold Ammann, National Marine Fisheries Service, arnold.ammann@noaa.gov
Matt Johnson, California Department of Fish and Wildlife, matt.johnson@wildlife.ca.gov
Alex McHuron, National Marine Fisheries Service, alex.mchuron@noaa.gov

Populations of wild spring and fall-run Chinook salmon in California's Central Valley once numbering in the millions have dramatically declined in recent years to all-time low numbers. Dam construction, habitat degradation, predation, water diversions and hatchery stocks have largely wiped out populations of wild spring-run Chinook in the Central Valley, with just a handful of populations persisting in a few tributaries to the Upper Sacramento River Basin. Mill Creek is one of these tributaries which offer some of the most pristine spawning and rearing habitat currently available to Chinook salmon in the Central Valley. Despite this pristine habitat its populations of spring and fall-run Chinook salmon have declined in recent years, with spring-run escapement reaching a low of 127 adults in 2015. In order to address this issue and study the survival rates of out-migrating smolts from Mill Creek we used Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic tags surgically implanted into migrating smolts captured with a rotary screw trap and seine net. Acoustic receivers placed throughout the migration corridor allow us to track reach-specific survival and movement rates from Mill Creek to the Pacific Ocean. After four years of data collection (2013-2016) we have acoustic tagged 330 smolts during their spring out-migration, which experienced extreme drought conditions in 2013-2015 followed by a wet year in 2016. The data suggests survival for smolts emigrating from Mill Creek during drought conditions is very poor, with the majority of them dying in Mill Creek and the Upper Sacramento River. In 2016 these smolts experienced high water conditions which should lead to higher survival rates. Continued acoustic tagging studies on these stocks will allow us to better manage the dwindling populations and focus restoration efforts in key locations.

Keywords: Chinook salmon, acoustic telemetry, survival, movement, predators
Session Title: Biology, Ecology and Management of Central Valley Salmonids II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 306

How Long Does it Take for Selenium to Bioaccumulate in the Diet and Tissues of Sturgeon?

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

In trying to answer the question “how much is too much” with respect to selenium in the Bay-Delta, attention rightly has been focused on the introduced Asian overbite clam that bioaccumulates selenium especially efficiently, and on the vulnerable sturgeon species that feed on this clam. In the Bay-Delta environment of fluctuating selenium and migrating sturgeon, to assess the risks of selenium to sensitive life stages of sturgeon, it is essential to understand the time delay between exposure to selenium in ambient water, and bioaccumulation of selenium in the tissues of the sturgeon species. Hitherto, estimating these lag times has been a matter of guesswork. Now, a statistical method has been demonstrated that enables us to provide more objective estimates. The method was developed using selenium monitoring data from the Grassland Bypass Project in the Kesterson area of the San Joaquin valley. The method can be used to infer estimated selenium bioaccumulation lag times of roughly 50-120 days for overbite clams, 178 days for white sturgeon, and 247 days for green sturgeon. Reliability of these estimates will be discussed, along with implications for risk of selenium to sturgeon species.

Keywords: selenium, bioaccumulation lag, trophic level, sturgeon, overbite clam
Session Title: Advances in Sturgeon Research
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 306

Fin Ray Microchemistry as a Tool to Reconstruct the Migratory History of White Sturgeon *Acipenser transmontanus*

Kirsten Sellheim, Cramer Fish Sciences, kirstens@fishsciences.net
Joseph Merz, Cramer Fish Sciences, jmerz@fishsciences.net
Malte Willmes, University of California, Davis, mwillmes@ucdavis.edu
Zachary Jackson, U.S. Fish and Wildlife Service, zachary_jackson@fws.gov

The objective of this study was validation of fin ray microchemistry (i.e., strontium isotope; 87Sr:86Sr ratios) analysis to identify White Sturgeon *Acipenser transmontanus* movement patterns within freshwater portions of the San Francisco Estuary watershed. This approach has high potential to provide valuable management information regarding juvenile and adult sturgeon habitat and behavior. To identify how time and water source are archived in pectoral fin ray microchemistry, we exposed rapidly growing juvenile hatchery sturgeon in laboratory tanks to two water sources exhibiting distinctive 87Sr:86Sr signatures for different periods of time. We also assessed how diet affected fin ray microchemistry by feeding a subset of fish a marine-derived diet, while others were fed a diet whose microchemistry matched that of the water source. We detected distinct shifts in fin ray microchemistry in sturgeon that were exposed to a water source for only two weeks. Diet did not significantly influence resulting fin ray microchemistry in the majority of the experimental sturgeon. For one of the water sources, fin ray strontium values matched those of the water source; for the other water source fin rays reached a uniform, but lower, strontium value as compared to that of the water source. The mechanism behind this disparity was explored with a follow-up experiment. Findings of these controlled laboratory studies have important implications for applying this methodology to field-collected fin ray samples.

Keywords: sturgeon, life history, microchemistry, migration, spawning, rearing, fin ray
Session Title: Advances in Sturgeon Research
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 306

Selenium in San Francisco Estuary White Sturgeon

Jennifer Sun, San Francisco Estuary Institute, jennifers@sfei.org
April Robinson, San Francisco Estuary Institute, april@sfei.org
Jay Davis, San Francisco Estuary Institute, jay@sfei.org
Philip Trowbridge, San Francisco Estuary Institute, philt@sfei.org
Robin Stewart, United States Geological Survey, arstewar@usgs.gov
Vince Palace, International Institute for Sustainable Development, vpalace@iisd-ela.org
Zachary Jackson, United States Fish and Wildlife Service, zachary_jackson@fws.gov

Selenium is an essential trace element that is toxic at high levels and has been shown to adversely impact reproduction in white sturgeon. To protect this sensitive species, the San Francisco Bay Regional Water Quality Control Board established the North San Francisco Bay Selenium (Se) TMDL. The monitoring target for the TMDL was established as ≤11.3 ug/g dry weight in white sturgeon muscle tissue. The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) has conducted long-term monitoring of selenium in white sturgeon throughout the Bay since 1997, and since 2014 has conducted two additional studies to develop non-lethal tissue monitoring methods to assist with the implementation of the TMDL. Non-lethal sampling methods to monitor for compliance with the TMDL are important due to the declining abundance of white sturgeon.

Muscle plug, muscle fillet, ovary, liver, fin ray, and otolith samples collected through various sampling efforts (fishing derbies, California Department of Fish and Wildlife sturgeon trammel net surveys, and RMP Status and Trends monitoring) between 2009 and 2016 were analyzed for Se concentrations. Microchemical analyses of Se in annual growth zones of otoliths and pectoral fin rays are being conducted to measure patterns of temporal exposure to Se. Se concentrations were relatively stable between 0.4 and 0.5 ppm in pectoral fin ray sections corresponding to the period of 1998-2015. Additionally, muscle plug sampling was determined to be a viable non-lethal technique for monitoring attainment of the TMDL target. Muscle plug Se concentrations are within the range of previously measured muscle tissue Se concentrations and are significantly correlated with muscle fillet Se concentrations. Additional relationships among Se in other tissues will indicate whether muscle plugs or other non-lethally collected tissue measurements (fin rays) are good proxies for Se accumulation in tissues of toxicological interest (ovaries, liver).

Keywords: selenium, non-lethal sampling, sturgeon, muscle plugs
Session Title: Advances in Sturgeon Research
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 306

Fish on the Edge: Assessing Environmental Constraints for Recruitment of White Sturgeon in the San Joaquin River, California.

Laura Heironimus, U.S. Fish and Wildlife Service, Laura_Heironimus@fws.gov
Zachary Jackson, U.S. Fish and Wildlife Service, Zachary_Jackson@fws.gov

Inadequate recruitment is a hallmark of declining sturgeon populations throughout the world. Efforts to understand and address the processes that regulate recruitment are of foremost importance for successful management and recovery. Prior to 2011, San Francisco Estuary White Sturgeon *Acipenser transmontanus* were only known to spawn in the Sacramento River, California. Although sturgeon captured in the San Joaquin River were reported by anglers, no direct evidence existed of spawning within the river. We assessed potential White Sturgeon spawning locations by deploying artificial substrate samplers and benthic drift nets during late winter and spring of 2011-2016 from river kilometers 115.2 to 145.3 of the San Joaquin River. Collections of fertilized eggs, compared with hydrology data, confirm that White Sturgeon spawn within the San Joaquin River during wet and dry water-year conditions; however, we were unable to document spawning during critical water-year conditions. Time of spawning was estimated by determining egg stage-of-development at time of capture coupled with available water temperatures. Time of spawning was also estimated from the collection of endogenous larval sturgeon (0-2 days post-hatch). Comparing environmental data with the spawning information and adult sturgeon telemetry data appears to demonstrate the importance of variable streamflow and temperature relief during late winter and early spring. Small pulse flow augmentations intended to benefit juvenile salmonids appear to have triggered White Sturgeon migration within this system throughout 2011–2016 and spawning during 2012 and 2016. Understanding the effects of water management on spawning and subsequent recruitment is necessary to increase White Sturgeon recruitment and aid in enhancing the San Francisco Estuary population.

Keywords: White Sturgeon, spawning, recruitment, flow augmentation, water management
Session Title: Advances in Sturgeon Research
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 306

Applying a Simplified Energy-Budget Model to Explore the Effects of Temperature and Food Availability on Life History of the Green Sturgeon (*Acipenser medirostris*)

Natnael Hamda, NOAA, tnatnael@gmail.com
Benjamin Martin, NOAA, benjamin.martin@noaa.gov
Eric Danner, NOAA, eric.danner@noaa.gov

The southern distinct population segment (sDPS) of North American green sturgeon (*Acipenser medirostris*) are listed as threated under the endangered species act. These fish use the Sacramento River and the Bay Delta as breeding and rearing habitat, and are potentially impacted by water management practices. Understanding of these impacts helps to answer key and wide range of problems in the conservation of the species and support decision-making processes. Particularly, it is crucial to understand the interaction between the life history of the organism and their environment. Empirical studies might help to understand some of these interactions; however, it is impossible to assess all possible organisms–environment interactions experimentally alone, and it is also dangerous to extrapolate results beyond the range of the observation points. We here use a simplified energy-budget model based on Dynamic Energy Budget theory to explore the effects of temperature and food limitation on the life history Green Sturgeon. We show here how the various model parameters can be estimated from different laboratory and field observations. Using the parameterized model, we are able describe the growth and reproduction data of Green Sturgeon obtained from primary and secondary data sets. Using our simulation model, we are able to predict the combined effect of food density and temperature on the growth and reproduction of Green Sturgeon. We are also able to characterize the nature of interaction of temperature and food limitation. We argue the model can easily be integrated with physical models to assess and predict the effects of temporal and spatial temperature change on the life history of Green Sturgeon.

Keywords: energy-budget model, DEB, DEBkiss, Green Sturgeon, environmental stressors, organism–environment interactions
Session Title: Advances in Sturgeon Research
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 306

Mechanisms for the Effective Biological Control of the Invasive Water Hyacinth, *Eichhornia crassipes*, in the Sacramento-San Joaquin River Delta, California

Julie Hopper, University of California, Davis, jvhopper@ucdavis.edu
Louise Conrad, California Department of Water Resources, Louise.Conrad@water.ca.gov
Paul Pratt, USDA, ARS, PWA, WRRC-EIW, Paul.Pratt@ars.usda.gov
Edwin Grosholz, University of California, Davis, tedgrosholz@ucdavis.edu

Services provided by the Delta are severely limited as a result of invasive aquatic weeds, such as the water hyacinth, *Eichhornia crassipes*. In the early-1980s, three biological control agents: a moth, *N. albiguttalis* and two weevils *Neochetina bruchi* and *N. eichhorniae* were released for the control of water hyacinth in the Delta. To date, it appeared that only *N. bruchi* persisted, and current control outcomes have not reached the desirable levels observed in other regions where classical biological control has been implemented. Here, we explore possible mechanisms for inadequate biological control of water hyacinth in the Delta including: 1) insufficient climate matching and temporal declines in the winter, 2) genetic bottlenecks, and 3) a microsporidian pathogen. We conducted monthly surveys from June 2015-2016 across 16 locations in the Delta to determine the spatial and temporal variation of the weevils, examine the genetic variation, and determine microsporidian abundance and distribution in *N. bruchi*. Averaging across months, densities of weevils per destructively sampled plant were 6.83 at one site and 0.31 at another site (26 km away). Averaging across locations, weevil densities ranged from 5.35 to 6.22 in August-November, and low densities ranged from 2.09 to 0.55 in February-June. Through morphological and molecular characterization, using PCR and sequencing the COI region, we discovered that both *N. bruchi* and *N. eichhorniae* have persisted in the Delta, with the majority of weevils identified as *N. bruchi*. Additionally, we confirmed the presence of a microsporidian in *N. bruchi* across the Delta, with seasonal variation in pathogen intensity. We will identify this microsporidian species and continue surveys to determine if this pathogen could be hindering the performance of *N. bruchi*. Lastly, we propose potential solutions to increase the efficacy of biological control of water hyacinth in the Delta.

Keywords: aquatic weeds, biological control, Delta, genetic variation, microsporidia, water hyacinth
Session Title: Species Invasions in the San Francisco Estuary
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 306

Food Web Impacts of Invasive Aquatic Weed Control in the Sacramento-San Joaquin Delta

Marie Stillway, UC Davis, mstillway@ucdavis.edu
Bruce Hammock, UC Davis, bghammock@ucdavis.edu
Andrea Cruz, UC Davis, afcruz@ucdavis.edu
Diana Hernandez, UC Davis, diahernandez@ucdavis.edu
Ida Flores-Avila, UC Davis, ijflores@ucdavis.edu
Ching Teh, UC Davis, fcteh@ucdavis.edu
Tomofumi Kurobe, UC Davis, tkurobe@ucdavis.edu
Jiali Jin, UC Davis, jijin@ucdavis.edu
Swee Teh, UC Davis, sjteh@ucdavis.edu

In the Sacramento-San Joaquin Delta and surrounding tributaries, invasive aquatic plants, such as water hyacinth, *Egeria densa*, and spongeplant, degrade physical habitats and change water quality, which negatively impacts the endangered Delta Smelt (*Hypomesus transpacificus*). To help combat this growing problem, the Division of Boating and Waterways has suggested the application of two new herbicides, Penoxsulam and Imazamox, for a more efficacious control over invasive aquatic vegetation. However, potential adverse effects of these herbicides on endangered Delta Smelt, and its prey, *Eurytemora affinis*, has not been extensively researched. This study compared the toxicity of Penoxsulam and Imazamox, as well as the current-use herbicides glyphosate, 2,4-D, and fluridone, to Delta Smelt and *E. affinis* (glyphosate only). Delta Smelt embryos (1-2 days post fertilization) and larvae (1-2 days post hatch) were exposed to chemicals for 96 h with an 80% renewal at 48-hr, then transferred to clean water until hatch (embryo) or up to 4 days (larvae). Endpoints evaluated included embryo hatching success, larval survival, and morphometry. Copepod tests were 96-hr chemical exposure with an 80% renewal at 48-hr and evaluated survival. Results demonstrate that 1) of the two species, *E. affinis* is more sensitive to these herbicides than *H. transpacificus*, as copepod LC50s were generally lower than Delta Smelt; and 2) the current use herbicides elicit more sub-lethal toxic effects on Delta Smelt than Penoxsulam and Imazamox. However, these negative effects were observed at concentrations well above application rates, lending an acceptable margin of safety for use of these herbicides. These findings are relevant to issues occurring within the Bay-Delta, as these results provide food web-level analyses, which will aid managers in choosing the appropriate control measures for combating these invasive aquatic plants while still maintaining the integrity of aquatic fauna within the Bay-Delta ecosystem.

Keywords: Food Web, Delta Smelt, Copepods, Herbicides, Ecology, Invasive Species, Contaminants
Session Title: Species Invasions in the San Francisco Estuary
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 306

Detecting Invasions and Changes in San Francisco Estuary Sessile Invertebrate Communities over Sixteen Years (2000 to 2015) in Response to Salinity and Temperature Conditions

Andrew Chang, Smithsonian Environmental Research Center, changal@si.edu
Gail Ashton, Smithsonian Environmental Research Center, ashtong@si.edu
Christopher Brown, Smithsonian Environmental Research Center, chris.brown@slc.ca.gov
Lina Ceballos, Smithsonian Environmental Research Center, ceballosl@si.edu
Jeffrey Crooks, Smithsonian Environmental Research Center, jcrooks@tijuanaestuary.org
Stephen Foss, California Department of Fish and Wildlife, Steve.Foss@wildlife.ca.gov
Stacey Havard, Smithsonian Environmental Research Center, HavardS@si.edu
Kristen Larson, Smithsonian Environmental Research Center, LarsonK@si.edu
Michelle Marraffini, Smithsonian Environmental Research Center, marraffinim@si.edu
Linda McCann, Smithsonian Environmental Research Center, mccannl@si.edu
Michele Repetto, Smithsonian Environmental Research Center, RepettoM@si.edu
Sharon Shiba, California Department of Fish and Wildlife, sharon.shiba@wildlife.ca.gov

Invasions by non-native species are well-known drivers of significant ecological change worldwide. Despite considerable available information on marine invasions in California, and particularly the San Francisco Bay region, it remains challenging to detect new invasions and estimate actual changes in invasion patterns, such as rate and spread. These data are key to understanding invasion processes and informing management and policy aimed at prevention of new invasions and responses to existing invasions. We addressed this issue for hard substrate-dwelling sessile invertebrate communities, which make up a significant portion of invasions worldwide, by conducting repeated, standardized surveys of fouling communities throughout the San Francisco Estuary over a fifteen-year period spanning a wide range of environmental conditions.

We characterized communities using settlement panel surveys at sites throughout the estuary, from Antioch to the Golden Gate to the Dumbarton railroad bridge in the South Bay, from 2000 to 2015. These years spanned recent dry and wet extremes, including major droughts and wetter winters.

Non-native species were prevalent throughout the estuary, but achieved greater dominance following dry winters. Community composition at any given site during the summer period (May to October) was predicted by temperatures during community development as well as the previous winter's salinity levels. Rarefaction analyses and richness estimators indicate that the number of species detected varied both as a function of the number of sites sampled in a given year and with environmental conditions, indicating that standardized sampling across a broad range of conditions over time is required to capture invasions. For years when at least ten sites were sampled, an asymptote in estimated richness was reached, indicating statistically sufficient sampling to estimate the true richness of the community. This large dataset allows us to better understand the influence of physical characteristics on invasion patterns in the San Francisco Estuary.

Keywords: non-native species, sessile invertebrates, temperature, salinity
Session Title: Species Invasions in the San Francisco Estuary
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 306

What is California Department of Water Resources' Spatially Intensive (GRTS) Benthic Sampling Telling Us? A Clearer Picture of Bivalve Reality

Jan Thompson, USGS, jthompso@usgs.gov
Francis Parchaso, USGS, parchaso@usgs.gov
Elizabeth Wells, CA Department of Water Resources, Elizabeth.Wells@water.ca.gov
Karen Gehrts, CA Department of Water Resources, karen.gehrts@water.ca.gov

The exotic, invasive estuarine clam (*Potamocorbula amurensis*) and freshwater clam (*Corbicula fluminea*) are important in the bay and delta food web due to their aggressive removal of phytoplankton and organic particles from the water column and their potential to limit habitat restoration. A spatially intensive benthic program (GRTS, administered by the California Department of Water Resources) that samples 175 sites in May and October, allows us to examine spatial and seasonal patterns in the biomass, growth, and recruitment of both clams over an eight year time period (2007-2012, 2014-2015). The spatially averaged biomass at salinity-appropriate sites for *Corbicula* (6-20 g ash-free-dry mass/m^2) was 2-40 times greater in magnitude than that of *Potamocorbula* (0.5-6 g AFDM/m2); biomass averages within geographic areas were generally consistent with this trend.

Potamocorbula biomass was seasonally dynamic in the shallow water; spatially averaged annual biomass in October in Grizzly Bay (2-7.6 g AFDW/m^2) was up to 40 times that in May (0.1-1.6 g AFDW/m^2). Maximum *Potamocorbula* biomass occurred in Suisun Marsh (143 g AFDM/m2) with the maximum *Potamocorbula* biomass for six of the eight years occurring here. Juvenile abundance was highest in Grizzly Bay (4800/0.05m^2) and weakly present in the confluence. Largest individuals of *Potamocorbula* were found in the upstream locations (10-18mm shell length), possibly reflected fast growth and or low predation/mortality rates on the adults in this region.

Corbicula biomass was more seasonally stable and the seasons were reversed (average annual spring biomass was 1-2 times greater than fall biomass). Maximum biomass was observed in the sloughs east of the San Joaquin River (3800g AFDM/m2) in 2015 and in the sloughs around the Sacramento River (500 g AFDM/m2) in 2007. Juvenile *Corbicula* occurred in all geographic regions during both seasons. Largest individual *Corbicula* were observed in Suisun Marsh (20-30 mm).

Keywords: bivalves, Corbicula, Potamocorbula, GRTS, biomass, grazing, juveniles, size
Session Title: Species Invasions in the San Francisco Estuary
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 306

Understanding a Drought Induced Die-back of Lepidium latifolium in Invaded Tidal Marshes

Rachel D Wigginton*, University of California Davis, rdwigginton@ucdavis.edu
Megan Kelso, University of California Davis, makelso@ucdavis.edu
Edwin Grosholz, University of California Davis, tedgrosholz@ucdavis.edu

Invasion by noxious weeds is a major conservation and management concern in tidal wetlands. When developing management strategies for these invaders, we must consider the impact of extreme climatic events, such as climate change-induced drought. A particularly problematic invader in San Francisco Bay Delta Estuary is *Lepidium latifolium* (white top). We monitored *Ledpidium* populations from 2014-2016. Between 2014 and 2015, near the peak of California's historic drought, we observed a significant decrease in *Lepidium* stem count ($p<0.05$), stem height ($p<0.05$), and percent cover ($p<0.05$). In order to understand the connection between this invasive plant dieback and drought, we established a manipulative experiment in winter 2016 at the Palo Alto Baylands Nature Reserve, where we altered precipitation in invaded salt marsh plots. We applied four precipitation treatments in a randomized block design (N=6/treatment): rain exclusion (rainout shelter), rain exclusion control (rainout shelter with reirrigation), rain addition (2" of additional water added), and unmanipulated control. Plots were assessed after removal of rainout shelters for stem count and height of *Lepidium*, height of native plants, and percent cover of all plant species. *Lepidium* stems were harvested to assess above ground biomass production within plots. Stem measurements differed between treatments, but covaried with the stem measurements in the plots the previous year. As climate continues to shift and become more variable, understanding how invasion interacts with these changes will likely be critical to effectively managing the *L. latifolium* invasion and preserving these important tidal habitats.

Keywords: Invasion, drought, Lepidium latifolium, tidal marsh, salt marsh, invasive plant
Session Title: Species Invasions in the San Francisco Estuary
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 306

How Unusual Was the 2016 Phytoplankton Spring Bloom in the Delta?

Anke Mueller-Solger, USGS California Water Science Center, amueller-solger@usgs.gov
Tiffany Brown, California Department of Water Resources, tiffany.brown@water.ca.gov
Sarah Lesmeister, California Department of Water Resources, sarah.lesmeister@water.ca.gov

Phytoplankton spring blooms are a common occurrence and important food source in many aquatic systems, including rivers, estuaries, and the ocean. In the Sacramento-San Joaquin River Delta (Delta), the long-term decline in spring diatom bloom frequency and magnitude has contributed to the food scarcity that has been identified as a major ecosystem stressor in this estuarine system. Many management strategies, from wetland restoration to flow manipulations, are aimed at improving the availability of nutritious food sources for aquatic organisms in the Delta. A better understanding of the dynamics and drivers of nutritious phytoplankton blooms is needed to improve the likelihood of success of these management strategies. An extensive network of high-frequency water quality and flow monitoring stations now spans most of the Delta. In spring 2016, Chlorophyll *a* fluorescence data recorded at these stations, along with additional data from boat-based monitoring cruises, showed a substantial Delta-wide phytoplankton bloom that started in the rivers and the Yolo Bypass along the margins of the Delta in February and March. By May, the bloom had greatly intensified and spread throughout the central and western portions of the Delta. This talk is intended to provide an introduction to a special session about the 2016 Delta spring bloom. It gives an overview of the temporal and spatial dynamics of the Delta-wide spring 2016 bloom and potential drivers and compares them to blooms observed in other seasons and in previous years in the Delta and elsewhere. Results presented in this talk are intended to stimulate further discussions about phytoplankton research, monitoring, and management strategies in the Delta.

Keywords: phytoplankton, spring bloom, monitoring, management strategies
Session Title: Anatomy of the Spring 2016 Phytoplankton Bloom in the Delta
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 307

Field and Satellite Observations of the Spring 2016 Phytoplankton Bloom in the Northern San Francisco Estuary

Richard Dugdale, Romberg Tiburon Center, SFSU, rdugdale@sfsu.edu
Frances Wilkerson, Romberg Tiburon Center, SFSU, fwilkers@sfsu.edu
Curtiss Davis, Oregon State University, cdavis@coas.oregonstate.edu
Fei Chai, University of Maine, fchai@maine.edu
Qianqian Liu, University of Maine, qianqian.liu@maine.edu
Nick Tufillaro, Oregon State University, nbt@coas.oregonstate.edu

The magnitude, location and timing of phytoplankton blooms in the northern San Francisco Estuary are all highly variable and not easily predictable. In the decade of the 70's, chlorophyll levels of 70-80 μg/L occurred regularly in the Low Salinity Zone (LSZ), but summer blooms diminished about the end of the 1980's coincident with the establishment of an invasive bivalve, *Potamocorbula amurensis* and increased ammonium discharge to the Sacramento River. The question of which element is the main driver of reduced phytoplankton productivity in the LSZ is controversial and unresolved; however, spring blooms are observed in the LSZ despite the presence of clams. The spring bloom of 2016 provides an opportunity to investigate the processes leading to blooms in this ecosystem. Our NASA funded project on modeling and remote sensing of the Bay/Delta ecosystem had cruises in March and May, 2016; the latter occurred at the height of the bloom and occupied stations in the bloom region. The data set acquired included nutrients, chlorophyll, measurements of N and C uptake, a full suite of optical measurements in support of satellite observations, standard CTD casts and underway recorded data. High resolution satellites images confirm the widespread bloom occurrence.

Keywords: bloom, phytoplankton, nutrients, remote sensing
Session Title: Anatomy of the Spring 2016 Phytoplankton Bloom in the Delta
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 307

Nutrients, Phytoplankton and Zooplankton in the Lower Sacramento River and Deepwater Ship Channel, 2012-2016

Erwin Van Nieuwenhuyse, Bureau of Reclamation, evannieuwenhuyse@usbr.gov
Randy Dahlgren, University of California, Davis, radahlgren@ucdavis.edu

The lower Sacramento River and Deepwater Ship Channel (DWSC) occupy ~30% of the Sacramento-San Joaquin Delta's total volume and are important rearing areas for Delta Smelt (*Hypomesus transpacificus*), an endemic fish population listed as threatened under the federal Endangered Species Act. The two areas differ markedly in their hydrodynamic, water quality and ecological characteristics. This talk will present the results of monthly sampling cruises conducted during 2012-2016 with a primary focus on concentration and composition of nutrients, phytoplankton and zooplankton during spring. The findings of this study will be used to inform and provide a baseline for experiments focused on increasing the food supply of the North Delta.

Keywords: Delta food supply, lower trophic level production, phytoplankton, zooplankton, smelt
Session Title: Anatomy of the Spring 2016 Phytoplankton Bloom in the Delta
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 307

Spring Phytoplankton Bloom in the Delta Determined with Dissolved Oxygen Data

Hwaseong Jin, Delta Science Program, Delta Stewardship Council, hwaseong.jin@deltacouncil.ca.gov
Anke Mueller-Solger, USGS, amueller-solger@usgs.gov

Phytoplankton spring bloom develops when the right environmental conditions induce a strong algal growth. Such algal growth response has been monitored by assessing the chlorophyll a sensors throughout the Delta. Diel changes in dissolved oxygen (DO) at three water quality monitoring stations (FPT: Freeport; SDC: above the Cross Channel; and SDI: Decker Island) along the Sacramento River were analyzed to assess the progression of algal growth. At FPT, the daily average DO % saturation stayed relatively constant ranging from 90% to 95% until mid-February; increased to 99% by late February; decreased to 90% in mid-March apparently by the storms; regained to 95% quickly and stayed until mid-April; then reached to almost 100% by late-April; maintained, and sometimes exceeded the saturation until the late-May indicating very high algal growth (bloom). SDC had a DO trend similar to FPT; with the late-February to early March algal growth followed by a brief period of low growth after March storms, and a period of high DO % from mid-April to late May. At SDI, the early season (until late February) DO % saturation values (85% - 90%) were slightly lower than upstream locations; briefly increased to 95% in early March, followed by a brief low DO period (76% - 90%) until late March; and reached and maintained high DO % saturation sometimes exceeding 110% in May. The continuous DO measurement data was used to calculate the gross primary production (GPP) and community respiration (CR) with the open-system method. Preliminary estimates for the SDC location (5/20/2016) indicated the overall low productivity (GPP = 0.79 mg/L/day; CR = 0.93 mg/L/day) and a heterotrophic system (NDM = -0.37 mg/L/day). The use of DO data would help to understand the dynamics of unusual phenomena such as spring algal bloom and to estimate algal production in the Delta.

Keywords: phytoplankton, Dissolved oxygen, spring bloom, food web, monitoring, long-term, high-frequency
Session Title: Anatomy of the Spring 2016 Phytoplankton Bloom in the Delta
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 307

Views of the 2016 Spring Bloom from Multiple Spatial and Temporal Scales

Brian Bergamaschi, USGS, bbergama@usgs.gov
Wim Kimmerer, Romberg Tiburon Center for Environmental Studies-SFSU, kimmerer@sfsu.edu
Bryan Downing, USGS California Water Science Center, bdowning@usgs.gov
Toni Ignoffo, Romberg Tiburon Center for Environmental Studies-SFSU, tignoffo@sfsu.edu
Katy O'Donnell, USGS California Water Science Center, kodonnell@usgs.gov
Travis von Dessonneck, USGS California Water Science Center, tvondes@usgs.gov

While one of the drivers of the widespread pelagic organism decline in the Sacramento-San Joaquin Delta and San Francisco Estuary is thought to be declines in aquatic primary production, particularly in diatoms, the spring of 2016 saw a large diatom bloom with chlorophyll concentrations exceeding 80 µg/L extending from the Cache Slough complex to Suisun Bay, and up the San Joaquin River past Prisoner's Point. The bloom appeared to originate within the Cache Slough complex well after storm flows receded from the system, and then propagated southward through the mainstem of the lower Sacramento River and into the confluence area. It persisted for a period of approximately 3 weeks. After this time it declined to near ambient chlorophyll concentrations within a matter of days despite ample nutrients and no obvious change in hydrodynamics. We will present data regarding the conditions that led to the bloom, the types and concentrations of phytoplankton comprising the bloom, and the extent to which this bloom may have benefited zooplankton. We will explore the biogeochemical dynamics, physical dynamics, and nutrient concentrations that preceded and existed during the bloom, seeking to understand the conditions that led to formation of this large bloom and what led to its decline. These results will help identify management actions that may promote pelagic productivity within the Delta and estuary.

Keywords: Phytoplankton, diatoms, spring bloom, primary production, aquatic ecosystems, zooplankton
Session Title: Anatomy of the Spring 2016 Phytoplankton Bloom in the Delta
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 307

Lost in Translation: The Art of Interpreting Complex Science for Policymakers

Darcy Austin, Delta Science Program

This session will explore communicating complex science for decision-making by featuring discussions between authors of chapters in The State of Bay-Delta Science, 2016 and the policymakers grappling with decisions related to the authors' chapters.

Topics and Panelists

- **Threatened and Endangered Species:** *Jim Hobbs (UC Davis) & Paul Souza (USFWS)*
- **Contaminants**: *Richard Connon (UC Davis) & Adam Laputz (Central Valley Regional Water Quality Control Board)*
- **Delta Levees:** *Steve Deverel (Hydrofocus) & Dustin Jones (Delta Stewardship Council)*
- **Predation:** *Gary Grossman (University of Georgia) & Doreen D'Adamo (State Water Resources Control Board)*
- **Landscape Ecology and Integrative Science:** *Michael Healey (University of British Columbia) & Petrea Marchand (Consero Solutions/Yolo Habitat Conservancy)*

Communicating complex science to policy- and decision-makers is a critical step towards effective management of the Bay-Delta. One way to bridge the communication gap is by utilizing a strategy that allows for communication to multiple audiences (scientists, the governor, legislature, policymakers, managers, regulators, and the public). *The State of Bay-Delta Science* (*SBDS*) is a synthesis of current scientific understanding of the Bay-Delta, emphasizing progress made on key research questions and remaining knowledge gaps. *SBDS* also explores policy implications of current science and ways to improve the delivery of science for management. The *SBDS 2016* Summary for Policymakers further distills and translates key science topics, with a focus on why these topics matter.

To explore how to make science useful as well as usable, this special session will feature a 'talk show' format panel discussion between authors chapters in the *State of Bay-Delta Science, 2016* (first volume can be found at: http://escholarship.org/uc/jmie_sfews?volume=14;issue=2) and the policymakers/decision-makers/regulators/or grappling with decisions related to chapter topics. Each topic area will include a discussion framed around translating complex science and could involve discussions about how "management concerns" get translated into scientific questions, how "scientific results" get translated into policy/management/regulation, whether policymakers ask answerable questions and whether scientists express the science in meaningful ways. The discussion also will explore how authors decided what to cover in their chapter and what the policymakers need next. We expect that this set of conversations will demonstrate why it's often difficult to bridge the gap between science and policy, which highlights the need for translating science in multiple ways.

Keywords: The State of Bay-Delta Science, SBDS, Science Communication
Session Title: Lost in Translation: the art of interpreting complex science for policymakers
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 307

Does Life History Diversity Provide Population Resilience in Delta Smelt?

James Hobbs, UC Davis, jahobbs@ucdavis.edu
Eva Bush, UC Davis, eebush@ucdavis.edu
Malte Willmes, UC Davis, mwillmes@ucdavis.edu

Problem Statement: The Delta Smelt (*Hypomesus transpacifics*) population has collapsed and may be approaching extinction. The resilience of the population appears to be dissipating as wetter years no longer provide the same degree of population "bounce-back". Delta Smelt exhibit a life history strategy termed partial migration, where the population consists of resident and migratory life history types. Thus attempts to understand the population dynamics in the low-salinity zone have largely ignored freshwater habitat and the smelt that reside in freshwater year-round.

Approach: In this study we evaluated the role partial migration provides to both population stability and population resilience using otolith strontium isotope ratios to determine the contribution of each life history type to the adult abundance.

Results: The migratory life history type comprised the majority of the population, although in some years the freshwater contingent comprised up to 40% of the adult population.

Conclusions: Unlike other species which exhibit partial migration, the migratory contingent provided population stability, while the freshwater contingent and brackish water contingents supported population resilience.

Keywords: Delta Smelt, Population Resilience, Population Stability, Partial Migration, Life History
Session Title: Delta Smelt
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 307

Linking Temporal and Spatial Data Sets for Hierarchical Bayesian Network Analysis and Prediction of Delta Smelt Populations

William (BJ) Miller, None, bjmiller41@gmail.com
Robert Oliver, University of California at Berkeley, rmo@berkeley.edu

Abundance of delta smelt dropped by two orders of magnitude in this century. Studies with regression-based, life-cycle models have produced no generally accepted conclusions about the relative importance of different factors contributing to the decline. The prevailing conclusion of multiple causal factors provides little guidance on the choice and consequences of corrective actions. Bayesian Network methods, widely used elsewhere, may be useful in designing prediction/decision models for delta smelt. These methods are based on a conceptual model consisting of influence diagrams representing a hierarchical structure of interdependent factors.

Ideally, prediction methods are based on synchronous data, that is, data collected at the same time and place for the response variable (delta smelt abundance or density, in this case) and the factors thought to influence that variable. Unfortunately, routine Bay-Delta surveys do not produce such data. Several surveys sample for delta smelt and a few other factors influencing delta smelt. Other surveys sample the density of predaceous fish or shrimp, another the densities of delta smelt prey, and yet others the nutrients that affect delta smelt's food web. None of these surveys have the same sample locations and times, yet all produce useful information that cannot be ignored. Omitting an important factor because its data are non-synchronous runs the risk of attributing that variable's effects to an unimportant, included factor. This presentation presents one method for dealing with this problem of non-synchronous data.

The purpose of this presentation is to describe a method for "laminating" data from various surveys to produce data sets that approximate the synchronous ideal. This method would improve analyses directed at causal factors for many Bay-Delta ecosystem problems. Results of analyses of such data sets are applied to the prediction of delta smelt populations and are reported in a companion presentation by Oliver and Miller.

Keywords: merging data sets, data preparation, population dynamics, non-synchronous sampling
Session Title: Delta Smelt
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 307

Predicting the Presence/Absence of Juvenile Smelt in the Bay Delta

Robert Oliver, University of California at Berkeley, rmo@Berkeley.edu
William Miller, Consulting Engineer, bjmiller41@gmail.com

The author provides several Decision Analysis models for predicting time-dependent presence/absence of larval-juvenile delta smelt at 20 mm Survey stations within distinct sub-regions or zones in the Bay Delta. The models include seasonal influences such as temperature, month, previous year FMWT adult populations, Sacramento river flows, as well as prey, predators, ammonia concentrations, N/P ratios, and, in a well-defined pumping influence Zone (PI), the flows in Old and Middle rivers. A hierarchical Bayesian Network approach, heretofore unused in this or similar Bay-Delta problems, is based on the influences of predator/prey/river flows/sewage/nutrients and data collected during 1995-2009. These data, collected from several surveys, were laminated into a single data set that mimics temporally and spatially synchronous sampling at each 20 mm survey station. The authors develop a log-odds Bayesian factor or conditional score model that de-seasonalizes survey records and extracts meaningful signals from noisy data. By defining non-overlapping zones within the Delta, one can (1) predict seasonal time-dependent probabilities of presence/absence of delta smelt at individual survey stations, (2) identify and separate seasonal influences that mask influence of important nutrients, habitat factors and water exports, (3) conclude that pumping/export policies are modestly informative within the PI Zone, but (4) appear irrelevant to the prediction of delta smelt populations at all other stations in non-PI zones. Measures of performance and fit, Divergence, ROC curves, Gini Coefficients and Posterior Likelihoods are described and summarized. Results of these admittedly preliminary analyses suggest that management of Bay Delta water exports has little influence on the growth or decay of smelt populations and that much more attention must be given to management and control of water quality, nutrients and invasive predatory species. The models and methods of analysis may be useful in application to other Bay-Delta prediction and decision problems.

Keywords: Juvenile Smelt, Prediction, Scoring; Hierarchical Bayesian Models; Seasonal Factors
Session Title: Delta Smelt
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 307

A Life Cycle Model and Population Viability Analysis for Wild Delta Smelt

Leo Polansky, None, leo_polansky@fws.gov
Ken Newman, U.S. Fish and Wildlife Service, ken_newman@fws.gov
Lara Mitchell, U.S. Fish and Wildlife Service, lara_mitchell@fws.gov
William Smith, U.S. Fish and Wildlife Service, william_e_smith@fws.gov

Delta smelt (*Hypomesus transpacificus*) are a native and endangered fish residing in the interior San Francisco Bay-Delta. Despite intensive study and management actions aimed at their protection and recovery, delta smelt abundances continue to decline. This is due in part to difficulties in studying their reproduction and survival in the wild. Past and proposed management actions to protect and recover delta smelt include manipulating interior Delta flow regimes, but the effectiveness of such actions remains a topic of scientific debate. To quantify the effects of flows, habitat volume, and food on delta smelt population dynamics, we first built a life cycle model that described recruitment and life-stage specific survival as functions of salient covariates. Life stages consisted of larva, juvenile, sub-adult, and adult. The resulting nonlinear, non-Gaussian state-space model was fit in a Bayesian framework using estimates of life-stage specific abundances, derived from long term monitoring survey data collected between 1995-2015. General findings were consistent with qualitative understanding: recruitment was enhanced when water temperatures were optimal, while increases in flow and habitat volume had positive effects on survival of other life stages. The fitted model served as the basis for a population viability analysis, in which we studied population growth rates and the risk of extinction across a range of time horizon, flow, and habitat volume scenarios. These results provide quantitative information on mechanisms driving delta smelt population dynamics and chances for survival, and it is hoped that such quantitative conservation biology can make more precise the comprehensive qualitative understanding about this species.

Keywords: Delta smelt; life cycle model; population viability analysis; state-space model
Session Title: Delta Smelt
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 307

A Delta Smelt Life Cycle Model: Separating Entrainment from other Sources of Mortality

William Smith, US Fish and Wildlife Service, William_e_smith@fws.gov
Lara Mitchell, US Fish and Wildlife Service, lara_mitchell@fws.gov
Ken Newman, US Fish and Wildlife Service, ken_newman@fws.gov
Leo Polansky, US Fish and Wildlife Service, leopolansky@gmail.com

Management of the Sacramento-San Joaquin River's endangered delta smelt population is limited by the lack of a unified quantitative framework with which to explore consequences of potential water and environmental management actions. The Delta Smelt Life Cycle Model (LCM) is an effort by the United States Fish and Wildlife Service to assess present and past delta smelt population status, quantify drivers of population dynamics, and find long-term, resilient solutions to conserve delta smelt in the Bay-Delta. As a critical nexus between water users and environmental managers, water operations and entrainment in the South Delta and their effects on endangered species are of primary conservation interest; however, the per capita risk of delta smelt entrainment and the factors associated with higher risk have not been quantified. The LCM quantified the relative effects of water operations on delta smelt abundance patterns by incorporating Central Valley and State Water Project salvage data as an index of direct entrainment and treating direct entrainment and other sources of mortality as competing risks. Incorporation of salvage data mirrored the treatment of fishery catch in fishery stock assessment models. Twenty Millimeter, Fall Midwater Trawl, and Spring Kodiak Trawl Surveys were used to estimate juvenile, subadult, and adult abundances, and environmental, trophic, and water operations covariates were used to estimate annual variation in survival and reproduction. Merits of this approach were the separation of direct entrainment from other sources of mortality and the derivation of salvage observation probability as a function of mortality rates; however, strong assumptions regarding the ratio of salvage to entrainment and the average of other sources of mortality were required.

Keywords: Delta smelt, population dynamics, entrainment, stock assessment, state-space model
Session Title: Delta Smelt
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 307

Juvenile Chinook Salmon: A Need for Population-Specific Bioenergetics Models?

Steve Blumenshine, Fresno State University, sblumens@csufresno.edu
Taylor Spaulding, Fresno State University, taylor.j.spaulding@gmail.com

Growth of juvenile salmonids is a critical variable affecting survival and recruitment to successive life history stages, essentially affecting the strength of subsequent cohorts. Consumption and temperature are key variables affecting growth for fishes in general. Temperature dictates the metabolic efficiency of prey conversion to production, and is thus a primary variable affecting growth. However, temperature optima and thresholds are variable for Pacific salmon populations. Yet many researchers using bioenergetic approaches to understand growth use temperature-dependent equations and coefficients for Chinook Salmon published in Steward & Ibarra (1991), which is based on adults from Lake Michigan, and uses coefficients from other salmonid species. To address this problem, we are using an approach using several lines of evidence to better understand relationships between temperature and growth. We focus this effort on juvenile Chinook Salmon used in the San Joaquin River Restoration Program, which seeks to restore the southern-most run in North America. Our approach includes a meta-analysis of growth rate and temperature relationships for wild populations, simulations with inSTREAM and bioenergetics models, and hatchery data sets. Results from these multiple lines of evidence suggest that juvenile Chinook Salmon growth rates in southern rivers are quite robust, despite the degraded conditions of these ecosystems. Our broader main objectives are to generate population and habitat specific bioenergetics algorithms and encourage a broader use of population-specific relationships of temperature and growth rate. A focus on these approaches can help fisheries managers set realistic expectations for restoration projects.

Keywords: Juvenile Chinook Salmon, Bioenergetics, Restoration, Fish Growth Rates
Session Title: Modeling Fish Populations
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 307

The Central Valley Spring-Run Chinook Life Cycle Model: A Tool to Manage the Recovery of Threatened Salmon Populations

Flora Cordoleani, UC Santa Cruz - NOAA Fisheries, Southwest Fisheries Science Center, flora.cordoleani@noaa.gov
Noble Hendrix, CEQA Consulting LLC, noblehendrix@gmail.com
Eric Danner, NOAA Fisheries - Southwest Fisheries Science Center, eric.danner@noaa.gov
Steve Lindley, NOAA Fisheries - Southwest Fisheries Science Center, steve.lindley@noaa.gov

Spring-run Chinook salmons were once a major component of the Central Valley Chinook stock, with annual catches of over a half million fish in the 1880's. Today, wild populations of spring-run Chinook thought to be self-sustaining survive only in three tributaries of the Sacramento River: Mill, Deer and Butte Creeks (Lindley *et al.*, 2007; Yoshiyama *et al.*, 1998). Since 1999 Central Valley spring-run Chinook salmon are state and federally listed as a threatened species. In order to better manage these stocks for future recovery, understanding their life history strategies is necessary in gaining insight into where and how these fish are facing adversity.

We developed a life cycle model describing the dynamics of these populations at different life stages throughout a range of various rearing, feeding and spawning habitats. This model includes management variables (e.g. flow, water temperature, fishery harvest rates) in both the aquatic and marine stages of the life cycle in order to assess their impact on the survival, movement and rearing strategies. For instance, water flow in the spawning habitat is shown to strongly influence the timing and proportion of fry dispersing from natal reaches to downstream habitats soon after their emergence. Moreover, results from an acoustic tagging study performed recently on spring-run smolts are used in the model to inform the survival of spring-run juveniles migrating to the Ocean and the factors affecting this survival. We will present the model predictions obtained for different water management and climate change scenarios and discuss the implications for Central Valley spring-run Chinook salmon recovery.

Keywords: life cycle model, spring-run Chinook salmon, population management
Session Title: Modeling Fish Populations
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 307

Life-cycle Models for Evaluating the effects of Hydromanagement on Chinook Salmon in the Central Valley

Noble Hendrix, QEDA Consulting, LLC, noblehendrix@gmail.com
Eva Jennings, Cheva Consulting, LLC, itseva@gmail.com
Anne Criss, NMFS Southwest Fisheries Science Center, anne.criss@noaa.gov
Andrew Pike, NMFS Southwest Fisheries Science Center, andrew.pike@noaa.gov
Correigh Greene, NMFS Northwest Fisheries Science Center, correigh.greene@noaa.gov
Vamsi Sridharan, NMFS Southwest Fisheries Science Center, vamsi.sridharan@noaa.gov
Steve Lindley, NMFS Southwest Fisheries Science Center, steve.lindley@noaa.gov

Balancing competing desires for fisheries, flood control, water supply and other ecosystem goods and services is a durable natural resource management challenge. The ongoing efforts to develop and approve new water project operating plans and WaterFix require models to evaluate how complex and interacting management actions affect salmon populations. Our general approach is to link existing physical (e.g., HEC-RAS) and biological models (e.g., enhanced Particle Tracking Model) to a stage-structured life-cycle model through stage-transition coefficients. In the model described here, we consider both developmental stage and geographic location (upper river, lower river, yolo, delta, bay, ocean) to define the state (e.g., fry in the upper mainstem river). Transitions among states then reflect survival, reproduction and movement among habitat areas at a monthly time step. Calibration is difficult due to the management focus of the model and the limited life-stage and geographic observations of abundance. Calibration of the model can occur through manual "tweaking" of coefficients or alternatively through statistical fitting of the model to the observations. We performed maximum likelihood estimation via numerical optimization to obtain coefficients of the transition functions in the life-cycle model that maximized the similarity of model predictions and observed data. For the winter-run life-cycle model, we used hatchery and natural origin escapement, juvenile abundance at Red Bluff Diversion Dam, catches of winter-run sized fish at Knights Landing, and abundance at Chipps Island. We found that average monthly temperatures above approximately 13.5 C during spawning had negative impacts in egg to fry survival; Wilkins Slough flow triggered movement past Knights Landing; export and flow effects were captured in ePTM survival; and different patterns of river, yolo, and delta habitat use under historical conditions. Furthermore, the calibration provided coefficients for running the life-cycle model prospectively to evaluate management actions such as restoration and hydrologic diversions under WaterFix.

Keywords: winter-run, hydromanagement, life-cycle model, calibration, estimation, WaterFix, scenario, decision analysis
Session Title: Modeling Fish Populations
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 307

Quantifying Uncertainty in Estimates of Juvenile Salmoinid Loss at the Central Valley and State Water Projects

Josie Simonis, Cramer Fish Sciences, josie.simonis@fishsciences.net
Steven Zeug, Cramer Fish Sciences, stevez@fishsciences.net
Kai Ross, Cramer Fish Sciences, Kai.ross@fishsciences.net

Mortality of juvenile salmonids at the Central Valley Project (CVP) and State Water Project (SWP) has been hypothesized to negatively impact special status populations. Both the CVP and SWP contain facilities that salvage entrained fishes and return them to the delta. However, mortality occurs in the diversion facilities and during the salvage process. This mortality is referred to collectively as "loss". In the National Marine Fisheries Service 2009 biological opinion on the long term operation of the CVP and SWP, loss per volume of water diverted was used as the metric to trigger actions in the Reasonable and Prudent Alternative. However, data are only collected on fish salvaged, not fish lost. Multiple reviews of the current method of calculating loss from salvage have been strongly critical of assumptions and methods, pointing out that they do not accurately represent the process of loss, cannot estimate loss when salvage is zero, and cannot properly incorporate the uncertainty in model parameters. We developed a Partially Observed Markov Process (POMP) model for estimating loss that addresses these issues and provides a flexible framework for estimation at both facilities. Using the POMP model and sound statistical inference we can estimate entrainment, loss, and salvage at time scales relevant for management decisions (*i.e.*, daily, annually), including the probability that triggers have been reached. Model results indicate that there is high uncertainty in loss estimates at both facilities. Uncertainty in model parameters estimated from experiments, and the lack of empirical entrainment estimates entirely, often accounts for over 50% of the variance in loss estimates. These results suggest that experiments designed specifically to inform loss estimates are needed and that operational decisions are currently based on highly uncertain loss estimates. The effectiveness of using of triggers to define operations should be reevaluated in light of these findings.

Keywords: diversion, entrainment, salmon, model, loss
Session Title: Modeling Fish Populations
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 307

A Road Map for Designing and Implementing a Biological Monitoring Program

Ken Newman, USFWS, ken_newman@fws.gov
Joel Reynolds, USFWS, joel_reynolds@fws.gov
Melinda Knutson, USFWS, melinda_knutson@fws.gov
Emily Silverman, USFWS, emily_silverman@fws.gov
William Thompson, USFWS, bill_thompson@fws.gov

Biological monitoring programs, such as status and trends monitoring, are commonplace in most natural resource agencies and can be a large fraction of management costs. However, the relevance and importance of the resulting data to resource management is sometimes questionable. In the worst case data are collected but never analyzed or used, and in other cases the data are inadequate due to biased collection procedures or failure to collect the right kind of data., Clarity is needed before a monitoring program is initiated to determine whether or not monitoring is in fact needed, and if it is needed, clarity is needed about exactly what data should be collected, how it should be collected, and how it should be used to assist with management decision making. To facilitate such clarity and to increase the value of biological monitoring programs, we have developed a how-to-monitor guide, a "Road Map" for monitoring. The Road Map has 10 steps of which only one step involves actual data collection. Other steps include components of structured decision making, sampling and monitoring designs, data analysis and modeling, and connecting analysis results to management decision making. The utility of the Road Map will be illustrated in application to the development of a monitoring program focused on entrainment of Delta Smelt.

Keywords: Sampling, Monitoring, Structured Decision Making, Adaptive Management
Session Title: Modeling Fish Populations
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 307

Effectiveness Monitoring of Tidal Restoration Projects

Ramona Swenson, ESA, RSwenson@esassoc.com
Robert Capriola, Westervelt Ecological Services, rcapriola@westervelt.com

The stakes are high for restoration in Suisun Marsh due to limited sites, costs, and ecological uncertainties. The State and Federal Contractors Water Agency's (SFCWA) Tule Red Tidal Restoration Project will restore 420 acres of tidal wetlands to meet OCAP Biological Opinion requirements. The Adaptive Management and Monitoring Plan (AMMP) is an objective-based framework designed to meet multiple purposes: verify permit compliance, document habitat credits, measure effectiveness/progress toward objectives, reduce key uncertainties, detect triggers for management, and improve overall restoration practices. Effectiveness monitoring focused on metrics linked to objectives: food web enhancement for delta smelt/longfin smelt, rearing for juvenile salmonids, brackish aquatic-tidal marsh-upland habitat for native species, and elevation gradients for habitat succession. We framed hypotheses about channel inlet and tidal regime, elevations and hydrology related to *Phragmites* colonization, vegetation establishment on the habitat berm, and residence time and productivity in the marsh ponds and pannes. Physical outputs (acres, topography, tidal inundation) and habitat structure (wetland vegetation) will be easier to measure than ecological outcomes (food web productivity and export, habitat use by fish). Fish sampling cannot be conducted without permits. Special studies are recommended for uncertainties (methyl mercury, nutrient flux) that require greater expertise and investment than basic monitoring. Metrics and methodologies were informed by regional IEP methods and other projects. The AMMP included triggers and responses for selected management issues, such as invasive weeds, obstruction of the channel inlet, low dissolved oxygen in discharge. Identifying roles and responsibilities between the property owners (SFCWA, then CDFW) and regional sampling and studies (UC Davis, DWR, IEP) can identify gaps and help ensure coordinated sampling. This AMMP is relevant for Delta restoration as a template for monitoring and adaptive management. As more projects come online, it will be important to coordinate monitoring and studies to maximize opportunities for learning and efficiency.

Keywords: Monitoring Plan Wetlands Food Web Fish Permit Requirement Aquatic
Session Title: Challenges in Meeting the Tidal Restoration Objectives of the Suisun Marsh
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 308-310

Designing Tidal Restoration Projects for Physical Processes

Brian Wardman, Northwest Hydraulic Consultants, bwardman@nhcweb.com
Brad Hall, Northwest Hydraulic Consultants, bhall@nhcweb.com

Tidal restoration design focuses on restoring natural processes vital for healthy and sustainable marsh habitats while balancing other regulatory and constructability design constraints. Tidal exchange is the driving process that creates and sustains tidal wetlands. Key elements of tidal exchange include inundation, sedimentation processes, and exchange of nutrients. Restoring the tidal exchange process promotes growth of marsh vegetation, allowing food web and ecological processes to occur. Elements which may inhibit these processes from occurring include undersized channels which mute tidal exchange, poor channel layout limiting sediment delivery and nutrient exchange to the entire marsh, invasive marsh vegetation which inhibits natural channel development, lack of suspended sediments, and other factors. The restoration design must understand these constraints and address them during the design. Functional design components required to satisfy species specific project objectives or regulatory requirements can then be incorporated into the design around the process based design components. Constructed channels and project features must be significant enough to restart natural processes, but limited enough to avoid unnecessary project impacts and be constructible. This presentation provides a case study discussing the design process of the Tule Red Tidal Restoration Site in Grizzly Bay. The approximate 400-acre managed marsh is composed of recently deposited sediments with dense stands of *Phragmites*. The proposed project includes excavation of over 7.5 miles of marsh channels reconnecting the marsh to Grizzly Bay including low order channels to enhance marsh connectivity and geomorphic progression. Functional design concepts were included to address objectives in the Suisun Marsh Plan as well as meet species specific design objectives. The design is currently being implemented.

Keywords: Tidal Restoration, Hydraulic Channel Morphology, Sea Level Rise, Shear Stress
Session Title: Challenges in Meeting the Tidal Restoration Objectives of the Suisun Marsh
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 308-310

Tidal Restoration in the Suisun Marsh and Conflicting Regulatory Requirements and Permits

Robert Capriola, Senior Conservation Planner, Westervelt Ecological Services, rcapriola@westervelt.com
Priya Finnemore, ESA, pfinnemore@esassoc.com

Problem Statement: A large number of regulatory agency approvals are needed for tidal restoration projects in the Suisun Marsh, and each agency has legal and policy requirements that often put those requirements in conflict with other agencies. Resolving these often unanticipated conflicts adds time to project approval and takes careful negotiation. Resulting long timelines for permit approval of tidal restoration projects increases cost and uncertainty when initiating projects for development.

Approach: The Tule Red Tidal Restoration Project began its planning and design phase in 2012 with a suite of resource agencies. Sufficient basis of design detail was developed by the spring of 2015 to initiate environmental review and permitting. Careful study of existing permits and approvals for other relevant projects provided a baseline of potential permit conditions. Early consultation with agencies will also give project proponents information on permit requirements, relevant interdependencies of other approvals, and timelines for approvals.

Results: Once permit applications and environmental documents were submitted, several conflicting requirements became apparent. Requirements for creation of a "habitat levee" to provide transitional habitat between wetlands and uplands for salt marsh harvest mouse converted wetlands to uplands, putting the project in conflict with California's no-net-loss wetland policy. One agency's guidance requires development of maximum feasible public access under any permit given for a shoreline project which is in conflict with the conservation easement required by a different agency.

Conclusion/Relevance: Within the Suisun Marsh and elsewhere in the Delta, tidal restoration projects would benefit from programmatic solutions to resource conflicts like the ones experienced in development of this project. Creating a "Regional Permit" that would apply to all tidal restoration projects meeting the goals of the Suisun Marsh Plan would be an economical and time-saving alternative to project-by-project permitting, often costing hundreds of thousands of dollars per project.

Keywords: Suisun Marsh Tidal Restoration Salt Marsh Harvest Mouse Permitting
Session Title: Challenges in Meeting the Tidal Restoration Objectives of the Suisun Marsh
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Problems and Promise of Restoring Tidal Marsh to Benefit Native Fishes in the North Delta during Drought and Flood

John Durand, UC Davis, jrdurand@ucdavis.edu

Implementing aquatic restoration projects that scale appropriately with seasonal flows, tidal energy, and food production remains a challenge in the highly disturbed Sacramento-San Joaquin Delta and Suisun Bay. Many restoration projects may achieve aesthetically pleasing results that will offer some benefits to recreationists, terrestrial animals and plants, without improving aquatic habitat for native fishes. Much of the disparity in benefits derives from the limited access that aquatic organisms have to the terrestrial environment. However, the historical Delta had a landscape that was much more integrated than today. Extensive wetlands merged with riparian corridors and shallow water habitats. Unfortunately, wetland restoration is unlikely to resume historical functions without structural modifications to increase integration between habitats. In addition, the elevation and structure of restoration sites must be calibrated to match tidal or flow action. Such restorations may feature mixed residence times of water and plankton, dendritic shallow channel networks that provide limited access during certain tides, and dispersed predation and foraging opportunities. I will examine a few existing and proposed restoration sites, evaluate their design, and determine how well they will support the stated aims or the project, and provide alternatives or design modifications that could improve function. Finally, I will discuss how configurable restoration projects can help build credibility in restoration success and support the implementation of adaptive management to hone desirable outcomes.

Keywords: restoration, tidal marsh, native fishes, landscapes, historical Delta, food production
Session Title: Challenges in Meeting the Tidal Restoration Objectives of the Suisun Marsh
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Tidal Restoration in the Suisun Marsh and Mitigating the Impacts to Waterfowl

Cliff Feldheim, California Department of Water Resources, Suisun Marsh Program, Cliff.Feldheim@water.ca.gov

Problem Statement: The Suisun Marsh (Marsh) has long been recognized for its importance to waterfowl throughout the Pacific Flyway. In 1974, the Legislature passed the Suisun Marsh Preservation Act which declared the need for the preservation of waterfowl carrying capacity in the Marsh. In general, tidal restoration in the Marsh will result in the loss of high quality waterfowl habitat. The Suisun Marsh Plan proposes to mitigate the impacts from tidal restoration on waterfowl by improving the carrying capacity of the remaining waterfowl habitat (as much as 45,000 acres of habitat enhancement). However, there is only limited data on what different waterfowl species eat during the winter and how they use habitats in the Marsh, so what habitat enhancement means in practice remains equivocal.

Approach: The Suisun Marsh Waterfowl and Managed Wetlands Research Program was established in 2014 to understand waterfowl habitat use and foraging ecology in the Marsh. We have begun implementation of a multi-year gps telemetry study on up to 13 species of wintering waterfowl and 2 species of breeding waterfowl that use the Marsh and San Francisco Bay Estuary.

Results: We have deployed more than 100 gps transmitters on a total of 7 species of waterfowl. To date, more than 600,000 data points have been collected.

Conclusion/Relevance: Since the 1974 Suisun Marsh Preservation Act, 4 species of wintering waterfowl have shown significant population declines in the Marsh, Northern Pintail (83%), Cinnamon Teal (82%), Mallard (68%), and Scaup (24 %). Our work demonstrates the many complexities surrounding developing appropriate waterfowl habitat enhancement including the need to understand factors limiting breeding waterfowl in the Marsh, factors limiting waterfowl populations during migration or on breeding grounds outside of California, as well as, the need to understand specific foods important to breeding and wintering waterfowl in the Marsh.

Keywords: Suisun Marsh, Adaptive Management, Waterfowl, Tidal Restoration, Radio Telemetry
Session Title: Challenges in Meeting the Tidal Restoration Objectives of the Suisun Marsh
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Describing Invertebrate Diversity Across Wetland Habitat Types

Rosemary Hartman, CDFW, Rosemary.Hartman@wildlife.ca.gov
Alison Furler, CDFW, Alison.Furler@wildlife.ca.gov
Bonnie Wang, CDFW, Bonnie.Wang@wildlife.ca.gov

In the spring of 2016, the Fish Restoration Program (FRP) Monitoring Team sampled macroinvertebrates using a variety of methods to characterize production of fish food resources in tidal wetlands. Sampling occurred in several subregions of the Cache Slough Complex that contained multiple habitat types associated with tidal wetlands. After we identified all invertebrates, we ran non-metric multidimensional scaling which showed differences in community composition between habitat types and between subregions. In some cases, there were also differences between sampler type within a given habitat. Fish dietary diversity and resilience may be enhanced by including multiple habitat types in construction of restoration sites and distributing restoration sites across multiple regions. However, to assess actual benefits, the effect of habitat diversity must be monitored as restoration sites develop. Samplers with the highest catch of invertebrates appearing in listed fish diets will be included in long-term monitoring of FRP tidal wetland restoration sites. We will continue to test the methods we piloted in this study to see if observed patterns in invertebrate diversity continue as restoration progresses in different areas of the of the Sacramento San-Joaquin Delta.

Keywords: invertebrates; wetlands; sampling methods; benthics; vegetation; diversity; restoration; insects
Session Title: Tidal Wetlands Ecology
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 308-310

A High Frequency Solution to Understanding Tidal Wetlands as Fish Habitat

David Ayers, USGS, dayers@usgs.gov
Collin Smith, USGS, cdsmith@usgs.gov
Paul Stumpner, USGS, pstump@usgs.gov
Fred Feyrer, USGS, ffeyrer@usgs.gov

Major tidal wetland habitat restoration efforts are planned to benefit Delta Smelt and other imperiled species in the Sacramento-San-Joaquin Delta. However, successful implementation of habitat restoration is constrained by a paucity of information on the function and services tidal wetlands provide for fishes. Because of their complicated physical structure and dynamic nature, sampling fishes in tidal wetland habitats is especially challenging. The dynamic nature of tidally influenced habitats requires high frequency data collection in order to accurately depict changing environmental conditions. Similarly, evaluation of fish utilization of tidal wetlands habitat should occur on a commensurate frequency. In this study, physical measurements of wetland environments were collected using continuous flow and water quality monitors. Using acoustic cameras, continuous fish sampling at the entrance to the tidal wetland habitat also occurred simultaneously in an effort to understanding physical-biological coupling mechanisms. The interdisciplinary work presented here is aimed at determining the influence of tidal phase, diel period, lunar cycle, and other relevant factors driving fish movement and habitat use in tidal wetlands. This results of this work will contribute to the knowledge required to implement successful habitat restoration projects.

Keywords: tidal wetland, fish behavior, acoustic camera, high frequency data, continuous
Session Title: Tidal Wetlands Ecology
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 308-310

Ecology of Non-Native Clams and Jellyfish in Suisun Marsh

John Durand, UC Davis, jrdurand@ucdavis.edu
Denise DeCarion, UC Davis, dpdecarion@ucdavis.edu
Nicole Aha, UC Davis, nmarieaha@gmail.com
Teejay O'Rear, UC Davis, taorear@ucdavis.edu
Peter Moyle, UC Davis, pbmoyle@ucdavis.edu
Jason Baumsteiger, UC Davis, jbaumsteiger@ucdavis.edu

Suisun Marsh is important habitat for many native and desirable non-native fishes, and is currently slated for large-scale tidal restoration. However, the marsh is also inhabited by several non-native invertebrates that consume copious phytoplankton and zooplankton, possibly reducing food abundance for imperiled pelagic fishes to which restoration is primarily targeted. Thus understanding factors influencing distribution and abundance of these potentially harmful invertebrates informs restoration design. We used several methods - long-term trawling data, benthic dredges, zooplankton tows - to assess distribution and abundance of three jellyfish species and overbite clam, and then related catches to a suite of environmental variables. In the case of the jellyfish, particularly large-bodied Black Sea jellyfish, warm water and moderate salinities were associated with the largest medusae blooms. For overbite clam, salinity was the most important variable, with saltier years finding clams pushing deeper into Suisun Marsh's interior. However, overbite clam were notably rare in smaller sloughs whether diked or undiked, suggesting softer substrates or limited hydrologic connectivity inhibited recruitment. Because warm, saltier water was generally associated with greater abundances of these non-native invertebrates, then climate-change effects will likely increase the populations of these clams and jellyfish in Suisun Marsh, suggesting future restoration should focus more strongly on limiting hydrologic connectivity, providing fresh water, and promoting softer substrates.

Keywords: Suisun Marsh, restoration, non-native clams, jellyfish
Session Title: Tidal Wetlands Ecology
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 308-310

The Influence of Climate on Vegetation Change Over 15 years at China Camp and Muzzi Marsh

Dylan Chapple*, UC Berkeley, dylanchapple@berkeley.edu
Adina Merenlender, UC Berkeley, adinam@berkeley.edu
Phyllis Faber, Independent Consultant, pmfaber@comcast.net

Understanding temporal trends in plant community composition is an important aspect of interpreting community dynamics and restoration outcomes. Here, we explore the influence of SF Bay salinity and time on plant community trends. From 1990 to 2005, vegetation data was collected along transects at a restoration site (Muzzi Marsh) and a reference site (China Camp) in Marin County, CA. Looking at community change over time using Bray-Curtis similarity metrics, community change was significantly related to SF Bay salinity at China Camp, but not at Muzzi Marsh. Emerging from the drought of the late 1980's and early 1990's, species richness at China Camp was low and began to increase following above average rainfall during the 1994-1995 rain year. These trends were largely driven by the increase in sub-dominant, high marsh species. Community change at Muzzi Marsh was related to time, with sub-dominant species appearing following low salinity conditions in 1994-1995 and increasing steadily through 2005. Overall plant community change at Muzzi Marsh was related to both sub-dominant species and shifts in the co-dominants *Salicornia pacifica* and *Spartina foliosa*. Using Detrended Canonical Analysis to explore these trends, change at Muzzi Marsh followed a directional pattern related to the restoration process while change at China Camp appears to follow a stochastic pattern related to climate. These results highlight the need to consider temporal trends at both reference and restoration sites to understand the dynamic nature of vegetation development. In high variability systems like the SF Bay climate plays an important role in structuring communities and determining restoration trajectories, so funding for long-term project monitoring should be implemented to aid management efforts.

Keywords: Restoration, Drought, El Nino, Plant Community, Climate, Adaptive Management
Session Title: Tidal Wetlands Ecology
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Species-specific Plant Responses to Salinity and Inundation in Tidal Wetlands of the San Francisco Bay-Delta Ecosystem

Christopher Janousek, Oregon State University, janousec@onid.oregonstate.edu
Kevin Buffington, Oregon State University, kevin.buffington@oregonstate.edu
Karen Thorne, U.S. Geological Survey, kthorne@usgs.gov
Bruce Dugger, Oregon State University, bruce.dugger@oregonstate.edu
John Takekawa, U.S. Geological Survey, john_takekawa@usgs.gov
Glenn Guntenspergen, U.S. Geological Survey, glenn_guntenspergen@usgs.gov

Anticipated climate change impacts to estuaries include sea-level rise and increasing salinity, factors which may alter wetland plant community structure and function. To better understand how climate change will shape future wetland ecosystems, it is necessary to assess how individual species vary in their functional responses to important climate drivers. To help address these data gaps for tidal marshes in the San Francisco Bay-Delta ecosystem, we are conducting field and laboratory experiments to quantify the effects of tidal inundation and salinity on plant productivity, fecundity, and litter decomposition. Using field mesocosms at Petaluma marsh over a range of tidal inundation conditions, we found different growth responses in major plant species to inundation. The common perennial forb, *Salicornia pacifica,* lost substantial biomass at moderate and elevated levels of flooding, suggesting its greater sensitivity to relative sea-level rise. We are currently assessing inundation and salinity effects on *Juncus balticus*, a high marsh species common in fresher Bay area wetlands. Using complementary greenhouse experiments, we are also determining species-level differences in growth and fecundity with elevated salinity using common species from Suisun marsh. Initial studies of decomposition of plant litter at Petaluma marsh showed that decomposition rates were largely unaffected by variation in tidal flooding, but did differ by species. On-going field and greenhouse studies are addressing salinity and plant root density effects on decomposition. Collectively, these experiments provide insight into functional responses of different species to changing gradients of inundation or salinity as climate change alters physical conditions in San Francisco Bay and the Delta. Our results help inform predictions about how marsh vegetation may change in composition in the future and how functional processes may be affected by sea-level rise and increasing estuarine salinity. Such data will help regional efforts to manage and restore tidal wetlands with impending climate change.

Keywords: climate change, decomposition, productivity, salinity, sea-level rise
Session Title: Tidal Wetlands Ecology
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 308-310

An Overview of the CASCaDE II Project

Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov

Integrated physical-ecological models spanning the San Francisco Bay-Delta (SFBD) are needed to assess likely consequences of the many resource management options available to decision-makers. CASCaDE II is developing an interdisciplinary suite of state-of-the-art models as a prototype for eventual support of model-informed decision-making. We will provide a broad overview of the project, including discussion of the project's goals, the overall approach involving a framework of linked models, the scenarios being evaluated, and the general status of the project. This talk will serve as an introduction to the CASCaDE II special session.

Keywords: climate change, interdisciplinary, modeling, ecosystem
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Sea Level Rise and Climate Change Scenarios for the Bay-Delta

Daniel Cayan, Scripps Institution of Oceanography, UC San Diego, dcayan@ucsd.edu
Julie Kalansky, Scripps Institution of Oceanography, UC San Diego, jkalansky@ucsd.edu
Sam Iacobellis, Scripps Institution of Oceanography, UC San Diego, siacobellis@ucsd.edu
Noah Knowles, US Geological Survey, nknowles@usgs.gov
Michael Dettinger, US Geological Survey, mddettin@usgs.gov

Understanding possible sea level rise in the Bay-Delta is a crucial issue to plan for future impacts and to form appropriate adaptation options. Projections of major components of SLR have considerable uncertainty and the science is rapidly evolving. Using recent modeling results from the published literature (not our work), a new set of sea level rise (SLR) estimates for San Francisco has been developed, in association with the ongoing California 4th Climate Change Assessment. A probabilistic approach was taken, using recent published results on the primary components that contribute to global and regional sea level rise, along with a model that produces continuous projections of sea level at selected locations along the California coast. Hourly SLR at individual California coastal tide gage sites are produced, allowing analyses of extreme events. Envelopes of possible SLR is based on greenhouse gas emission scenarios RCP 4.5, and 8.5, and a subset of global climate models (GCMs) run under those scenarios. This GCM subset was determined by the California Department of Water Resources Climate Change Technical Advisory Group in support of DWR's need for a tractably sized subset of GCMs which performs reasonably well in simulating global, the Southwest region, and California climatological and climate variability patterns. For present day-mid 21st Century, projections of SLR are broadly consistent with previous estimates, but for long time horizons and high greenhouse gas emissions scenarios, the upper end of the modeled distribution of SLR is considerably higher than many previous estimates. Concerning extreme coastal events, the downscaling from GCM is consistently applied, so that we can investigate how storm systems that drive sea level fluctuations might reinforce with weather patterns that produce heavy precipitation in the upstream Sierra Nevada.

Keywords: sea level rise flooding climate change
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Hydrological and Management Responses to Scenarios of Climate Change in the Bay-Delta Watershed

Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov
Collin Cronkite-Ratcliff, U.S. Geological Survey, ccronkite-ratcliff@usgs.gov

Downscaled meteorology from climate scenarios were used to drive a model of unimpaired hydrology (VIC) which in turn drove models of operational responses (CalSim II, CRESPI). Twenty daily climate change scenarios from WY1980-2099 were evaluated, with the goal of producing inflow boundary conditions for a watershed sediment model and a downstream estuarine hydrodynamic model. The resulting managed-flow time series were analyzed for century-scale trends. All of the twenty scenarios portrayed warming trends, and most had increasing annual flows. Nearly all exhibited increasing frequency of extreme flows and earlier flow timing. Trends in annual mean flow, flow timing, and frequency of extreme flows were found to be highly correlated across GCM runs. Managed-flow timing trends were driven more by precipitation trends than by trends in air temperature. Scenarios for evaluation by the D3D-FM hydrodynamic model and other CASCaDE II models were selected based on these and other trends.

Keywords: climate change, hydrology, management, modeling
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Conditional Simulation of Streamflow Time Series and Application to Boundary Conditions in the San Francisco Bay-Delta Watershed

Collin Cronkite-Ratcliff, U.S. Geological Survey, ccronkite-ratcliff@usgs.gov
Noah Knowles, U.S. Geological Survey, nknowles@usgs.gov

CASCaDE II requires estimates of daily streamflow below physical impairments throughout the San Francisco Bay-Delta watershed. At many of these locations, the distribution and temporal patterns of the unimpaired daily streamflow time series, estimated by the VIC land surface hydrology model, are distinct from those of the streamflow below the respective impairments. This talk will present CRESPI, a new statistical model for the simulation of daily streamflow time series developed as part of the CASCADE II project. In this application, the CRESPI model is used to simulate daily inflow boundary conditions for 1) a watershed sediment model with boundary conditions located below physical impairments, and 2) the upstream boundary of an estuarine hydrodynamical model of the San Francisco Bay-Delta. For each of the climate scenarios considered in CASCaDE II, the streamflow simulated by CRESPI is conditioned on the daily unimpaired streamflow estimated by VIC. This output can also be constrained to monthly impaired streamflow estimated by the CalSim II water management model. Additionally, information on storage levels in surface reservoirs can be incorporated into the model in order to improve the reproduction of peak flow rates.

Keywords: cascade, hydrology, modeling, statistics, streamflow, timeseries, machine-learning, watershed, reservoir
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Future Trends of Sediment Supply to the San Francisco Bay-Delta Using Downscaled CMIP5 Climate Scenarios and a Calibrated Watershed Model of the Sacramento River Basin, CA

Michelle Stern, USGS, mstern@usgs.gov
Lorraine Flint, USGS, lflint@usgs.gov
Alan Flint, USGS, aflint@usgs.gov
Noah Knowles, USGS, nknowles@usgs.gov
Scott Wright, USGS, sawright@usgs.gov

Turbidity in the San Francisco Bay-Delta, which affects the habitat suitability of key species and the ability of delta marshes to keep up with sea level rise, is highly dependent on sediment supply from contributing watersheds. A watershed model of the Sacramento River Basin in northern California was developed to simulate daily streamflow and suspended sediment transport to the San Francisco Bay-Delta for 2010-2100 using the Hydrological Simulation Program – FORTRAN (HSPF) as part of the Computational Assessments of Scenarios of Change for the Delta Ecosystem (CASCaDE II) project. The HSPF model for the Sacramento River Basin is one of a set of interconnected models and provides sediment inputs to a hydrodynamic model of the San Francisco Bay-Delta used for the assessment of hydrologic, water quality, and biologic impacts of climate. The HSPF model was calibrated to available historical streamflow and sediment data from 1958-2008 for 99 sub-basins. The model was applied using 10 Localized Constructed Analogs (LOCA) future climate change scenarios with two representative concentration pathways (RCP 4.5 and 8.5) and the Livneh modeled climate dataset (1979-2013) for baseline comparison. The average results from the 10 climate-change scenarios indicated 37% and 42% increases in sediment loads by mid-century and increases of 52% and 73% by the end of the century for RCP 4.5 and RCP 8.5, respectively. Four scenarios that highlight the range of potential climate change effects on streamflow and sediment indicated that sediment loads decreased 18% for the 'warm and dry' scenario and increased 30%, 107%, and 230% for the 'hot and dry', 'warm and wet', and 'hot and wet' scenarios by the end of century.

Keywords: Sacramento River, Sediment supply, CASCaDE II, CMIP5, Watershed model, HSPF
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 308-310

Projections of Bay-Delta Hydrodynamics under Future Climate and Hydrology Conditions using a 3D Numerical Model

Rosanne Martyr-Koller, University of California - San Diego, rmartyr@ucsd.edu
Julia Vroom, Deltares Inc., Julia.Vroom@deltares.nl
Mick van der Wegen, UNESCO-IHE, m.vanderwegen@unesco-ihe.org
Lisa Lucas, US Geological Survey, llucas@usgs.gov
Noah Knowles, US Geological Survey, nknowles@usgs.gov
John Helly, University of California San Diego, hellyj@ucsd.edu

San Francisco Bay-Delta water-quality, ecosystem health, and species viability can be affected by planned and unplanned changes in regional infrastructure and future climate conditions. The USGS-led CASCaDE II project comprises a model-based approach for determining how multiple drivers of environmental change, including climate change and infrastructural alterations, could impact the Bay-Delta ecosystem (http://cascade.wr.usgs.gov/).

CASCaDE II implements Delft3D-FM, an unstructured grid, coupled hydrodynamics and water-quality model that describes the evolution of hydrodynamic and water-quality characteristics as the critical drivers in the Bay-Delta system. The model domain encompasses the coastal ocean, estuary, and lower watershed, and includes regional rivers, freshwater withdrawal at major local, state, and federal sites, and regional barriers and gates. The 3D model has been applied to replicate historical hydrodynamic parameters over multiple seasons and wide-ranging hydrological conditions. Model performance was assessed through model timing and scalability on various parallel (high-performance) computing platforms, and fidelity to historical observations of water levels, flow, salinity, and temperature.

Recent Delft3D-FM applications have been driven by a subset of downscaled climate scenarios based on the UN IPCC 5th Assessment, resulting in year-long projections of Bay-Delta hydrodynamics for the near-future and end of century. This talk will focus on these year-long projections by exploring variations in mean sea levels, tides, and salinity and temperature distributions under near-term and end of century conditions. Frequency of extreme environmental conditions, including peak water levels, salinity intrusion, and water temperature relative to historical observations will be discussed. These hydrodynamics projections will be used to partly drive water-quality and ecological models in the CASCaDE II framework. In addition, the model will be made available for third parties via the San Francisco Bay-Delta Community Model website (www.d3d-baydelta.org) after publication of the main findings. Third parties will be allowed to download and adapt the Bay-Delta model for their own use.

Keywords: Climate change, Hydrodynamics, Modeling, Environmental Indicators, Extremes
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Three-Dimensional Chemical Transport Modeling of Selenium in the San Francisco Bay-Delta

James Bishop, U.S. Geological Survey, jmbishop@usgs.gov
Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov

Selenium has been a contaminant of concern in the San Francisco Bay-Delta system since the 1980's when elevated Se concentrations were observed in estuarine vertebrates. Despite reductions in Se loading from oil refineries in 1998, Se concentrations in estuarine organisms remain elevated. While the sources and loads of Se are well documented, the transport pathways and residence times of Se are uncertain. In this study, we couple a DELWAQ water-quality model with a Deltft3D-FM 3-dimensional hydrodynamic model, developed within the USGS CASCaDE II project, to examine travel times and transport pathways from various Se sources and the residence time of Se in different ecoregions of the Bay-Delta. We also examine the effect of changes in flow from the San Joaquin and Sacramento Rivers on estuarine Se concentrations and residence time. Finally, we compare modeled aqueous Se concentrations at specific locations to measured Se concentrations in clam tissues (*Potamocorbula. amurensis*) at the same location. *P. amurensis* bioaccumulate Se and are prey for a number of estuarine fishes and thus are good indicators of Se concentrations in those fish species. This work will aid in understanding the various sources and hydrodynamic factors controlling selenium distributions and entry into the estuarine food web and how proposed river water diversions may affect Bay-Delta selenium loading and exposures.

Keywords: selenium, CASCaDE II, modeling, contaminant, bioavailability, transport, estuary, hydrodynamic, hydrology
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Physical Models to Ecological Response: Challenges in Understanding the Effects of Climate Change on the San Francisco Estuary

Larry Brown, U.S. Geological Survey, lrbrown@usgs.gov
Judith Drexler, U.S. Geological Survey, jdrexler@usgs.gov
A. Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov
Janet Thompson, U.S. Geological Survey, jthompso@usgs.gov
Francis Parchaso, U.S. Geological Survey, parchaso@usgs.gov
James Bishop, U.S. Geological Survey, jmbishop@usgs.gov
Marissa Wulff, U.S. Geological Survey, mwulff@usgs.gov

The CASCaDE II project includes 10 modeling components representing 5 physical processes and five ecological processes. In this presentation we share information concerning the ecological processes: marsh sustainability, contaminants in organisms, phytoplankton production, clam grazing, and fish habitat use. Our objective is to understand how climate change could impact these ecological processes, with specific emphasis on the recovery of listed species in the Delta. Evaluations of previous climate-change scenarios have shown that Delta Smelt would experience increasingly stressful conditions throughout their life cycle, in particular, high temperatures (>24°C) during summer and fall. High temperatures are directly stressful to individuals and would decrease the time available for fish maturation before spawning. In CASCaDE II, we expect to learn more about impacts on Delta Smelt by modeling available habitat based on selected environmental parameters. We used CASCaDE II outputs to carry out 450 simulations by using the one-dimensional marsh surface elevation model (WARMER), and learned that the primary drivers affecting Delta marsh sustainability were the rate of sea-level rise and sediment supply. In particular, we learned that sea-level rise rates of 133 and 179 cm by 2100 resulted in only 32% and 11%, respectively, of scenarios having sustainable marshes. Preliminary modeling of within-estuary selenium loads in CASCaDE I highlighted the importance of tidal dispersion in understanding Se distributions. CASCaDE II modeling will incorporate changes in flows from the Sacramento and San Joaquin Rivers to provide insight into how water management could affect selenium delivery to the estuary's food webs. The interacting phytoplankton and grazing models are still being developed because they are highly dependent on outputs from the physical-process models, but should be ready for application in 2017. Projections regarding ecological impacts of climate change will be critical for planning future management and restoration activities in the Delta.

Keywords: climate change, scenarios, modeling, biological processes
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Impact of Sea Level Rise and Foreseen Engineering Measures in Sediment Trapping Efficiency by Means of a 2D Process-Based Model

Fernanda Achete, UNESCO-IHE, fernandaachete@gmail.com
Mick van der Wegen, UNESCO-IHE, m.vanderwegen@unesco-ihe.org
Bruce Jaffe, USGS-Pacific Science Center, bjaffe@usgs.gov
Dano Roelvink, UNESCO-IHE, Deltares, d.roelvink@unesco-ihe.org

Rivers transport fine sediment, carrying nutrients and contaminants, which partly deposit in the channel network. We use a two-dimensional horizontal, averaged in the vertical (2DH), process-based, numerical model (Delft3D FM) to evaluate the impact of sea level rise and engineering-related changes on trapping of fine sediment in the Sacramento-San Joaquin Delta. Trapping efficiency (Ψ) dictates the amount of sediment that will be available in the Delta system, for example for marsh restoration projects.

The base-case (BCS) reflects current conditions and is used as the standard run for comparison with the other scenarios. Here we show 3 additional scenarios: sea level rise (+1.67m), Delta island flooding, and a decrease in sediment input. The flooded island scenario floods former leveed land where levee breaches result in a "lake" and increases the delta tidal prism by 20%. The scenario of a decrease in sediment input is based on an average rate of 0.8% per year, which is observed in the long term in situ observation and is linked with river damming.

On average 70% of the input sediment in the system is trapped in the Delta. The model reproduces these Ψ within 90% of accuracy. The Ψ decreases by 10% in the sea level rise scenario due to increase in the flow velocities in the Delta. In contrast, the flooded island scenario decreases flow velocities and creates more accommodation space increasing Ψ by 20%. The decrease in sediment input does not affect Ψ.

The increase in tidal prism by flooding from breaches in levees has the most impact on sediment trapping efficiency in the Delta. Our approach shows that validated process-based models are a useful tool to address long-term (decades to centuries) changes in sediment dynamics. In addition, they provide a useful starting point for long-term, process-based studies addressing ecosystem dynamics and health.

Keywords: fine sediment, numerical model
Session Title: CASCaDE II: Computational Assessments of Scenarios of Change for the Delta Ecosystem II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 308-310

Remote Sensing to Infer Surface SPM in San Francisco Bay

Joseph H Adelson*, The Bob and Norma Street Environmental Fluid Mechanics Laboratory (BNSEFML), Dept. of Civil and Env. Engineering, Stanford University, joe.adelson@gmail.com
Nathan Kau, BNSEFML, Dept. of Civil and Env. Engineering, Stanford University, nathankau@gmail.com
Oliver B Fringer, BNSEFML, Dept. of Civil and Env. Engineering, Stanford University, ofringer@gmail.com

Multi-spectral satellite images of the San Francisco Bay region have the potential to provide broad spatial information about biological productivity, water quality, suspended particulate matter (SPM), and light attenuation. While satellite remote sensing algorithms are well established for quantification of sea-surface temperature and biological productivity in the ocean, there is currently very little remote sensing work designed to predict SPM in estuaries like San Francisco Bay. As part of a project in which we seek to deploy UAVs with high-resolution, multispectral cameras to measure surface SPM, we have developed algorithms to infer surface SPM in San Francisco Bay from Landsat Enhanced Thematic Mapper Plus data and validated the results with USGS Polaris cruise measurements. We tested several regression algorithms including: linear regression, Huber regression, and an artificial neural network. Neural networks are a class of machine learning algorithms well suited to non-linear statistical modeling. Our calibrated neural network best reconstructed a reserved testing set of *in situ* SPM measurements with an R^2 value of 0.76. Although the Huber regression—an alternative to linear regression that is robust against outliers—did not predict SPM concentrations as well as the neural network (R^2 = 0.74), it is a recommended alternative, because it possesses the attractive quality of being a linear equation that is straightforward to understand without sacrificing a large amount of performance. Therefore, we have implemented the Huber regression on a series of satellite images and used it to estimate surface SPM concentrations throughout San Francisco Bay.

Keywords: suspended sediment, suspended particulate matter, remote sensing, satellite imagery
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions I
Session Time: Wednesday 8:20 AM – 10:00 AM Room 311-313

Evaluation of the Effects of Long-Term Trends in Sediment Supply and Wind Speeds on Suspended Sediment and Turbidity in Suisun Bay and the Delta

Michael MacWilliams, Anchor QEA, mmacwilliams@anchorqea.com
Aaron Bever, Anchor QEA, abever@anchorqea.com
David Fullerton, Metropolitan Water District, dfullerton@mwdh2o.com

Observed long-term trends indicate a decline in sediment supply to the Delta on the order of 1.3% per year, which corresponds to a decline of 23% over the past 20 years. In addition, recent analysis of historic wind data in Suisun Bay and the Sacramento-San Joaquin Delta indicates a statistically significant decline in wind speeds over the past two decades, which is most pronounced in fall. Both the long-term decline in sediment supply and the long-term trends in wind speed have the potential to influence sediment transport and turbidity in Suisun Bay and the Delta. The 3-D UnTRIM Bay-Delta model was applied together with the SWAN wave model and the SediMorph morphodynamic model to evaluate the relative effect of long term trends in wind and Delta sediment supply on turbidity both during wet and dry water years. An understanding of how these long term trends in wind and Delta sediment supply affect turbidity in Suisun Bay and the Western Delta has important management implications for species such as Delta Smelt that are more likely to be detected in areas with higher turbidity. This presentation will discuss the observed declines in sediment supply and wind speed, how these declines have affected turbidity over the past 20 years, and the potential implications of these changes for habitat and management decisions.

Keywords: Sediment Transport, Wind, Turbidity, Waves, Sediment Supply, Delta Smelt Habitat
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 311-313

Observations of Cohesive Sediment Flocculation in San Francisco Bay: Implications on Sediment Transport and Light Availability

Ivy B. Huang*, Stanford University, ibhuang@stanford.edu
Andrew J. Manning, Coasts & Estuaries Group, HR Wallingford Ltd.; and Department of Geography, Environment & Earth Sciences, University of Hull, a.manning@hrwallingford.com
David H. Schoellhamer, USGS California Water Science Center, dschoell@usgs.gov
Stephen G. Monismith, Stanford University, monismith@stanford.edu

This research is focused on determining cohesive sediment properties in San Francisco Bay, identifying the controls on flocculation dynamics, and investigating the effects of particle size changes on sediment residence time and light penetration. High-resolution transect and stationary measurements of flow, turbulence, turbidity, sediment concentration, particle size, and light penetration were collected between 2008 and 2015, spanning from South Bay to Sacramento. We make the following main observations. First, suspended sediment flocculation significantly enhances particle fall velocity and, therefore, sediment removal from the water column. Second, we argue that estuarine physics is the main driving mechanism behind floc size changes, rather than chemical or biological factors. Lastly, we show that suspended sediment and light penetration relationships can be improved by accounting for floc size changes under certain conditions. Overall, conclusions drawn from this research will aid in the evaluation of pressing environmental problems in the Bay-Delta estuary that are intimately linked to sediment and light relationships.

Keywords: Cohesive sediment, turbulence, flocculation, turbidity, light penetration
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 311-313

Three-dimensional Modeling of Turbidity in the Sacramento-San Joaquin Delta to Investigate the Mechanisms Resulting in Tidal Time-scale Lateral Turbidity Gradients

Aaron Bever, Anchor QEA, abever@anchorqea.com
Michael MacWilliams, Anchor QEA, mmacwilliams@anchorqea.com

The 3-D UnTRIM Bay-Delta hydrodynamic and sediment transport model was used to predict the suspended sediment concentration throughout the Sacramento-San Joaquin Delta. The 3-D suspended sediment concentration was converted to turbidity and the turbidity then underwent data assimilation using observations from turbidity monitoring sensors. This method preserved both the Delta-scale and the small-scale lateral and vertical turbidity gradients predicted by the 3D model while also ensuring the simulated turbidity field matches the locally observed turbidity magnitude throughout the Delta. The model results were examined taking into account a simple conceptual model proposed by Bennett and Burau (2015) of across-channel turbidity gradients, to determine the mechanisms influencing lateral turbidity gradients in the Sacramento River near the junction with Three Mile Slough. The high-resolution predicted turbidity highlights the large influence of channel junctions on lateral turbidity gradients near Three Mile Slough and throughout the Delta. Tidal time-scale variability in water flow and the resulting effects on sediment erosion, deposition, and transport is also shown to influence the formation and breakdown of lateral turbidity gradients.

Keywords: Turbidity, Numerical Modeling, Sediment, Lateral Turbidity Gradients
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 311-313

Influence of the 2016 Yolo Bypass Flood Event on Suspended Sediment in Little Holland Tract

Emily Carlson, USGS, emilycarlson@usgs.gov
Jessica Lacy, USGS, jlacy@usgs.gov

Delta smelt favor regions of elevated turbidity, and in much of the Delta turbidities are low. During the fall of 2015 and the winter of 2016 a suite of instruments were deployed in Liberty Island and Little Holland Tract (LHT) in the northern Sacramento Delta as part of a collaborative effort to characterize the suitability of Little Holland Tract as fish habitat. Persistent rain events in February and March of 2016 resulted in the overtopping of the Fremont Weir for the first time in three years, diverting flow from the Sacramento River into the Yolo Bypass from March 12th until March 24th. LHT is located approximately 32 miles south (downstream) of the weir, near where the bypass reconnects to the main Sacramento River channel. During the flood event, water levels were elevated in LHT, and both tidal stage fluctuations and tidal currents were significantly damped, increasing the potential for sediment deposition. The greatest suspended-sediment concentration (SSC) in the study area since observations began in August 2015 occurred directly before and during the Yolo Bypass flood. After the flood event, SSC in LHT remained higher than before the period of highest SSC, suggesting that erodibility increased. Bed sediment samples collected at two sites before and after the flood event show an increase in fines and a decrease in larger particle size. The apparent change in erodability and particle size distribution indicate that there was an influx of new sediments into LHT from the flood bypass area. In contrast, the westerly adjacent water body, Liberty Island, experienced similar elevations in water levels but did not exhibit comparable changes in SSC and grain size distribution. These results illustrate the importance of location relative to sediment sources in selecting restoration sites.

Keywords: sediment transport, sediment dynamics, Yolo Bypass, turbidity, management decisions
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 311-313

Mudflat Morphodynamics and the Impact of Sea Level Rise in South San Francisco Bay

Mick van der Wegen, UNESCO-IHE and Deltares, m.vanderwegen@unesco-ihe.org
Bruce Jaffe, USGS, bjaffe@usgs.gov
Amy Foxgrover, USGS, afoxgrover@usgs.gov
Dano Roelvink, UNESCO-IHE, Deltares and TU Delft, d.roelvink@unesco-ihe.org

Estuarine tidal mudflats form unique habitats and maintain valuable ecosystems. They provide an important source of sediment to adjacent salt marshes. In addition, wave attenuating by the salt marsh-mudflat system provides a natural defense against wave attack during storms. Although many mudflats seem to be in equilibrium, it is unknown how mudflats will react to scenarios of sea level rise and decreasing sediment supply.

We developed a 1D morphodynamic profile model (Delft3D) that is able to reproduce the 2011 measured profile at a 800 wide mudflat south of Dumbarton Bridge. The physics-based model included tide and wave action as well as the Krone-Parteniades sediment transport formulation. The modeling approach allows for a detailed analysis of governing processes during the tidal cycle at a 10 m spatial resolution as well as morphodynamic developments over a 100 year time frame.

The model is able to reproduce the measured Dumbarton mudflat profile in equilibrium conditions including high, wave induced, suspended sediment concentrations at the mudflat. Shear stresses are highest during low water, while shear stresses are lower than critical (and highest at the landward end) along the mudflat during high water. Scenarios of sea level rise and decreasing sediment supply drown the mudflat and reduce intertidal area. For example, a 1.67m rise in sea level in a century reduces the intertidal area by about 30 percent. This is despite the fact that the mudflat profile accretes on average 1 m.

This research suggests that sea level rise is a serious threat to the presence of many estuarine intertidal mudflats, adjacent salt marshes and their associated ecological values.

Keywords: estuarine mudflats, morphodynamic modeling, sea level rise impact
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 311-313

Morphologic Change and Mercury Mobilization in Alviso Slough, South San Francisco Bay

Amy Foxgrover, USGS Pacific Coastal and Marine Science Center, afoxgrover@usgs.gov
Theresa Fregoso, USGS Pacific Coastal and Marine Science Center, tfregoso@usgs.gov
Bruce Jaffe, USGS Pacific Coastal and Marine Science Center, bjaffe@usgs.gov
Mark Marvin-DiPasquale, USGS, Branch of Regional Research, Western Region, mmarvin@usgs.gov

The potential for localized and regional erosion of intertidal mudflats, sloughs, and channels is a major concern associated with salt pond restoration in South San Francisco Bay. Two of the primary uncertainties in restoration of the Alviso Salt Ponds are: (1) Will opening these severely subsided ponds to tidal action result in erosion of the adjacent mudflats? (2) Will the enlarged tidal prism significantly increase the rate of scour within Alviso Slough and remobilize legacy mercury deposits that were previously buried? Restoration began in 2010 when the levees surrounding Pond A6 were breached, and muted tidal action was restored to the Pond A8 complex through an adjustable flood control structure, allowing for progressively increased size and duration of tidal flushing. As part of the adaptive management process, we collected a baseline high-resolution bathymetric survey of the study area during 2010, followed by semi-annual surveys ever since. Thus far, the greatest amount of erosion has occurred within Alviso and Guadalupe Sloughs in the vicinity of the A6 breaches. From 2010 to 2015 the nearby intertidal mudflats have either accreted or maintained their elevation. Patterns of deposition and erosion vary along the length of Alviso Slough and through time. There has been a dominant pattern of erosion in the winter followed by either no change or slight deposition with only localized areas of erosion during spring and summer months. Our measurements of scour within Alviso Slough, in combination with mercury data from deep (ca. 2 meter) sediment cores indicate that approximately 35 kg of legacy mercury has been remobilized within the slough between 2010 and October 2015. This study provides critical insight into the morphological evolution of slough/intertidal mudflat/bay systems as levees are breached and the tidal prism increased, while informing future wetland management and restoration practices.

Keywords: South San Francisco Bay, restoration, Alivso, salt ponds, mercury, bathymetry
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 311-313

Seasonal Variations in Suspended Sediment in San Pablo Bay Shallows

Rachel Allen*, University of California, Berkeley, rachelallen@berkeley.edu
Evan Variano, University of California, Berkeley, variano@berkeley.edu
Jessica Lacy, USGS Pacific Coastal and Marine Science Center, jlacy@usgs.gov

Models of marsh response to sea-level rise require sediment supply as a key input, and it is currently parameterized with high uncertainty. This work aims to improve the mechanistic understanding of suspended sediment dynamics with long-term measurements in San Pablo Bay.

San Pablo Bay is the site of an extensive historic marsh and several large-scale marsh restoration projects. The sediment supply to these marshes depends on conditions in adjacent bay shallows. It is known that currents, waves, water level, and their interactions drive suspended sediment conditions in San Francisco Bay shallows. However, the importance of longer term forcings on a seasonal scale, such as winter storms, event-driven freshwater inflows, sustained winds, variations in wind direction, and long-term low-energy periods, have not previously been investigated. We observed suspended sediment concentrations and wave, current, and turbulence conditions in San Pablo Bay over 16 months, between Dec 2013 and April 2015. We collected data every 15-20 min at two stations about 7 km apart along the western shore, both located at 1 m below mean-lower-low water.

Suspended sediment concentrations were generally lower at the southerly station, which is protected from the prevailing winds. The highest concentrations were observed during the 2014-2015 winter, while the drier 2013-2014 winter showed similar behavior to the rest of the 2014 spring-summer-fall. To investigate these differences and the seasonal variation of suspended sediment dynamics, we explore resuspension and critical shear stress, spatial variation within the shallows and between the shallows and the marsh, and the relationship of seasonal-scale drivers to currents, waves, winds, and tides.

This study improves our mechanistic understanding of suspended sediment dynamics, and enables us to make better predictions of marsh survival with sea level rise and better management decisions about marsh restoration around San Francisco Bay.

Keywords: suspended sediment dynamics, seasonal trends
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 311-313

Linking Sediment Flux to Marshes with Dynamics in Bay Shallows

Jessica Lacy, USGS Pacific Coastal and Marine Science Center, jlacy@usgs.gov
Rachel Allen, UC Berkeley, rachelallen@berkeley.edu
Madeline Foster-Martinez, UC Berkeley, madeline@berkeley.edu
John Callaway, University of San Francisco, callaway@usfca.edu
Matthew Ferner, San Francisco Bay National Estuarine Research Reserve, mferner@sfsu.edu

Predictions of marsh resilience to sea-level rise rely on estimates of sediment supply, yet the links between dynamics in estuarine shallows and sediment supply to marshes are poorly understood. We are investigating these connections in the San Pablo Bay shallows and the adjacent accretionary marsh in China Camp State Park. Data collected in winter 2013/14 and winter 2014/15 show net sediment export from the marsh through tidal creeks, predominately during the largest ('King') tides of the year. During four days of King tides, 10 tons of sediment per meter of creek width were exported during the first winter, and 15 tons/m during the second winter. Ebbing tides after extreme high waters are delayed over the marsh surface by vegetative drag, increasing the along-creek gradient in water surface elevation. As a result velocities are elevated (> 1 m/s) in the creeks, suggesting that channel scour, rather than erosion of the marsh, accounts for much of the bayward suspended-sediment flux (SSF). Tidal creek SSF was landward (with low magnitude) during neap tides and wind events. From May to June 2016 we conducted a third deployment to capture the influence of the summer sea breeze and the highest tides of summer on SSF. Our data show that the highest suspended-sediment concentrations (SSC) occur over the intertidal mudflat adjacent to the marsh edge, due to wind-wave resuspension. During flood tides when the mudflat was inundated, the 85th percentile of near-bed SSC over the mudflat was 263 mg/L, compared to 191 mg/L in the subtidal shallows, and 56 mg/L over the vegetated marsh. Flood-tide SSC over the mudflat and in the tidal creek were highly correlated. These results indicate the importance of the dynamic region immediately bayward of the marsh edge to sediment supply, both through marsh creeks and directly across the bay-marsh interface.

Keywords: suspended sediment; sediment flux; tidal marsh; wind waves
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions II
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Wetland Sedimentation in Natural and Restored Tidal Wetlands in San Francisco Bay

John Callaway, University of San Francisco, callaway@usfca.edu

There is large-scale interest in restoring tidal wetlands within the Bay-Delta; however, many restoration sites are highly subsided and will require substantial sediment accumulation to reach threshold elevations for plant establishment. In addition to these issues, there is growing concern regarding impacts from increased rates of sea-level rise and reductions in suspended sediment concentrations within the Bay-Delta. Given these concerns, it is critical to better understand wetland sediment dynamics within both restored and natural wetlands in the Bay-Delta. To address this issue, we have measured sedimentation rates in a range of sites using both long-term and short-term approaches, including dated sediment cores, feldspar marker horizons and SETs. Sampling has occurred at multiple natural and restored wetlands, and across a wide range of intertidal elevations, from unvegetated mudflats to high-elevation marsh plains. Results indicate that existing tidal wetlands throughout San Francisco Bay and Suisun Bay are keeping pace with current rates of sea-level rise, with overall accretion rates ranging from 2-4 mm/yr in high-elevation marsh plains to 6-8 mm/yr in low marsh areas. Recently restored sites have substantially higher rates of accretion (up to 200 mm/yr), due to more frequent tidal inundation at lower elevations within subsided restoration sites. It is not certain if these extreme rates of accretion are likely to continue as more sites are restored within the Bay-Delta and if suspended sediment continues to decline into the future; however, at present, conditions indicate that restoration sites have the potential to increase elevation rapidly. Continued monitoring of additional wetlands within the Bay-Delta will allow for the development of models which can be used to predict sediment dynamics in future restoration projects, as well to understand longer-term development of restored wetlands under scenarios of increased sea-level rise and reduced suspended sediment concentrations.

Keywords: accretion, restoration; sea-level rise, sedimentation, wetland
Session Title: Linking Sediment Dynamics to Long-Term Management Decisions II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 311-313

Food Web Fuel: Differences across Space and Time, with Implications for Restoration

Matthew Young*, University of California, Davis, mjyoung@ucdavis.edu
Emily Howe, The Nature Conservancy, ehowe2@uw.edu

Estuarine food webs are fueled by a variety of different primary producers. However, in complex, heterogeneous environments it is difficult to identify the relative importance of these producers, particularly to fishes, which typically integrate multiple sources due to their mobility and generally high trophic levels. Through a series of studies within the San Francisco Bay and Delta we have identified the importance of primary producer contributions to local food webs, and noted dramatic spatial and seasonal differences. These dissimilarities exist both on large and small spatial scales, suggesting the impact of restoration efforts on local food webs will be high. Although relative contributions differed, fishes were consistently reliant on a diversity of primary sources, suggesting that restoration efforts should emphasize a wide variety of primary producers to support consumers. In this talk we summarize recent research on Bay-Delta tidal marsh food webs within the context of restoration goals.

Keywords: food webs, fish, restoration
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 311-313

Advancing Tidal Wetland Restoration in a Regional Adaptive Management Framework

Gerrit Platenkamp, Environmental Science Associates, gplatenkamp@esassoc.com
Michelle Orr, Environmental Science Associates, morr@esassoc.com
Ramona Swenson, Environmental Science Associates, rswenson@esassoc.com
Ann Borgonovo, Environmental Science Associates, aborgonovo@esassoc.com
Chris Fitzer, Environmental Science Associates, cfitzer@esassoc.com
Eric Ginney, Environmental Science Associates, eginney@esassoc.com

Key objectives of large-scale tidal wetland restoration in the Delta and Suisun Marsh are to support the habitat requirements of several threatened and endangered fish species, and aid in the recovery of those species. However, substantial uncertainty exists regarding the most effective approach to meeting these objectives. Based on over 20 years of tidal wetland restoration implementation and research, we ask how key uncertainties can be addressed by incorporating adaptive management experiments in restoration designs. We use the designs of recent projects as examples of how key uncertainties can be investigated experimentally. The design of DWR's Dutch Slough Tidal Marsh Restoration Project, for instance, allows for the assessment of how native fish utilize different tidal wetland scales and marshplain elevations. Examples of other design elements that could be experimentally manipulated are size, depth and residence time of artificial tidal pannes, and the slope and length of constructed wetland – upland ecotones. We assess how monitoring results from multiple restoration projects could be used within the coordinated regional framework of an overall adaptive management program to improve the future success of tidal wetland restoration. Lastly, we discuss the potential institutional and regulatory impediments to this approach and suggest programmatic solutions that would likely provide superior results compared to the current project-by-project approach to adaptive management. Our findings show the benefits of a regional adaptive management approach that includes adaptive management experiments that are coordinated among individual projects. Regional coordination within one adaptive management framework would be the most efficient approach to resolve key uncertainties in tidal wetland restoration designs and would help to improve the contribution of tidal marsh restoration to native fish species recovery in the Delta and Suisun Marsh.

Keywords: adaptive management, tidal marsh restoration, delta smelt, monitoring, regulatory permitting
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 311-313

The Importance of Emergent Vegetation Dynamics in Post-Restoration Outcomes of the Novel Freshwater Marshes

Iryna Dronova, University of California Berkeley, idronova@berkeley.edu
Sophie Taddeo, University of California Berkeley, sophie.taddeo@berkeley.edu

The dynamics of emergent vegetation affect multiple ecosystem services of restored wetlands in the Delta estuary, including sequestration of carbon, regulation of greenhouse gas fluxes, counteraction to land subsidence and provision of wildlife habitat. However, it is not well understood how specific restoration outcomes may depend on the initial objectives and site designs. This study assessed the differences in canopy structure and landscape configuration of vegetation among different-aged restored freshwater marshes with similar species composition in the western Delta using 2013-2014 field surveys and remote sensing image analysis. The key post-restoration transformations of these sites included colonization and lateral expansion of emergent vegetation (*Typha* spp. and *Schoenoplectus acutus*) and accumulation of standing litter (dead biomass) within plant canopies. These processes affected the heterogeneity in vertical canopy structure and leaf area index (LAI; green leaf area per ground area) that differed among older and younger wetland sites. The contrasts between higher-litter patch interior and low-litter green edge were more pronounced in larger-sized patches, indicating the increasing importance of shading and constraints on plant density with time and litter build-up. Major changes in landscape-scale wetland structure included increases in vegetation cover and high-litter patch interior and decreases in open water extent. Collectively, these outcomes point to potential post-restoration homogenization of vegetation structure, landscape composition and habitat, which may be slower in sites with more complex configuration where water depth and disturbance constrain vegetation colonization and expansion. Because open water, green vegetation and litter contribute differently to ecosystem function and habitat properties, these observed dynamics have multiple important implications for restoration objectives and emerging management needs. The important future task is to quantify specific feedbacks between local plant canopy processes and landscape site structure and to develop a spatially explicit modeling framework to simulate vegetation composition and restoration outcomes under different site configurations.

Keywords: Restoration, vegetation, freshwater, marsh, canopy, LAI, litter, habitat, patches, homogenization
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
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Geospatial Initiatives to Support Adaptive Management in the Delta and the Watershed

Carol Ostergren, US Geological Survey, costergren@usgs.gov

Is data management important for Bay-Delta habitat restoration? Are geospatial datasets integrated into project planning, post-project monitoring and regional assessments? Data and information are key component of an adaptive management process, from planning to modeling, to monitoring and analyses, to assessment and evaluation. Remote sensing and large-scale datasets, terrain datasets and earth and ocean observation data system are increasingly sophisticated and available. Tidal wetland restoration planning success is dependent on site elevation mapping. Fine topographic details are needed for hydrological modeling, restoration evaluation and planning. The National Map initiative lead by US Geological Survey National Geospatial Program includes the 3D Elevation Program to respond to growing need for high quality topographic data and for a wide range of other three-dimensional representations of the natural and constructed features. The 3D Elevation Program systematically collects enhanced elevation data in the form of high-quality light detection and ranging (lidar) data. New lidar data, along with updated, high resolution surface water network data (The National Hydrography Dataset), currently in collection for the Bay-Delta will provide an integrated detailed terrain and surface water flow framework for understanding the complexity, availability, and movement of water within the Bay-Delta. This unique high resolution data will further the understanding and monitoring of subsidence in the Bay-Delta, the integrity and settlement of existing levees, the viability and cost effectiveness of intertidal habitat restoration, identifying critical fish passage alternatives, and focus protection of vital farming areas. Similar data that surrounds the Bay-Delta (foothills, San Francisco Bay Area, northern and southern Central Valley) provides critical contextual information about the conditions and volume of water entering and exiting the Bay-Delta system.

Keywords: geospatial, elevation, lidar, hydrography
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 311-313

Human Use of Restored and Naturalized Delta Landscapes

Brett Milligan, UC Davis Landscape Architecture, Department of Human Ecology, bmilligan@ucdavis.edu
Alejo Kraus-Polk, UC Davis Geography Graduate Group, akrauspolk@ucdavis.edu

Current legislation and plans for the Delta call for large-scale restoration of aquatic and terrestrial habitats, which will require significant changes in land uses and cultural patterns.
These rewilded landscapes will be subject to a variety of new human uses, which Delta planning and adaptive management literature has yet to adequately consider. Failing to account for human uses can lead to diminished performance and public support for Delta restoration efforts.

Our one year empirical study examined restored and naturalized Delta landscapes from an integrative human--environment perspective; adopting a landscape planning approach that seeks to reconcile multiple goals and land use agendas spanning ecological, social, economic and political domains. Research was conducted through a combination of surveys and interviews with approximately 100 land managers, scientists, landowners, law enforcement personnel, agency representatives and Delta residents; review of existing delta planning literature; extensive field work, and specific case studies.

Initial findings have shown that human uses of the Delta's restored landscapes are diverse and pervasive. They are subject to multiple and sometimes conflicting uses and values. Therefore, reconciling human uses with ecological restoration will require a more inclusive and multifunctional approach to designing and adaptively managing these landscapes. Case studies revealed that more participatory and proactive planning for human uses is a sound investment in the long term, as it helps to discourage undesirable activity while also building constituency and public support for these projects. The general public has the potential to be an asset in restoration through citizen science and civic ecology programs, which are currently almost non-existent in the Delta. Thus we propose that human uses of restored landscapes be integrated into adaptive management efforts and that more resources and research be dedicated to planning for human uses of these expanding lands.

Keywords: human use, adaptive management, restored landscapes, rewilding, integrative planning
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
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Red Light / Green Light: A Decade after the Start of Restoration, How is the South Bay Salt Pond Restoration Project Performing?

Laura Valoppi, U.S. Geological Survey, Laura_Valoppi@usgs.gov
John Bourgeois, California Coastal Conservancy, John.Bourgeois@scc.ca.gov
Cheryl Strong, US Fish and Wildlife Service, cheryl_strong@fws.gov

The South Bay Salt Pond Restoration Project is the largest tidal wetland restoration project on the West Coast of the United States. As planned, the project will restore 15,100 acres of former industrial salt ponds to a mosaic of wetlands habitats for the benefit of native wildlife, public access, and flood risk reduction. As we finish up our first decade on the Project and ramp up design and planning for the next phase, we created a score card to gauge progress of our adaptive management program and investigations of key uncertainties. In collaboration with our project management and local science team, we derived a "traffic light" system for rating. Most topics were favorably in the green, including snowy plovers, sediment dynamics and mercury contamination; while water quality and island design for nesting birds clearly need more attention. This check-in comes at a time when funding uncertainties and impending sea level rise are key issues for us moving forward. However, we wish to acknowledge the progress that has been made in just 10 years: 3000 acres restored to the tides, 700 acres of ponds enhanced and reconfigured, and sightings of endangered species in new marsh habitat. The traffic light system can help guide the use of limited science and monitoring funds as we move forward with the next phase of restoration.

Keywords: adaptive management, wetland restoration, South Bay
Session Title: South Bay Salt Pond Restoration: Adaptive Management Success Story
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 311-313

Sediment Supply for Restoring and Sustaining South San Francisco Bay Tidal Marsh

David Schoellhamer, U.S. Geological Survey, dschoell@usgs.gov
John Bourgeois, South Bay Salt Pond Restoration Project, John.Bourgeois@scc.ca.gov
Laura Valoppi, U.S. Geological Survey, laura_valoppi@usgs.gov
Maureen Downing-Kunz, U.S. Geological Survey, mdowning-kunz@usgs.gov
Paul Work, U.S. Geological Survey, pwork@usgs.gov
Lester McKee, San Francisco Estuary Institute, lester@sfei.org
Greg Shellenbarger, U.S. Geological Survey, shell@dcn.org

The South Bay Salt Pond Restoration Project requires sediment deposition to succeed. Sediment is needed in restored subsided ponds to obtain elevations high enough for plant colonization and, along with organic accretion, to help sustain marshes as sea level rises. The primary source of sediment to the Project area is net southerly transport in South San Francisco Bay driven by tides, wind-generated currents, and wind-wave resuspension, particularly during dry periods.

Previous studies have shown that when freshwater enters Central San Francisco Bay from the Delta, Central Bay becomes fresher than South Bay, and the resulting density difference flushes South Bay and exports sediment out of South Bay. A tidal Froude number determines when tidally-driven or density-driven flows dominate and it accurately hindcasts a density-driven flushing event observed in 2011. Lack of density driven flushing during the recent drought likely increased sediment supply and deposition in the Project area as indicated by increasing suspended-sediment concentrations at Dumbarton Bridge. Flooding in local South Bay tributaries that results in large sediment delivery to the Project area has not occurred during the period of record of sediment flux measurements at the Dumbarton Bridge, so the threshold at which local tributaries begin to dominate sediment supply is unknown.

Given the importance of sediment to the ultimate success of the restoration, project managers are eager to understand the baywide trends and linkages. Additional work at the scale of the individual pond/marsh has indicated high accretion rates with little to no measureable erosion of the surrounding mudflats. To sustain these marshes in the context of sea level rise, managers are looking to reconnect marshes to natural sediment pathways and are participating in regional conversations about sediment management practices in the Bay.

Keywords: sediment, marsh, South San Francisco Bay, restoration, adaptive management, sea-level-rise
Session Title: South Bay Salt Pond Restoration: Adaptive Management Success Story
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South Bay Salt Ponds Restoration: Managing for Mercury Contamination

Mark Marvin-DiPasquale, U.S. Geological Survey, mmarvin@usgs.gov
John Bourgeois, State Coastal Conservancy, John.Bourgeois@scc.ca.gov
Josh Ackerman, U.S. Geological Survey, jackerman@usgs.gov
Darell Slotton, UC Davis, dgslotton@ucdavis.edu
James Hobbs, UC Davis, jahobbs@ucdavis.edu
Bruce Jaffe, U.S. Geological Survey, bjaffe@usgs.gov
Laura Valoppi, U.S. Geological Survey, laura_valoppi@usgs.gov

The South Bay Salt Pond Restoration Project has grappled with legacy mercury contamination from historic mercury mining operations, especially in the Alviso Complex in far South Bay, a known hot spot for mercury contamination within the San Francisco Estuary. This contamination gave restoration project managers pause in moving forward with a full tidal breach of the Pond A5/A7/A8 complex (Pond A8), as previous studies indicated that Pond A8 had some of the highest mercury levels detected in San Francisco Bay estuarine surface water, sediment, bird eggs, fish and other organisms. The concerns with opening up Pond A8 to tidal flows were twofold: 1) Opening Pond A8 would increase the sediment erosion in Alviso Slough, which would likely release additional mercury that had long been buried in the slough sediment, and 2) Opening Pond A8 might increase the mercury methylation and result in increased uptake of methylmercury in birds, fish, and other aquatic life. Methylmercury is the more toxic form of the compound and of most concern. In response, managers installed eight 5-foot gates on a levee between the pond and Alviso Slough. Starting in 2010, prior to the opening of gates in 2011, the effect of incrementally opening the gates over time was studied with respect to mercury speciation, concentration, mobilization and bioaccumulation within the pond itself, as well as in the adjacent slough. This presentation will describe the study results and the cooperation between scientists and managers to adaptively manage this pond complex.

Keywords: wetland restoration; mercury; salt ponds
Session Title: South Bay Salt Pond Restoration: Adaptive Management Success Story
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Measuring Waterbird Response to Salinity, Depth and Foraging Area Manipulation: An Experiment to Inform Adaptive Management

Susan De La Cruz, USGS Western Ecological Research Center, sdelacruz@usgs.gov
John Krause, California Department of Fish and Wildlife, john.krause@wildlife.ca.gov

The goal of the South Bay Salt Pond Restoration Project (Project) is to restore 50-90% of former salt ponds to tidal marsh and reverse historic wetland losses in the San Francisco Bay estuary. However, the Project is faced with the key challenge of balancing the needs of tidal marsh obligate species with those of waterbirds that depend on mud flats and managed former salt ponds. Project managers are currently exploring techniques to enhance managed ponds such that waterbird populations that can be sustained in fewer areas of open water. Towards this goal, the Department of Fish and Wildlife together with Ducks Unlimited reconfigured two former salt ponds (E12 and E13) in the Eden Landing Ecological Reserve with cells comprised of three different salinities and foraging berms designed to maximize prey resources for waterbirds. The U.S. Geological Survey is currently assessing the response of waterbirds and their invertebrate prey to experimental manipulation of salinity and depth within these experimental ponds, with the primary objective of determining optimal conditions for waterbirds during the key periods of wintering and spring migration. Waterbird density, foraging rates, habitat selection, invertebrate prey density and biomass, and water quality are measured at several spatial and temporal scales from September through May. Preliminary results suggest that invertebrate density is highest in low salinity cells, but diversity is greatest in medium and high salinity cells. Small shorebird are the most abundant waterbird guild using the ponds. Their use of different salinities varied across the winter, but their densities were highest in high salinity cells during most winter months. On-going analyses will define which pond and foraging berm characteristics are associated with highest densities of waterbird and invertebrates. Lessons learned from this experimental approach will help managers optimize pond characteristics to meet Project goals of maintaining pre-restoration waterbird populations.

Keywords: Adaptive Management, salt ponds, waterbirds, foraging ecology
Session Title: South Bay Salt Pond Restoration: Adaptive Management Success Story
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Environmental Drivers of Water Hyacinth and Other Floating Aquatic Macrophytes, and Their Impact on Water Quality and Habitat

John Madsen, USDA ARS, jmadsen@ucdavis.edu

Each summer and fall for the past few decades, floating invasive aquatic plants have interrupted the movement of commercial and recreational boats, obstructed access to docks and marinas, and hindered water conveyance for Delta regional agricultural and domestic water use, as well as the state and federal water projects to the Central Valley. Equally significant, but less documented, are the ecological impacts of these floating plants. Before an integrated management plan can be implemented, the first step is to understand the environmental drivers and ecological effects of floating aquatic plant growth. While some native plants are present, most of the nuisance growth is caused by water hyacinth (*Eichhornia crassipes* (Mart.) Solms). Water hyacinth is well adapted to grow in a freshwater estuary such as the Delta, whether freely moving with winds and tides, or loosely rooted in shallow water. In addition to abundant light energy in the dry summer, water hyacinth growth is accelerated by Delta-wide warm air and locally warm water temperatures, possibly excess nutrients available in the water and sediment, and the presence of flooded islands and other backwater areas protected from wind and waves. Under optimal conditions, water hyacinth may double its area coverage or biomass in 8 days. A lack of stormflow and freezing temperatures in the past few years have allowed large quantities of water hyacinth to overwinter, acting as 'nurseries' to increase summer populations. Dense water hyacinth mats restrict reoxygenation of the water, increase sedimentation, and add organic matter to the sediment. Water hyacinth displaces native vegetation, and may impact habitat quality for rare, threatened, endangered, and sensitive fish and other species. The USDA-ARS funded Delta Region Areawide Aquatic Weed Project (DRAAWP) is supporting, among other foci, detailed studies of water hyacinth population growth, phenology, and dispersal, in relation to management techniques.

Keywords: invasive plant, integrated plant management, *Eichhornia crassipes*
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 314

Environmental Drivers and Effects of Invasive and Native Submerged Aquatic Macrophytes in Suisun Bay and the Delta

Katharyn Boyer, Romberg Tiburon Center, San Francisco State University, katboyer@sfsu.edu
Melissa Patten, Romberg Tiburon Center, San Francisco State University, mvpatten@gmail.com
Evyan Borgnis, California State Coastal Conservancy, Evyan.Borgnis@scc.ca.gov
Jen Miller, Romberg Tiburon Center, San Francisco State University, millerj@sfsu.edu

Understanding the factors that influence the distribution and abundance of native and invasive submerged aquatic vegetation (SAV) in San Francisco Estuary is important to the management of these species. We evaluated the distribution and characteristics of native *Stuckenia pectinata*-dominated beds in Suisun Bay and invasive *Egeria densa*-dominated beds in the west Delta through field surveys, and conducted experiments testing the effects of salinity, turbidity, and herbivory on, and competition between, *Stuckenia* and *Egeria*. Our results suggest *Egeria* is limited to the Estuary's fresh waters because it cannot endure higher salinities, with signs of severe stress at a salinity of 5 and complete mortality at 10 or 15. In contrast, *Stuckenia* biomass increased 4-fold over 3 months at salinities of 0 and 5, doubled at 10, and maintained biomass at 15. Competition may also be important in determining distributions at low salinities, as *Egeria* presence led to a 70% decrease in *Stuckenia* biomass in fresh water, while at a salinity of 5, a decline in *Egeria* performance coincided with a doubling of *Stuckenia* shoot density. An experiment testing increased light availability, as is expected with depletion of the erodible sediment pool, showed enhanced growth and flowering for both species with greater light, but that only *Stuckenia* had negative effects of salinity ameliorated through increased light. Common invertebrates (two amphipods, an isopod, and a snail) consumed little live biomass of either species regardless of salinity, with *Egeria* a highly undesirable food choice. In addition to aiding our understanding of current patterns in native and invasive SAV within the low salinity zone, these results can help to predict future patterns under a variety of scenarios of management and climate change. Other submerged plants in the region have not been evaluated for these kinds of biotic and abiotic interactions.

Keywords: Stuckenia, Egeria, pondweed, salinity, turbidity, herbivory, competition
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 314

A Delta-wide Programmatic Approach: Evaluating the Effects of Aquatic Invasive Macrophyte Control on ESA-listed Salmonids and their Habitat

Melanie Okoro, National Oceanic and Atmospheric Administration, NMFS, melanie.okoro@noaa.gov

Aquatic invasive macrophytes are capable of causing extinction of native aquatic plants, reducing biodiversity, competing with native organisms for limited resources, and altering ecosystem processes. Recent initiatives to better understand and address aquatic invasive macrophyte impacts to Endangered Species Act (ESA)-listed fish and their habitat in the Delta have highlighted the complexity of the programs and the regulatory environment in which they operate. As a result, NOAA's National Marine Fisheries Service (NOAA Fisheries) and stakeholders (*e.g.,* California Department of Boating and Waterways, United States Department Agriculture, and United States Fish and Wildlife Service), propose to develop a more holistic and comprehensive approach to aquatic invasive macrophyte control in the Delta that links data and decisions. We propose a new process for planning and regulatory compliance that could streamline the existing process and manage the on-going, expanding, and challenging issues facing invasive macrophyte control. The current control programs are based on a species-by-species approach. The new approach proposes one comprehensive ESA Section 7 Programmatic that incorporates all current and potential future control activities. This shifts the focus from a particular plant species to treatment methods used to control multiple invasive species (*e.g,* chemical, mechanical, physical, and biological). This type of program-level consultation process: (1) provides a new adaptive frame-work for prescribed management actions, (2) has the potential to streamline the existing regulatory process, and (3) decreases the time to implementation. A Delta-wide programmatic approach to aquatic invasive macrophyte control is a prudent step forward to help better inform management actions, minimize future risk to listed species and their habitat to help meet ESA-listed species recovery goals and objectives.

Keywords: aquatic invasive species, macrophytes, Endangered Species Act, Section 7, NOAA
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 314

Watershed-Scale Modeling of Land-Use and Altered Environment Impacts on Aquatic Weed Growth in the Delta

David Bubenheim, NASA Ames Research Center, Earth Science Division, david.l.bubenheim@nasa.gov
Christopher Potter, NASA Ames Research Center, Earth Science Division, chris.potter@nasa.gov
Minghua Zhang, UC Davis, Department of Land, Air and Water Resources, mhzhang@ucdavis.edu

The California Delta is the hub for California's water supply. Changes in climate, long-term drought, and water quality have all been suspected as playing role in the dramatic expansion of invasive aquatic plants and their impact on ecosystems of the Bay / Delta complex. NASA, USDA, Cal-DBW, and UC Davis have partnered to develop science-based, adaptive-management strategies for invasive aquatic plants in the Delta. Effective management strategies to require understanding of how the magnitude of fluctuations in land-use and climate / drought induced altered environments affect plant growth. We utilize the Soil Water Assessment Tool (SWAT), a watershed-scale model, as the backbone for a customized Delta model – Delta-SWAT. The model uses land-use, soils, elevation, and hydrologic routing to characterize pesticide and nutrient transport from the Sacramento and San Joaquin watersheds and loading into the Delta. Land-use within the Delta, as well as water extraction to supply those functions, and the resulting return of water to Delta waterways are included in Delta-SWAT. Delta-SWAT water quality trend estimates are compared with water quality monitoring conducted throughout the Delta. Aquatic plant response to water quality and other environmental factors is carried out using a customized model component. Plant response to the range of water quality factors, response times, and altered temperature and light regimes of the Delta have required gap-filling studies to provide model parameters. Delta-SWAT provides a tool for evaluating temporal and spatial effects of land-use and altered environments in the Delta and contributing watersheds on aquatic weed growth. Using Delta-SWAT for simulation modeling allows evaluation of historic and current conditions as well as consideration potential climate change and management practice outcomes. Delta-SWAT adds to the scientific understanding of dynamics in the Delta and enhances development of science-informed, management strategies and practices.

Keywords: modeling, invasive aquatic plants, climate change, drought
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 314

High-Resolution Mapping for Determining Long-Term Trends in the Distribution of Floating and Submerged Aquatic Macrophytes in the Delta

Shruti Khanna, University of California, Davis, shrkhanna@ucdavis.edu
Joaquim Bellvert, University of California, Davis, jbellvert@ucdavis.edu
Jennifer D. Boyer, University of California, Davis, jenboyer@ucdavis.edu
Kristen Shapiro, University of California, Davis, kdshapiro@ucdavis.edu
Erin L. Hestir, North Carolina State University, elhestir@ncsu.edu
Maria J. Santos, Utrecht University, m.j.ferreiradossantos@uu.nl
Susan L. Ustin, University of California, Davis, slustin@ucdavis.edu

The Sacramento-San Joaquin Delta is one of the most modified estuaries in the world with a network of levees, dams, and canals, which has made it vulnerable to biological invasions. There are two dominant invasive floating aquatic vegetation (FAV) genera, water hyacinth (*Eichhornia crassipes*) and water primrose (*Ludwigia* spp.), and several non-native submerged aquatic vegetation (SAV) species that have invaded the Delta. We acquired imaging spectroscopy data in June 2004 through 2008, November 2014, and September 2015 at a pixel resolutions of 2.5 to 3 m for the entire Delta (~2500 km^2). The two main objectives of our current study are: 1) classify SAV, emergent, and FAV communities in the Delta, and quantify change in abundance and distribution; and 2) determine the interactions between these communities and their response to the California drought. We used the machine learning algorithm Random Forest to classify the communities and species, and multiple change detection algorithms to determine species interactions. Our results show the total invaded area increased from 6,700 acres in 2008, to 11,400 acres in 2014, with the largest increase in spatial spread of FAV species. Both water hyacinth and water primrose have replaced native pennywort (*Hydrocotyle umbellata*) cover becoming the two main co-dominant FAV plants. Invasive SAV cover remains relatively constant and is still dominated by invasive *Egeria densa*. Furthermore, our results show that invasive FAV invade areas already colonized by SAV and when they are treated and removed, SAV re-colonize the same areas. SAV species reduce water velocity by increasing roughness causing sediment to fall out of the water column and turbidity to decrease. These results have major implications for the restoration and management of invasive species in the Delta, potentially guiding control efforts in major nurseries of both FAV and SAV invasive species.

Keywords: invasive floating macrophytes, submerged macrophytes, remote sensing, delta
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta I
Session Time: Wednesday 8:20 AM – 10:00 AM, Room 314

Testing New Herbicides for Control of Invasive Aquatic Plants in the Delta

Guy Kyser, UC Davis Plant Sciences, gbkyser@ucdavis.edu
John Madsen, USDA-ARS, jmadsen@ucdavis.edu

A limited selection of herbicides is available for controlling aquatic plants. In particular, the chemicals most commonly used for controlling emergent species include glyphosate and 2,4-D, both of which have come under increasing scrutiny. We have addressed this issue by conducting screening trials for new and under-used herbicides on two of the Delta's most problematic invasive aquatic plants, water hyacinth and egeria. The new herbicides selected are classified as reduced-risk pesticides by US EPA. Water hyacinth studies were conducted during summer 2016, in 1-m^2 floating quadrats anchored to the sediment within a submerged island in the Sacramento/San Joaquin River Delta. Ramets were placed in the quadrats, allowed to propagate for four weeks, then treated with foliar herbicides at several rates, in four replications per treatment. Among other treatments, the newly registered chemicals penoxsulam and imazamox were compared with the established herbicides glyphosate and 2,4-D. Evaluations were conducted four weeks after application. This study was repeated during the season, with some changes in the rates of herbicides tested. In a second study, we evaluated the effect of available labeled aquatic herbicides on egeria. This trial was conducted on established colonies of egeria in 40-gallon mesocosms at the USDA-ARS Aquatic Weed Lab, Davis, California. Ten registered herbicides, in four replications, were applied in standard concentrations. Treatments were evaluated ~12 weeks after application. This set of studies will allow us to make best-use recommendations for herbicide control of water hyacinth and egeria, with the ideal outcome of reducing populations of invasive aquatic plants in the Delta while minimizing environmental risks.

Keywords: invasive, weeds, aquatic, herbicides, egeria, hyacinth
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 314

The Present and Future Contribution of Biological Control to Integrated Adaptive Management of Water Hyacinth and other Invasive Aquatic Macrophytes in the Delta

Patrick Moran, USDA-ARS Exotic and Invasive Weeds Research Unit, Patrick.Moran@ars.usda.gov
Paul Pratt, USDA-ARS Exotic and Invasive Weeds Research Unit, Paul.Pratt@ars.usda.gov

Non-native, invasive aquatic plants in the Delta block water conveyance for irrigation and urban use, impede navigation, and negatively influence critical aquatic habitat quality parameters. Chemical and mechanical control of floating water hyacinth (*Eichhornia crassipes*) and submersed Brazilian waterweed (*Egeria densa*) are hindered by lack of access to some invasive plant populations. The use of biological control, specifically insects from the native range that can survive only on the weed and that disperse to all weed populations, needs to be increased. Three insects were previously released for biocontrol of water hyacinth. In the present study, water hyacinth was surveyed monthly at 16 locations in the Delta and nearby. Only one weevil species, *Neochetina bruchi*, was present, averaging five adults and 14 larvae per plant in early summer and fall population peaks. Weevil densities were not associated with water nitrogen content. Efforts are underway to test accessions of the weevil *N. eichhorniae* that are better-adapted to Delta climatic conditions than the one previously released. The planthopper *Megamelus scutellaris* was released in 2011 and has established a population on water hyacinth upstream of the Delta, increasing its density 10-fold between 2012 and 2015. A potential agent of Brazilian waterweed, a leaf- and stem-mining fly, was not released due to nontarget feeding in laboratory tests. In recent years, other floating invasive macrophytes have emerged as significant threats, including water-yellow primrose (*Ludwigia* spp.) and South American spongeplant (*Limnobium laevigatum*). Insects are being searched for and tested by foreign collaborators as potential biocontrol agents of these weeds. The development of well-established, efficacious biocontrol agents targeting invasive aquatic macrophytes in the Delta is expected to contribute to an adaptive, integrated management framework being implemented under a USDA-ARS-funded Delta Region Areawide Aquatic Weed Project. Improved control is expected to protect water resources and enhance habitat quality.

Keywords: Biological control, Invasive aquatic weeds, herbivory, integrated weed management
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta II
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Early Results of Improved Delta-Wide Integrated Adaptive Management of Water Hyacinth, Brazilian Waterweed and Curly-Leaf Pondweed

Angela Llaban, California State Parks Division of Boating and Waterways, angela.llaban@parks.ca.gov
Jeffrey Caudill, California State Parks Division of Boating and Waterways, jeffrey.caudill@parks.ca.gov

Invasive plants cost the state of California at least $82 million each year for control, monitoring, and outreach while negatively impacting property values, agricultural productivity, outdoor recreation and ecosystem health. The California State Parks Division of Boating and Waterways (Parks-DBW) is designated as the lead State agency for cooperating with Federal, state, and regional public agencies to control invasive aquatic plants in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh. The Delta provides water for more than 25 million Californians, millions of farmland acres, fish and wildlife habitat and recreational opportunities. Parks-DBW currently implements chemical and mechanical control measures through an integrated management approach for water hyacinth (*Eichhornia crassipes*), Brazilian waterweed (*Egeria densa*), South American spongeplant (*Limnobium laevigatum*), and curly leaf pondweed (CLP) (*Potamogeton crispus*). Mechanical control has been utilized for water hyacinth since 2013 in the Delta. Annual acres of water hyacinth and *Egeria* treated with herbicides have averaged 1,600 and 1,643 since 1990 and 2004, respectively, but increased to 4,447 acres in the case of water hyacinth in 2015. Plans for 2016 target similar acreage for water hyacinth and spongeplant, and over 2,200 acres of *Egeria* and CLP. A new adaptive management program is being developed with research partners based on knowledge derived from remote sensing, weed population growth modeling, the testing and use of new herbicides, efficacy tracking, surveys of aquatic plants, and analysis of water quality in relation to weeds control. While chemical treatments remain the most effective control option available, other methods including targeted mechanical control and possible biological control pending federal approvals are being implemented as part of Parks-DBW's integrated management approach to maximize efficacy and minimize program impacts. Ongoing research and conceptual models provide valuable insight into determining the sustainable balance between the various control measures and ecosystem health.

Keywords: Invasive species, nonnative, integrated pest management, water hyacinth, Egeria densa
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta II
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Analysis of Satellite and Airborne Imagery for Detection of Water Hyacinth and other Invasive Floating Macrophytes in the Delta

Christopher Potter, NASA Ames Research Center, chris.potter@nasa.gov

Waterways of the Sacramento San Joaquin Delta have recently become infested with invasive aquatic weeds such as floating water hyacinth (*Eichhoria crassipes*) and water primrose (*Ludwigia peploides*). These invasive plants cause many negative impacts, including, but not limited to: the blocking of waterways for commercial shipping and boating; clogging of irrigation screens, pumps and canals; and degradation of biological habitat through shading. Zhang et al. (1997, Ecological Applications, 7(3), 1039–1053) used NASA Landsat satellite imagery together with field calibration measurements to map physical and biological processes within marshlands of the San Francisco Bay. Live green biomass (LGB) and related variables were correlated with a simple vegetation index ratio of red and near infra-red bands from Landsat images. More recently, the percent (water area) cover of water hyacinth plotted against estimated LGB of emergent aquatic vegetation in the Delta from September 2014 Landsat imagery showed a 80% overall accuracy. For the past two years, we have partnered with the U. S. Department of Agriculture (USDA) and the Department of Plant Sciences, University of California at Davis to conduct new validation surveys of water hyacinth and water primrose coverage and LGB in Delta waterways. A plan is underway to transfer decision support tools developed at NASA's Ames Research Center based on Landsat satellite images to improve Delta-wide integrated management of floating aquatic weeds, while reducing chemical control costs. The main end-user for this application project will be the Division of Boating and Waterways (DBW) of the California Department of Parks and Recreation, who has the responsibility for chemical control of water hyacinth in the Delta.

Keywords: Sacramento San Joaquin Delta, water hyacinth, Landsat remote sensing
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 314

Bio-Economic Modeling of Invasive Aquatic Weed Management

Karen Jetter, University of California Agricultural Issues Center, jetter@primal.ucdavis.edu

Problem statement: Effective management of invasive weeds requires knowledge of current management costs, and the cost of alternative management options.

Approach: A summary of costs by different agencies that are affected by aquatic weeds in the Delta will be presented. A bio-economic management model will then be presented demonstrating cost trade-offs in weed management. This model takes into account weed spread and whether an area is primarily a site from which weeds spread (i.e. a nursery site) or a site where weeds accumulate (i.e. a slough). Different weed management options are then simulated, and the cost estimated for each option. The options are then compared to determine the least cost solution.

Results: The result of the surveys show that the costs incurred by agencies, such as the Port of Stockton, and marinas that manage aquatic weeds in the Bay-Delta have been increasing. In addition, many agencies and marinas are looking into investing in more long-term solutions to local weed management such as purchasing harvesters or conveyors to remove weeds.

The results of the bio-economic model show that the least cost solution when all agencies are grouped together is the one that treats infestations when they are as small as possible. However, when costs are separated into costs incurred by agencies that provide areawide control, and those agencies that manage local infestations, the least cost solution may change. It also shows that the size of the infestation to manage may not be the determining factor. For effective cost management of invasive weeds the determining factor may be how many times an area will be treated.

Relevance: The bioeconomic model uses both weed growth models and economic models to determine optimal management under different scenarios. The model can also be adapted to incorporate additional weed management scenario as new information becomes available.

Keywords: Management costs, bio-economic modeling, simulation models
Session Title: Integrated Scientific Approaches for Adaptive Management of Invasive Aquatic Plants in the Delta II
Session Time: Wednesday 10:20 AM – 12:00 PM, Room 314

The Effect of Three Agricultural Barriers on Migrating Anadromous Salmonid Juveniles in the Southern Portion of the Sacramento-San Joaquin River Delta

Mark D. Bowen, Environmental Science Associates, mbowen@ESAssoc.com
Tracey W. Steig, Hydroacoustic Technology, Inc., tsteig@htisonar.com
Samuel V. Johnston, Hydroacoustic Technology, Inc., sjohnston@htisonar.com
Kevin W. Clark, California Department of Water Resources, Kevin.Clark@water.ca.gov
Richard A. Horsfield, Turnpenny Horsfield Associates, Richard.Horsfield@THAaquatic.com
Hannah Marchant, Turnpenny Horsfield Associates, hannah.marchant@THAaquatic.com
Benjamin T. Geske, California Department of Water Resources, Benjamin.Geske@water.ca.gov
Jason G. Romine, U.S. Geological Survey, jromine@usgs.gov
Christopher W. Fitzer, Environmental Science Associates, CFitzer@esassoc.com

The California Department of Water Resources installs temporary barriers in the southern portion of the Delta to maintain water levels for agricultural diversions (South Delta Agricultural Barriers: SDABs). The barriers could impede the outmigration of juvenile salmonids. In addition, the SDABs may provide refugia for ambush predators such as largemouth bass (*Micropterus salmoides*). During 2010 and 2011 acoustic telemetry and DIDSON imaging were employed to evaluate routing, survival, and predator abundance at the SDABs before, during and after barrier installation. Preliminary results showed that of those Chinook juveniles that entered the Old River in 2011, 98% selected the Old River Route and 2% selected the Middle River route for their migration through the south Delta. In 2011, the joint probability of route entrainment and survival from the "ORS" hydrophone array to the hydrophone array immediately upstream of Clifton Court Forebay's Radial Gates (Array: RGU) was 0.229 before-construction and 0.437 after-construction of the Old River at Tracy barrier. The "ORS" hydrophone array was located 0.5 km downstream of the Middle River-Old River divergence. In both 2010 and 2011, DIDSON imaging showed an increase in predator density through time. For example, the Middle River barrier in 2011 showed that predator density increased from 0.73 to 3.27 predators/1000 cubic meters from the before to after-construction phases. At the Old River at Tracy barrier density increased from 0.87 to 2.61 predators/1000 cubic meters. The DIDSON results suggested that the construction of these agricultural barriers created in-stream structure that could provide velocity refugia and/or increased predation attack success. Alternatively, predatory fishes might accumulate in these areas due to blockage of migratory routes. Ecosystem sustainability may be affected by these barriers because they alter the local density of predators, cause changes in survival and could cause indirect effects to outmigrating Chinook and steelhead.

Keywords: Chinook salmon, migration, fish barriers, survival modeling, predator density
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 314

Combining Models of the Critical Streak Line and the Cross-Sectional Distribution of Juvenile Salmon to Predict Fish Routing at River Junctions

Dalton J. Hance, USGS, Western Fisheries Research Center, dhance@usgs.gov
Russell W. Perry, USGS, Western Fisheries Research Center, rperry@usgs.gov
Adam Pope, USGS, Western Fisheries Research Center, apope@usgs.gov
Xiaochun Wang, California Department of Water Resources, Xiaochun.Wang@water.ca.gov
Jon Burau, USGS, California Water Sciences Center, jrburau@usgs.gov
Aaron Blake, USGS, California Water Science Center, ablake@usgs.gov

Agent based models of juvenile salmon in the Delta are implemented within hydrodynamic models that vary from simple one-dimensional models to three-dimensional models. In one-dimensional models, an individual's location is modeled in the streamwise dimension. However, the hydrodynamic model provides no information about water velocities in the cross-stream or vertical dimension, which would be expected to influence the cross-stream location of fish. Yet the distribution of juvenile salmon across a channel's cross-section upstream of a river junction affects the proportion of fish that will enter one channel or the other. For example, fish located on one side of the critical streakline — the location in the channel cross-section that divides parcels of water entering one channel or the other — are more likely enter one channel than the other. By analyzing two-dimensional tracks of acoustic tagged juvenile salmon, we investigate how river flow and tides affect the cross-sectional distribution of juvenile salmon approaching the junction of the Sacramento River and Georgiana Slough. We then predict the probability of fish entering Georgiana Slough as the proportion of fish located to the Georgiana Slough side of the critical streakline. We found that the cross-section distribution of juvenile salmon is concentrated near center channel with fewer fish located near the shoreline. The critical streakline was nearly always to the Georgiana Slough side of the mean fish location in the cross section, leading to a lower probability of fish entering Georgiana Slough relative to the proportion of water entering Georgiana Slough. Our analysis provides a mechanistic understanding of why migrating juvenile salmon do not distribute among channels in direct proportionality to flow. Our framework also provides a simplified model for predicting migration routing in one-dimensional hydrodynamic models that do not inform the cross-stream location of inividuals.

Keywords: Juvenile salmon, hydrodynamic models, critical streakline, Georgiana Slough
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 314

Vector and Optomotor Analyses Indicate that Adult and Juvenile Green Sturgeon Exhibit Rheotaxis

Peter Klimley, UC Davis, Dept. of Wildlife, Fish, & Conservation Biology, apklimley@ucdavis.edu
Myfanwy Johnston, Dept. of Wildlife, Fish, & Conservation Biology, UC Davis, merowlands@ucdavis.edu

The spatial and temporal dynamics of water flows can profoundly affect the movements of fish. Moving in opposition to a current increases the energetic cost of transport since the animal has to exert an added effort to compensate for the opposing movements of the water mass in which it is swimming. Alternatively, currents may facilitate an individual's movement and decrease energetic costs. Given such costs and benefits, fish would be expected to have evolved means to both detect currents and use them when possible to move efficiently, thus minimizing energy output. Species thus have evolved a behavioral capability termed rheotaxis, the ability to detect flowing water, and in some cases derive the direction of flow and move either in its direction (positive) or its reverse direction (negative). Adult green sturgeon forage near the bottom in the presence of negligible currents in the San Francisco Estuary, but ascend in the water column and migrate during strong flows. They perceive the direction of flow, and move upriver or downriver actively swimming in the direction the current is flowing. Vector analysis was applied to tracking and current data to demonstrate that the direction of sturgeon swimming is non-random and statistically similar to the direction the current flow. Experiments were carried out on juvenile green sturgeon in a flow chamber with a moving background above and below the subject. While the presence of flow was an excellent predictor of proportion of time spent positively rheotactic, the presence of visual stimuli was not. We recommend that similar field and experimental studies be carried out on juvenile salmonids to improve the ability to predict their rates of movement through the estuary in variable flows.

Keywords: Sturgeon, flows, rheotaxis, vector analysis
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 314

Are All Who Wander Lost? Evaluating the Mechanistic Potential for Altered Juvenile Salmonid Routing and Navigation in a Hydrodynamically Complex and Modified Tidal Estuary

Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Travis Hinkelman, Cramer Fish Sciences, travis.hinkelman@fishsciences.net

Anadromous fishes have evolved to migrate through complex environments to survive and exploit available resources (food and habitat). In simple river-estuary systems, juvenile salmonids migrating to the ocean may require no navigation beyond "going with the flow" until saline waters are reached. However, for juvenile salmonids migrating and rearing in tidal channels of an inverted estuary (such as the Delta) or traversing large open waters such as San Francisco Bay (or the Pacific Ocean), navigation by hydrodynamic, chemical, or geomagnetic cues are likely to be important. Field studies, modeling exercises, and management decisions related to juvenile passage through the Delta can benefit from a clear understanding of these navigation cues and their likely importance to salmonid rearing and migration. Utilizing model simulation results and other data sources, we will provide an overview of how migration cues suggested by the scientific literature functioned in a natural Delta and how they have changed in response to physical changes and water project operations in the modern Delta. From this foundation, we will propose hypotheses for how water project operations may influence juvenile salmonid navigation in the Delta, examine conclusions supported by available data, recommend areas where additional investigation is needed, and discuss implications for models of juvenile salmonid migration through the Delta.

Keywords: salmon, navigation, hydrodynamics, routing, rearing, behavior, evolution
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 314

Using an Individual-Based Model to Explore How Routing, Predation, and Export Salvage Can Influence Through-Delta Survival for Juvenile Salmonids Originating from the San Joaquin River Basin

Travis Hinkelman, Cramer Fish Sciences, travis.hinkelman@fishsciences.net
Bradley Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net

Tagging studies show poor through-Delta survival for juvenile salmonids in the South Delta; management actions that can improve survival for these fish are urgently needed. Early coded-wire tag studies suggested survival was best for fish remaining in the mainstem San Joaquin River, but recent acoustic telemetry studies have not confirmed this earlier finding. We developed an individual-based model of juvenile salmonid passage through the Delta (called the IB-DPM) that incorporates routing based on hydrodynamics, salvage based on exports, and survival based on the XT model, which includes both distance traveled and exposure time. We used the IB-DPM to conduct simulation experiments that involved varying South Delta exports and varying the in-river survival of juvenile salmonids through key migratory routes in the South Delta. We found that when in-river survival rates are high, natural migration through the San Joaquin River provides the best outcomes. Conversely, we found that when in-river survival is low, migrating fish have higher through-Delta survival when entrained, salvaged, and trucked because salvage and trucking incurs less mortality than migrating in river through a (presumed) gauntlet of predators. We also found that overall survival to Chipps Island was higher for total exports (CVP + SWP) of 5,000 cfs than exports of 1,500 cfs over a large range of survival values because increasing exports increases the probability that fish will be salvaged, particularly at the CVP facility, which has much lower pre-screen mortality (0.15) than the SWP facility (0.85). Given poor habitat and high predation mortality in the South Delta, these findings suggest placement of the HORB blocks access to what can be the highest survival route for juvenile salmonids originating from the San Joaquin River basin.

Keywords: individual-based, agent-based, model, salmonid, exports, predation, XT model, gauntlet, exposure
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters I
Session Time: Wednesday 1:35 PM – 3:15 PM, Room 314

Hydrological Landmarks, Hydrodynamic Transport, Final Destinations and Travel Times of Commuter Salmon in an Urban Estuary

Vamsi Krishna Sridharan, UCSC, NMFS NOAA Affiliate, vamsi.sridharan@noaa.gov
Doug Jackson, ERG, doug.jackson@erg.com
Russel Perry, USGS, rperry@usgs.gov
Adam Pope, USGS, apope@usgs.gov
Xiaochun Wang, DWR, California, xiaochun.wang@water.ca.gov
Eric Danner, NMFS NOAA, eric.danner@noaa.gov
Stephen Monismith, Stanford University, monismith@stanford.edu
Steven Lindley, NMFS NOAA, steve.lindley@noaa.gov

The population of the endangered Chinook Salmon depends on physical stressors in their early-life habitat in California's Central Valley rivers; altered hydrology, water use, and predation as they transit through the Sacramento-San Joaquin Delta (henceforth, the Delta) and San Francisco Bay; and physical and biological processes in the coastal ocean. Of these, the Delta is where targeted management action can have the most impact. It is also the most contentious setting in terms of multipurpose water use, varied interest groups and legislation. A mechanistic understanding of fate is crucial to informing best management practices. In this study a novel particle tracking model with accurate hydrodynamics and well-reasoned behavior hypotheses has been developed and used to simulate the movement and fate of Chinook Salmon smolts as they swim towards the ocean via the Delta. The effects of (i) flow, (ii) water diversion and gate operations, (iii) predation, and (iv) hydraulics induced habitat quality manifest themselves on the ultimate fates of simulated smolt and the time to those fates. Spatial correlations with fate occur due to the combination of these four stressors, such as entrainment by water diversions occurring within the zone of influence of the pumping projects and increased escapement due to better habitat. Temporal dynamics of the fates are explained by the dominant travel pathways of Salmon through the Delta and the system scale hydrodynamic transport and mixing mechanisms along these pathways. A comparison of simulated smolt with simulated tracer particles decomposes the fish biology from the hydrodynamics, and also addresses three key questions: (i) what data gaps need addressing in fish monitoring and modeling, (ii) can environmental parameters be used as surrogates for fish surveys in data-poor situations, and (iii) can the hydrodynamics help us infer the fate of other species in the Delta and in other estuarine systems.

Keywords: Particle Tracking, Salmon, transport and mixing, Spatial and temporal fate
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 314

ELAM (Evaluating Likely Animal Movement) at Georgiana Slough: Leveraging 52 Data Sets Over 17 Years toward Representing Fish in Any 2-D/3-D Hydrodynamic and Water Quality Model

R. Andrew Goodwin, U.S. Army Engineer R&D Center, Env. Lab, R.Andrew.Goodwin@gmail.com

Understanding key fish behavior phenomena, such as the repeated observation that fish change their response to unchanging hydraulics, is key to reducing infrastructure design iterations. I analyzed fish movement behavior across 52 data sets representing 17 years of observation when hydraulics was concurrently measured. Results support observations dating back to the 1950s, and earlier, regarding the importance of water acceleration and inertial stimuli in fish movement. Findings also support the notion that fish, like other animals, evaluate the world in relative terms. I leverage this prior work to understand the potential for guiding fish in critical Bay-Delta areas such as Georgiana Slough. Water acceleration can "shape" individual trajectories of downstream migrating fish based on four behaviors: *B*{1} fish moves as a correlated random walk biased in the direction of water flow; *B*{2} fish swims toward faster water when water acceleration changes (increases) by sufficient magnitude; *B*{3} fish swims upstream when water acceleration changes (increases) by a larger magnitude; *B*{4} fish swims towards its acclimatized depth if pressure (depth) changes by sufficient magnitude. Key to evaluating likely animal movement (ELAM) in a 2-D or 3-D hydrodynamic and water quality model are (i) very few tunable parameters, (ii) realism in describing behavior switching, and (iii) computationally efficient optimization appropriate for the parameters of the behavior algorithm and the spatial statistics used. Computer simulations can then elucidate behavior combinations, *B*, that satisfactorily reproduce measured fish patterns. At Georgiana Slough, fish behavior is important. Particles, with no behavior, released at the same times and positions as real fish observations enter the slough in greater numbers than remain in the Sacramento River for two time periods we have evaluated so far: 1-7 January 2009 (53.6% Georgiana versus 46.4% Sacramento) and 16-22 January 2009 (55.8% Georgiana versus 43.5% Sacramento; 0.7% exit upstream).

Keywords: Individual based model, fish passage, ecohydraulics, fish navigation, fish movement
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 314

Examining Hypothesized Delta Smelt Environmental Cues and Swimming Behaviors using an Agent-Based Model

Benjamin Saenz, Resource Management Associates, Inc., benjamin.saenz@rmanet.com
Edward Gross, Resource Management Associates, Inc., ed@rmanet.com
Stephen Andrews, Resource Management Associates, Inc., steve@rmanet.com
Richard Rachiele, Resource Management Associates, Inc., richard@rmanet.com
Lenny Grimaldo, ICF, Lenny.Grimaldo@icfi.com
Stacie Grinbergs, Resource Management Associates, Inc., stacie@rmanet.com

Understanding the cues and mechanisms of delta smelt migration smelt in the Sacramento-San Joaquin Delta would enable improved management of resources during the rapid seasonal changes in fish distribution. Migratory cues may be related to decreasing salinity and/or increasing turbidity as flows increase after winter rains. Catch history indicates these small fish move upstream rapidly, at 1.8-6.3 km/day, requiring some version of tidal surfing behavior to avoid unrealistic energy expenditure. We developed several simple behaviors including swimming along depth, salinity or turbidity gradients, rheotaxis, and lateral or cross-stream taxis for use in agent-based modeling frameworks. Behaviors were triggered by absolutes or gradients of water quality, current speed, depth, distance to shore, and flood or ebb tidal status. Behaviors and associated triggers were combined into simple behaviors sets using delta-smelt swimming speeds, with the goal of examining the efficacy of turbidity seeking, lateral tidal migration strategies, and rheotaxis both independently and in combination with other likely behaviors. These behavior sets were applied to particle tracking routines using both depth-averaged (RMA2) and 3-dimensional (UnTRIM) calibrated hydrodynamic models that include sediment-transport-derived turbidity and salinity. Results showed that tidal migration that involved swimming along depth gradients (i.e. swim shallower during ebb) retained particles at higher flows compared to tidal migration with respect to current speed (i.e. swim to lower velocity water during ebb). In general, following turbidity gradients results in lower particle retention and less upstream movement than depth or speed based cues. During high flows, simulated delta smelt have difficulty moving upstream in the Sacramento. Currently, the hydrodynamic models do not resolve velocity very near to the shore, yet migrating fish may take advantage of these low velocity refugia during strong ebb flows. Higher resolution modeling of critical migration corridors may be necessary to examine fish behavior in high-flow scenarios.

Keywords: delta model, particle tracking, hydrodynamic, delta smelt behavior, fish, Sacramento
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 314

Using Gaussian Process Models to Fit an Enhanced Particle Tracking Model to Acoustic Telemetry Data of Juvenile Salmon

Russell W. Perry, USGS, Western Fisheries Research Center, rperry@usgs.gov
Adam Pope, USGS, Western Fisheries Research Center, apope@usgs.gov
Doug Jackson, Energy Research Group, doug.jackson@erg.com
Vamsi Sridharan, NOAA, Southwest Fisheries Science Center, vamsi.sridharan@noaa.gov

Particle tracking models embedded within hydrodynamics models provide a means for understanding how passive particles are transported in a complex hydrodynamic environment such as the Sacramento-San Joaquin River Delta. Recent efforts have focused on adding behaviors to particles to simulate how juvenile salmon negotiate the complex channel structure and tidal environment of the Delta. Modeling fine-scale hydrodynamics coupled with fish behaviors can provide a better understanding of patterns in migration timing, routing, and survival. However, methods for estimating values of behavioral parameters in stochastic particle tracking models are lacking. Here we present techniques for estimating behavioral parameters in an enhanced particle tracking model (ePTM) employed in the DSM2 (Delta Simulation Model 2) hydrodynamic model by fitting the ePTM to acoustic telemetry data. First, we used Gaussian process models (i.e., Kriging) to map specific values of behavioral parameters (e.g., swimming velocity) to ePTM outputs that can be evaluated against the telemetry data (e.g., reach-specific travel times). The Gaussian process model allowed us to predict the outputs of the ePTM at any input value of the behavioral parameters without having to actually run the ePTM, which is computationally prohibitive. Next, we estimated behavioral parameters by fitting the ePTM outputs, as predicted by the Gaussian process model, to telemetry data on juvenile late-fall Chinook salmon collected from 2007-2010. The fitting was implemented in a Bayesian framework using Markov Chain Monte Carlo techniques, which allowed us to incorporate multiple sources of uncertainty such as stochasticity of the ePTM, error from the Gaussian process model, and inherent sampling error associated with the telemetry data. Our methods provide a general framework for fitting complex agent based models to empirical data, providing not only estimates of behavioral parameters, but also estimates of uncertainty.

Keywords: particle tracking model, juvenile salmon, DSM2, hydrodynamic model
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 314

Particle Swarm Optimization Techniques for Estimating Juvenile Salmon Behavioral Parameters in an Enhanced Particle Tracking Model

Adam C. Pope, USGS, apope@usgs.gov
Russell W. Perry, USGS, rperry@usgs.gov
Jason G. Romine, USGS, jromine@usgs.gov
Xiaochun Wang, CADWR, Xiaochun.Wang@water.ca.gov

The Sacramento-San Joaquin Delta (hereafter Delta) is an intensively managed network of interconnected channels that juvenile salmon must negotiate. Tools that can predict the effect of changing flows on fish movement and survival through the Delta are becoming increasingly important as ecosystem-level impacts such as climate change and water exports increase. Enhanced particle tracking models that incorporate simulated fish behavior within a hydrologic model of the Delta can provide these predictions. Accurately modelling fish behavior within this context, however, presents numerous challenges. Optimizing behavioral movement parameters to fit simulations to empirical data necessitates iteratively generating simulation results, a process which can require intensive computing resources. Furthermore, the simulations contain a stochastic component, which causes results to vary even when using the same set of behavioral inputs, thus complicating efforts to fit the simulation results to data.

Our analysis focuses on a novel method for estimating the behavioral parameters of an enhanced particle tracking model (ePTM) by fitting the model to empirical field data. We utilize a simulated maximum likelihood approach within the context of a particle swarm optimization routine to fit the DSM2 ePTM to travel times of acoustically tagged juvenile salmonids in the north Delta. We expect the calibrated ePTM to become a valuable tool for managers seeking to understand and predict how changes to Delta hydrology will affect juvenile salmonid behavior and survival.

Keywords: particle tracking model, behavioral parameter estimation, particle swarm optimization
Session Title: Developing Spatially Explicit Agent-Based Models for Delta Fishes: Patterns, Processes, and Parameters II
Session Time: Wednesday 3:35 PM – 5:15 PM, Room 314

Quantifying the Abundance, Distribution, and Predation of Salmon by Non-Native Fish Predators in the San Joaquin River

Joseph Smith, University of Washington, jsmithuw@uw.edu
David Huff, Point Adams Research Station, Northwest Fisheries Science Center, david.huff@noaa.gov
Cyril Michel, NOAA Southwest Fisheries Science Center and UC Santa Cruz, cyril.michel@noaa.gov
David Demer, NOAA Southwest Fisheries Science Center, david.demer@noaa.gov
George Cutter, NOAA Southwest Fisheries Science Center, george.cutter@noaa.gov
Suzanne Manugian, NOAA Southwest Fisheries Science Center, suzanne.manugian@noaa.gov
Thomas Quinn, University of Washington, tquinn@uw.edu
Sean Hayes, NOAA Northeast Fisheries Science Center, sean.hayes@noaa.gov

Understanding the factors that influence the survival of native resident and migratory species within the Sacramento-San Joaquin Delta is of great interest to researchers, managers, and stakeholders. The recent survival estimates of juvenile salmon emigrating from the Delta have been extremely low. One of the hypothesized causes of low survival rates is predation by non-native fishes but there has been insufficient research in the Delta to rigorously evaluate this hypothesis. To address this need, we conducted a study in a portion of the San Joaquin River with the following objectives: 1) examine the abundance, distribution, and movement of non-native fish predators, 2) quantify the magnitude of smolt predation with genetic analysis of predator stomach contents, 3) manipulate the density of predators to assess the influence of predator density on the predation rates of salmon smolts, and 4) determine how predation on salmon smolts may be influenced by physical habitat, water chemistry, and other environmental features. In 2014 and 2015 we estimated predator population sizes from electrofishing and hydroacoustics surveys, we described predator movement using acoustic telemetry, quantified predator diets using genetic analysis, relocated predators from removal reaches to addition reaches and determined relative predation rates with predation event recorders (PER) before and after relocation events, and mapped habitat among nine study reaches covering 25 river km of the San Joaquin River. Our results indicated that there were differences in relative abundance, movement patterns, and smolt consumption rates among different predator species. A total of 2,846 predators were removed and relocated but, surprisingly, these removals and additions had negligible influence on predation rates. However, PER predation was influenced by water velocity and other environmental conditions. Our study results will inform salmon life-cycle models and refine future study objectives.

Keywords: predator, salmon, diet, telemetry
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 306

Insight into the Diets of the Primary Fish Predators of the California Delta using DNA Barcoding, and Implications for Salmonid Populations

Cyril Michel, NOAA-NMFS Southwest Fisheries Science Center and UC Santa Cruz, cyril.michel@noaa.gov
Joseph Smith, Univ. of Washington, School of Aquatic & Fishery Sciences, jsmithuw@u.washington.edu
David Huff, NOAA-NMFS Northwest Fisheries Science Center, Hammond, OR, david.huff@noaa.gov
Nicholas Demetras, NOAA-NMFS Southwest Fisheries Science Center and UC Santa Cruz, nicholas.demetras@noaa.gov
Sean Hayes, NOAA-NMFS Northeast Fisheries Science Center, Woods Hole, MA, sean.hayes@noaa.gov

Few studies have been adequately equipped to find direct evidence of predation on salmon smolts. Novel DNA barcoding methods now allow definitive identification of predator stomach contents, even at trace levels. Predator stomachs from largemouth bass (LMB), striped bass (STB), white catfish (WHC), and channel catfish (CHC) were collected from nine 1-km long reaches of the lower San Joaquin River in the spring of 2014 and 2015, totaling 1030 samples. These stomachs were tested for presence of DNA from 12 different fish species, including imperiled native fish and common prey species. We found 46 stomachs containing Chinook salmon DNA, 9 containing steelhead, 9 containing delta smelt, and no detections of green sturgeon or longfin smelt. Focusing on salmonids, 19.2% of CHC, 6.0% of STB, 4.8% of WHC, and 2.8% of the LMB stomachs tested positive for salmonid DNA.

Additionally, we estimated population sizes of LMB and STB in the three primary 1-km collection reaches using electrofishing multi-pass depletion. Using the frequency of salmonid occurrence in LMB and STB diets, coupled with estimates of total metabolic demand of all STB and LMB in those reaches generated using a bioenergetics model, we are able produce an estimate of total salmonids eaten per predator species per reach. The window of temporal inference is approximately 2-4 days for STB, and unknown but likely similar for LMB. Preliminary estimates suggest STB were eating 1 to 160 smolts per reach, with wide variation being primarily due to the heterogeneous distribution of striped bass.

Our current understanding of predator-salmonid interactions in the Delta is largely based on highly localized studies. This study provides a methodology and region-specific results on the critical next step: estimating population-level impacts of predators. Furthermore, understanding the relative effects of different predator species on imperiled prey species can facilitate prioritization of management actions.

Keywords: salmon, predation, diets, bioenergetics, DNA-barcoding
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 306

Development of Predation Event Recorders (PERs) to Quantify Predation of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in a River Environment

Nicholas Demetras, UC Santa Cruz, Southwest Fisheries Science Center - NMFS, nicholas.demetras@noaa.gov
David Huff, Point Adams Research Station, Northwest Fisheries Science Center - NMFS, david.huff@noaa.gov
Cyril Michel, UC Santa Cruz, Southwest Fisheries Science Center - NMFS, cyril.michel@noaa.gov
Joseph Smith, School of Aquatic & Fishery Sciences, Univ. of Washington, jsmithuw@u.washington.edu
George Cutter, Southwest Fisheries Science Center - NMFS, george.cutter@noaa.gov
Sean Hayes, Northeast Fisheries Science Center- NMFS, sean.hayes@noaa.gov

In an effort to evaluate predation as a cause of low survival among juvenile Chinook salmon we designed and tested autonomous, GPS-enabled, predation-event recorders (PERs) for use in a river environment. PERs were outfitted with temperature/light sensors, underwater cameras and predation-activated timers for the purposes of identifying individual predators, precise predation times and locations, and to capture environmental variables that may influence predation. PERs were baited with live juvenile Chinook salmon and were successfully tested and used on the lower San Joaquin River in the spring of 2014 and 2015. Preliminary results from one of the nine study sites suggest a positive relationship between water velocity and predation risk, and a negative relationship between water depth and predation risk. PERs proved to be an inexpensive and reliable tool that successfully quantified relative predation, identified predators, and allowed us to ascertain environmental conditions and locations that resulted in relatively higher predation risks. These studies will provide critical complementary information for acoustic telemetry and predator diet studies, as well as give resource managers the capability to predict the effect of different environmental conditions on the predation of imperiled fish species.

Keywords: Predation, Predation Event Recorder, PER, Chinook Salmon, Sacramento-San Joaquin Delta
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 306

Do Barriers for Deterring Juvenile Salmonids Away from High-Risk Migration Pathways Affect Survival at Important Channel Junctions in the Sacramento-San Joaquin Delta, California?

Marin Greenwood, ICF, marin.greenwood@icfi.com

California's Department of Water Resources is mandated to investigate engineering solutions to reduce juvenile salmonid migration into the low-survival interior Sacramento-San Joaquin Delta. To this end, various barriers have been investigated at important channel junctions. Predation risk near such barriers could increase because of the predator habitat provided by the in-water structures or because of changed juvenile salmonid behavior. The present study investigated survival of acoustically tagged juvenile salmonids at the San Joaquin River-Head of Old River (HOR, 2009-2012) and Sacramento River-Georgiana Slough (GS, 2014) junctions. Predation probability of juvenile Chinook Salmon (CS) at HOR was significantly greater with a bioacoustic fish fence (BAFF) turned on (2009/2010) and a rock barrier (2012) in place than with the BAFF turned off, largely because the barriers guided the CS as intended away from the low-survival route, but inadvertently toward a predator-dense ambush location. In addition, predation probability was positively related to ambient light level, perhaps because visual predators were more successful by day. The estimated proportion of juvenile CS that were preyed upon at HOR ranged from 0.10 in 2011 (high flow, no barrier) to 0.39 in 2012 (lower flow, rock barrier). Bioenergetics modeling illustrated that the potential proportional consumption of CS entering HOR by Striped Bass could have been greater in 2012 (~0.17) than 2011 (<0.005) because 2012 had higher predator density, lower prey density, and higher temperature. At GS, predation probability was not related to the operation of a floating fish guidance structure, but was negatively related to turbidity, possibly because visual predators were more successful in clearer water. The present study illustrates that site-specific considerations are key because barriers and other factors can affect survival at important channel junctions. Additional studies with true no-barrier control conditions are essential to define potential barrier effects on predation.

Keywords: predation; barrier; junction; migration; Chinook Salmon; predator; Striped Bass; bioenergetics
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 306

Shocking for Survival: An Overview of the Pilot Year Effort to Remove Non-Native Predatory Fish from Clifton Court Forebay

Mike Cane, California Department of Water Resources, mcane@water.ca.gov

The California Department of Water Resources (DWR) is conducting a research project to understand the effectiveness of using systematic non-native predatory fish removals as a tool for improving Chinook salmon and steelhead survival across Clifton Court Forebay (Forebay) to the John E. Skinner Delta Fish Protective Facility. Predatory fish are collected using boat based electrofishing and relocating them to Bethany Reservoir. The 2016 effort was a pilot effort to determine catch rates, fish distributions and logistics for the full scale effort which will occur in 2017 and 2018. Removals of non-native predatory fish occurred from April 20, 2016 to May 18, 2016 over 11 days of sampling. Timing is intended to coincide with Chinook salmon and steelhead outmigration period to improve their survival across the Forebay to the fish protective facility. To target different predatory fish species and increase effectiveness for different habitat types, three methods of boat-based electrofishing: 1) electrofishing along the banks and shallow areas focusing on structures that centrarchids tend to associate with, 2) stationary electrofishing with a low frequency (15 pulses per second) current for 5 minutes, a method effective for sampling catfish, 3) electrofishing open water environments which allowed for the capture of striped bass. Concurrent tagged Chinook salmon and steelhead releases at the Forebay radial gates will allow DWR to understand the relative effects that electrofishing will have on the survival of entrained salmonids. During the 2016 pilot study, 2059 striped bass, 594 black bass and 33 catfish were captured. Striped bass fork lengths ranged from 89 mm up to 1040 mm with an average of 290 mm, black bass fork lengths ranged from 99 mm to 625 mm with an average of 309 mm, and catfish fork lengths ranged from 135 mm to 664 mm with an average of 364 mm.

Keywords: predator, fish, salmon
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 306

Mobile Acoustic Methods to Survey Salmon Smolt Predators and their San Joaquin River Habitat

David Demer, NOAA Southwest Fisheries Science Center, david.demer@noaa.gov
George Cutter, NOAA Southwest Fisheries Science Center, george.cutter@noaa.gov
Josiah Renfree, NOAA Southwest Fisheries Science Center, josiah.renfree@noaa.gov
Suzanne Manugian, University of California Santa Cruz, suzanne.manugian@noaa.gov
Sean Hayes, Northeast Fisheries Science Center, sean.hayes@noaa.gov
Joseph Smith, Univ. of Washington, School of Aquatic & Fishery Sciences, jsmithuw@u.washington.edu
David Huff, NOAA Northwest Fisheries Science Center, david.huff@noaa.gov
Cyril Michel, University of California Santa Cruz, cyril.michel@noaa.gov

Predation is thought to be one of the major sources of salmon smolt mortality in the San Joaquin River (SJR) because there are many non-native predatory fishes (e.g. striped bass, largemouth bass, white catfish, and channel catfish). The distributions and abundances of these fish are unknown. To survey these predators and their riverbed habitats an array of sonars was deployed from a small boat. The array included one or two multibeam sonars (500 kHz Simrad M3), one down-looking sonar (200 kHz Simrad ES15 or EK60), and one side- or forward-looking sonar (120 kHz Simrad EK60). Surveys were conducted between March and May 2014 and 2015 spanning nine reaches in the SJR between Port of Stockton and Lathrop as part of an associated predator removal study. The multibeam sonar data were used to measure bathymetry and track fishes. The echosounder data were used to detect, track, and enumerate fishes beneath, to the side, and in front of the survey boat. All of the acoustic data were geolocated using differential GPS positioning, and the bathymetry was compensated for pitch, roll, heave, and tide. The interpretation of backscatter from fishes was aided by the fish length and weight data collected as part of the predator removal study and X-ray images taken from representative specimens of the dominant species and sizes. The shapes of the fish and their swimbladders supported a Kirchoff-Ray Mode model used to estimate frequency-specific backscatter versus fish length. These relationships were used to refine the acoustical survey detections of salmon-smolt predators and the estimations of their numbers and sizes.

Keywords: salmon smolt predation, mobile active acoustic surveys, predator abundance
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 306

Multibeam Mapping of Bathymetry, Riverbed Type, and Predator Habitats in the San Joaquin River

George Cutter, NOAA Southwest Fisheries Science Center, george.cutter@noaa.gov
Suzanne Manugian, University of California Santa Cruz, Suzanne.Manugian@noaa.gov
David Demer, NOAA Southwest Fisheries Science Center, david.demer@noaa.gov

Characteristics of bathymetry and submerged aquatic vegetation (SAV) may be conducive to predation by non-native fish on salmon smolt in the San Joaquin River (SJR). Here, we use multibeam acoustics to map these riverbed habitat characteristics from Port of Stockton to Lathrop, March through May 2014 and 2015. One (2014) or two (2015) Mesotech M3 multibeam sonars were used to fully insonify this shallow river, typically <4 m with holes as deep as 10 m. Full-coverage, 1-by-1-m grid-cell bathymetric maps were generated despite low grazing angles, high-reverberation and clutter, and strong second bottom returns induced by this environment. Riverbed habitats were discriminated by morphology metrics and backscatter intensity. Bathymetry data were used to constrain echosounder detections of fish and convert fish densities to abundances. Novel signal processing of M3 water-column data was used to detect fish among clutter, and patches of SAV. Resulting maps of bathymetry and SAV characterize conditions associated with high salmon-smolt predation along this migration route.

Keywords: multibeam sonar, shallow-water bathymetry, riverbed mapping, riverbed habitats
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 306

Acoustic Detection, Tracking, and Enumeration of Salmon Smolt Predators

George Cutter, NOAA Southwest Fisheries Science Center, george.cutter@noaa.gov
Suzanne Manugian, University of California Santa Cruz, suzanne.manugian@noaa.gov
David Demer, NOAA Southwest Fisheries Science Center, david.demer@noaa.gov

Salmon smolt mortality in the Sacramento-San Joaquin River (SJR) system is impacted by predatory fish. To quantify the abundance, distribution, and habitats of these predators, we devised and implemented a novel active-acoustic method to sample the fish and bathymetry in this shallow-water environment. Acoustic surveys were conducted during March through May, 2014 and 2015 from the Port of Stockton to Lathrop in the area of complementary fish tethering and tagging studies. The survey deployed vertically- and horizontally-oriented split-beam and multi-beam echosounders on a small vessel. Individual fish were acoustically detected using single-target detection and echo-track processing methods with target strength thresholds determined by scattering models developed using specimens from the river. Counts of fish per sampled volume were estimated from fish tracks found within river segments defined by 1- to 100-m distance intervals along the river centerline. Aggregated fish counts were converted to densities by compensating for the integrated sampled volumes of the acoustic beams weighted by the probability of target detections. Assuming uniform densities within river segments, fish abundances were estimated by compensating for river volume. Data provide evidence of temporal and spatial trends of predator abundances and suggest associations with the river environment. Results provide important information for management by elucidating potential areas, times, and conditions where predators and smolt interact.

Keywords: active-acoustic fish detection, predator density/abundance, split-/multi-beam sonars
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 306

Linking Predation Mortality to Predator Density and Survival for Out-Migrating Chinook Salmon in the Lower San Joaquin River and Delta

Alison Collins, MWD, acollins@mwdh2o.com
Shawn Acuna, MWD, sacuna@mwh2o.com
Steve Zeug, Cramer Fish Sciences, stevez@fishsciences.net
Brad Cavallo, Cramer Fish Sciences, bcavallo@fishsciences.net
Lenny Grimaldo, ICF, Lenny.Grimaldo@icfi.com
Jasson Hassrick, ICF, Jason.Hassrick@icfi.com
Marin Greenwood, ICF, Marin.Greenwood@icfi.com
Annie Brodsky, Cramer Fish Sciences, annieb@fishsciences.net

It is currently not clear what proportion of juvenile salmonid mortality can be directly attributed to fish predation and it is difficult to interpret results regarding population-level survivorship in the Bay-Delta because the data have limited spatial scales, used various tagging methodologies, and do not clearly connect tag loss or mortality to predation. It is essential to improve the linkage between mortality events and predation. We will address this research need through the use of baited tethers as predation event recorders and enclosure experiments. Tether experiments allow estimation of relative predation rates in various environments, and reveal information about mortality produced by different species of fish predators. Enclosure experiments allow for controlled manipulation of predator density and habitat type to quantify predation rates and will provide information on how consumption changes as a function of density which is essential for evaluating predation effects on salmon survival while passing hotspots and predicting the benefits and effectiveness of predator control activities. Initial results and lessons learned from a pilot study to build the experimental enclosures, secure them in a tidally influenced channel, design of PIT antennas, and trials of releasing PIT tagged fish through the enclosures will be shared. The full study will be conducted in the spring 2017. These data will be used to identify and characterize statistical relationships between predation mortality rates and other factors to determine how environmental conditions and predator density affect predation mortality. This study will couple survivorship with predation mortality estimates to quantify if fish predation is a substantial component of total mortality in the Bay-Delta and under which circumstances this occurs.

Keywords: salmonid predation
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 306

Predator Diet and Movement Patterns in the Lower Feather River and their Effects on Hatchery Smolts

Andrew Hampton, PSMFC CA DWR, ahampton@water.ca.gov
Ryon Kurth, CA DWR, rkurth@water.ca.gov

Full in-river release of hatchery origin salmonids, as close to the hatchery as possible, was one of several reforms recommended by the California Hatchery Scientific Review Group (CAHSRG 2012), and a goal of draft Hatchery and Genetic Management Plans for the Feather River Fish Hatchery. However, results from acoustic studies on hatchery origin spring run Chinook salmon and Central valley Steelhead (CVST) smolts in the Feather River (and out to the ocean) reveal their downstream migration success is very poor. Such high mortality is problematic for advancing toward our goal of full in-river release. Various release techniques have been implemented to improve migration success, however very little improvement has been observed and the direct cause of mortality has not been identified. Predation is one likely source of mortality that may explain poor outmigrating smolt survival in the Feather River. In an effort to better understand the role of predation, we conducted a fish predator study, focusing on movements and diet. Predators such as striped bass, largemouth bass, smallmouth bass, white catfish, channel catfish and Sacramento pikeminnow were tagged with Vemco acoustic tags and monitored over the course of two years. Stomachs from these species were also collected and compared to identify prey selection in the Lower Feather River throughout the entire year. We compared seasonal diets and noted presence and absence of certain species found in the stomach contents. Using angling and acoustic tag data we were able to identify 'predator hotspots'. Identifying these hot spots may provide opportunity to adjust release strategies to minimize predator success.

Keywords: Predator Diet Movement Patterns Feather Effects Hatchery Smolt
Session Title: Non-Native Predator Fish Research in the Sacramento-San Joaquin Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 306

Status of Sacramento River Winter Run Chinook Salmon: What is Needed to Achieve Viability?

Steve Lindley, NOAA Fisheries, steve.lindley@noaa.gov
Maria Rea, NOAA Fisheries, Maria.Rea@noaa.gov
Rachel Johnson, NOAA Fisheries, Rachel.Johnson@noaa.gov
Noble Hendrix, QEDA Consulting, LLC, noblehendrix@gmail.com

Sacramento River Winter Run Chinook Salmon (SRWRC) are listed as Endangered under the US Endangered Species Act. They exist as a single population restricted from their historical spawning area, in a heavily managed and modified river, dependent on cold-water releases from Lake Shasta. Following listing and a series of conservation actions, SRWRC increased from critically low to moderate abundance levels, but have since declined during a period of poor ocean conditions and prolonged drought. Recent modeling advances reviewed here give deeper insight into the interacting causes of SRWRC's vulnerability to extinction and add further support to the need for the high-priority actions identified in the SRWRC recovery plan. These actions include restoring access to headwater spawning areas that would provide refuge in droughts, and to rearing areas that would increase the productivity of the population.

Keywords: Sacramento River Winter Chinook; Viability; Drought; Modeling
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 306

There and Back Again:
Winter Run Chinook Salmon Drought/Temperature Management from 1988-2013

James Smith, US Fish and Wildlife Service, jim_smith@fws.gov

This presentation will focus on the history of management actions directed towards Winter Run Chinook salmon taken in the upper Sacramento River from the mid 70's to 2016. Winter run chinook salmon have gone through several major droughts in 1977-76, 1988-92 , and 2013-2016 where environmental conditions were extremely poor. Management actions designed to protect and restore the population have varied from doing nothing during the first drought to nearly cutting 100+ year old sacrosanct water rights in recent years. Management actions during the second drought focused on improving fish passage at Red Bluff Diversion Dam and improving in-river water temperatures during spawning. Additional regulatory actions through conditioning of water rights and the issuance of several ESA Biological Opinions were also important towards the protection of winter run. The development of a winter run conservation hatchery starting in the late 1980's whose success in recent years has played a critical role in the protection of the species. In recent years, additional efforts in monitoring as well as improving the science behind survival modeling have assisted in making improved management decisions. With each new drought, new insights are realized and additional levels of management actions are taken or proposed using an ever-increasing science based knowledge base.

Keywords: Red Bluff Diversion Dam Water Temperatures Sacramento River Biological Opinions
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 306

Coupling Headwaters, Reservoirs, and Rivers to Model Water Flows and Temperatures

Miles Daniels, UCSC, miles.daniels@noaa.gov
Eric Danner, NOAA, eric.danner@noaa.gov

Winter-run Chinook salmon is an endangered species largely dependent on regulated water flows and temperatures for survival during their initial and finale life cycle stages. The most southerly remaining run of Chinook rely on the cold-water discharge from California's largest storage reservoir, Shasta Reservoir, in the Sacramento River Watershed to provide suitable conditions from egg to fry development. Drought conditions, however, have put added strain on the multi-use resource of Shasta Reservoir and resulted in Chinook redds being exposed to above than desirable temperatures even after the reservoir was outfitted with a temperature control device to selectively withdraw colder water from deeper regions when needed. Lessons from the ongoing drought have highlighted the potential benefits of improved forecasting capabilities of temperature dynamics above, within, and below Shasta Reservoir for better management of cold-water resources. Therefore, to better understand factors affecting flows and temperature discharges into the Sacramento River downstream from Shasta Reservoir, we coupled hydraulic models of Shasta Reservoir headwaters (i.e. Sacramento, McCloud, and Pit Rivers), Shasta Reservoir, its downstream forebay Keswick Reservoir, and the upper Sacramento River. Models were forced with local meteorological data and scenarios of different reservoir operations examined. Factors observed to affect temperature dynamics will be discussed in the context of cold-water resource management.

Keywords: Hydraulic modeling, Water temperature, Winter-run Chinook
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 306

Why Lab-Derived Estimates of Thermal Tolerance Failed to Predict Survival of Winter-Run Eggs in the Sacramento River and What We Can Do About It

Benjamin Martin, UC Santa Cruz, SWFSC, benjamin.martin@noaa.gov
Andrew Pike, UC Santa Cruz, SWFSC, andrew.pike@noaa.gov
Sara John, UC Santa Cruz, SWFSC, Sara.John@noaa.gov
Natnael Hamda, UC Santa Cruz, SWFSC, natnael.hamda@noaa.gov
Jason Roberts, CDFW, Jason.Roberts@wildlife.ca.gov
Eric Danner, SWFSC, eric.danner@noaa.gov

Predicting species responses to climate change is a central challenge in ecology, with most efforts relying on lab derived phenomenological relationships between temperature and fitness metrics. We tested one of these models using the embryonic stage of the endangered Sacramento River winter-run Chinook. We parameterized the model with laboratory data, applied it to predict survival in the field, and found that it significantly underestimated field-derived estimates of thermal mortality. We used a simple biophysical model based on mass-transfer theory to show that the discrepancy was due to the differences in water flow velocities between the lab and the field. This mechanistic approach provides testable predictions for how the thermal tolerance of embryos depends on egg size and flow velocity of the surrounding water. We found strong support for these predictions across more than 180 fish species, suggesting that flow and temperature mediated oxygen limitation is a general mechanism underlying the thermal tolerance of embryos. We conclude that descriptive models of thermal tolerance can drastically underestimate species responses to climate change and that simple mechanistic models can explain substantial variation in the thermal tolerance of species.

Keywords: Thermal tolerance, salmon, model, temperature, embryo, survival, oxygen, flow
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 306

Impacts of Shasta Dam Water Operations on Endangered Winter-Run Chinook Salmon

Eric Danner, NOAA Fisheries, eric.danner@noaa.gov
Ben Martin, NOAA Fisheries, benjamin.martin@noaa.gov
Sara John, NOAA Fisheries, sara.john@noaa.gov
Andrew Pike, NOAA Fisheries, andrew.pike@noaa.gov
Miles Daniels, NOAA Fisheries, miles.daniels@noaa.gov

Sacramento River Winter run Chinook salmon are listed under the Endangered Species Act and have a very restricted stretch of spawning habitat on the Sacramento River below Keswick Dam. The quality of this habitat is heavily impacted by water operations, particularly by the amount and temperature of water released from Shasta Lake, the largest reservoir in the state. We have developed science-based decision-support tools to evaluate how water operations impact winter run salmon populations in the past, present, and future, to improve our management decision process. These support tools consist of a series of linked physical models the track the movement of water and heat through the system from the watershed to the ocean. The output from these models can then used to estimate the impact on various life stages, such as developing salmon eggs on the Sacramento River. Our initial results indicate that some years, temperature dependent mortality can be as high as 78% for winter run salmon eggs. These tools allow us to estimate the physiological responses to key environmental stressors, such as the ongoing drought, through science-based management strategies to protect fish populations.

Keywords: modeling, decision support, temperature, flow, reservoir, salmon
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 306

Genetic Evaluation of Sacramento River Winter-Run Chinook Salmon

Christian Smith, USFWS, christian_smith@fws.gov
John Rueth, USFWS, john_rueth@fws.gov
Jennifer Von Bargen, USFWS, jennifer_vonbargen@fws.gov

Sacramento River Winter-run Chinook salmon were largely blocked from their historical freshwater habitat by an impassible dam and were listed as “endangered” under the Endangered Species Act in 1994. A conservation hatchery program for this species was initiated in 1989 at an existing facility, and was subsequently moved to Livingston Stone National Fish Hatchery in 1998. Since its inception, the Winter-run Chinook salmon program has operated under an integrated hatchery paradigm, and has incorporated several measures to minimize genetic risks of hatchery propagation to the population. In order to prevent inadvertent hybridization with other populations of Chinook salmon, all fish collected as potential broodstock at Livingston Stone National Fish Hatchery were screened with either microsatellite or single nucleotide polymorphism markers. The genetic samples and data collected during this screening process provide an opportunity for evaluating change in the population over time. Here we present an overview of how the genetic profile of the population has changed over time as well as how the role of genetic data in hatchery operations has continued to evolve.

Keywords: Winter Run Chinook Salmon, Genetic assignment, effective population size
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 306

Potential Impacts of *Ceratonova shasta* and *Parvicapsula minibicornis* Infection on Survival of Natural Sacramento Juvenile Chinook Salmon: Comparison to Rivers of Known Infectivity

Scott Foott, U.S. Fish and Wildlife Service, Scott_Foott@fws.gov
Jennifer Jacobs, U.S. Fish and Wildlife Service, Jennifer_Jacobs@fws.gov
Kim True, U.S. Fish and Wildlife Service, Kimberly_True@fws.gov
Anne Voss, U.S. Fish and Wildlife Service, Anne_Voss@fws.gov
Ron Stone, U.S. Fish and Wildlife Service, Ron_Stone@fws.gov
Alana Imrie, California Department of Water Resources, AImrie@psmfc.org

Infection by the myxozoan parasites, *Ceratonova* (previously *Ceratomyxa*) *shasta* and *Parvicapsula minibicornis*, has been observed in all Sacramento River adult runs, and juvenile fall and winter-run Chinook. In 2014, infections were lethal for over half of the spring out-migrants sampled from the lower river. In fall of 2015, sentinel juvenile salmon, held above Red Bluff diversion dam, incurred a high prevalence of severe infection. In contrast, only 15% prevalence of early stage infections were observed in juvenile Winter-run Chinook collected at the dam. Drought conditions (lower winter flows, higher spring and summer temperatures) appear to increase parasite infectivity. The effect of different river conditions in 2016 will be compared to 2015 data. Reduced juvenile salmon survival due to *C. shasta* has been documented in both the Klamath and Feather Rivers. Characteristics of these systems on the life cycle and infectivity of *C. shasta* will be discussed in the context of the Sacramento River.

Keywords: winter-run Chinook, disease
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 306

Predator Swamping and Movement under High Flows: Comparing Winter-Run Chinook Juveniles Released only Days Apart

Arnold Ammann, National Marine Fisheries Service, NOAA, arnold.ammann@noaa.gov

Predator swamping is a form of reproductive synchrony thought to reduce the fraction of prey taken by a predator. For salmon in a natural system increased river flow from rainstorms is the environmental cue that causes synchronous mass out-migration of juveniles. However, for hatchery raised fish, this takes the form of a mass release with thousands of fish released all at once. In 2015, the Livingston Stone National Fish Hatchery released 200,000 winter-run pre-smolts each night for three days on the Sacramento River in Redding. In the first and third release there were 249 and 318 pre-smolts implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters. Movement and survival of these two groups of acoustic tag fish were compared at several reaches using detections from an array of JSATS receivers. The predator swamping hypothesis would predict that the fish in the third release will have higher survival because fish from the first and second release have satiated all available predators. Survival of both release groups for the first 15 river km was nearly perfect. High river flow reduced detection efficiency of the tagged fish in the third release group for the next 140 river km making survival comparisons uncertain. In the next three river reaches covering the area of the river from Hamilton City to Colusa survival for tagged fish in the third release group was higher, supporting the possibility of predator swamping for those reaches. The range of arrival times to receiver locations was affected by flow conditions, with a narrow range during low flow conditions and a broader range during high flow conditions. The high resolution data generated by acoustic tagging is useful for identifying areas where predation is a problem and is helpful to hatchery managers to optimize releases of fish with natural or managed river flows.

Keywords: Winter-run Chinook salmon, juveniles, smolt, acoustic tag, survival, predator, swamping
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 306

Otolith Chemistry Reveals the Diverse Rearing Habitats of Winter-Run Chinook Salmon

Corey Phillis, Metropolitan Water District of Southern California, CPhillis@mwdh2o.com
Anna Sturrock, University of California, Berkeley, a.sturrock@berkeley.edu
Rachel Johnson, National Marine Fisheries Service & UC Davis, rachel.johnson@noaa.gov
Lynn Ingram, University of California, Berkeley, ingram@eps.berkeley.edu
Peter Weber, Lawrence Livermore National Laboratory, weber21@llnl.gov

Protecting or restoring the juvenile rearing habitat of winter-run Chinook salmon (WRCS) will be critical to recovery of the species. However, identifying where important rearing habitats occur with current juvenile monitoring is challenging because 1) the length-at-date criteria does not reliably distinguish WRCS from the other Central Valley Chinook (CCV) salmon stocks, and 2) habitats outside the sampling area will not be considered. Indeed, the importance of non-natal rearing habitats—here defined as rearing occurring somewhere other than the Sacramento River between the spawning grounds and Knight's Landing—are not likely to be recognized because WRCS using these habitats will either go unsampled or be misidentified as another CCV stock. Further, non-natal habitats may provide important safe-havens from degraded conditions in the mainstem Sacramento River (e.g. high temperatures, predator density). Therefore, we used strontium isotopes in WRCS spawning adult otoliths to reconstruct their juvenile rearing habitats. The strontium isotope signatures of the Sacramento River are geographically variable, allowing for differentiation between mainstem Sacramento River reaches, tributary streams, and the Delta. We found that of the WRCS spawning adults sampled from escapement years 2007 – 2009, 64%, 65%, and 47% reared as juveniles in non-natal habitats, respectively. Non-natal habitats that could be identified were the Mt. Lassen tributaries (used by 56%, 19%, and 15% of all non-natal rearing fish from escapement years 2007-2009), the American River (22%, 40%, and 38%), and the Delta (11%, 36%, and 32%). The time period spent within the non-natal habitats ranged from approximately 2 to 16 weeks. These results suggest the extent of WRCS juvenile rearing habitat is likely under sampled and that non-natal habitats are potentially contributing significantly to the WRCS spawning population. Thus, we believe protecting and restoring non-natal rearing habitats can play an important role in recovering the winter-run Chinook salmon population.

Keywords: life-history diversity, life-history strategy, migration, restoration, rearing habitat, otoliths, strontium
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 306

Effects of Out-Migration Size and Timing on Early Marine Survival of Chinook Salmon in the Ocean

Brian Wells, NOAA Fisheries, brian.wells@noaa.gov

The first period at sea is a critical time for Chinook salmon during which recruitment strength is typically set. Ultimately, the productivity of the shelf ecosystem is tied to the survival and growth of the out-migrating salmon. However, the impact of the environment is not equally shared across all members of the out-migrating population. For example, the timing of out-migration is linked to survival; those fish that migrate following the development of a diverse forage base have a greater likelihood of success than those that migrate early relative to the development of a productive shelf ecosystem. As well, larger out-migrating individuals, when faced with an unproductive ecosystem, have a greater likelihood of survival. I demonstrate that a dominant agent of mortality on these out-migrating salmon is predation. Namely, during periods of reduced forage availability, seabirds change their foraging behavior which has the effect of increasing their interactions with juvenile salmon. Freshwater discharge can be tied to the growth and timing dynamics of out-migrating salmon and, therefore, their survival on the shelf ecosystem. Ultimately, I demonstrate an ecosystem analysis across the life-cycle of the salmon that demonstrates management of freshwater, forage fishes, and protected seabirds in the context of a variable environment is critical to the success of salmon recovery efforts.

Keywords: forage fish, seabird, predation, shelf ecosystem, survival
Session Title: Winter-Run Chinook Salmon Science and Management in a Changing Climate II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 306

Evaluation of the Impacts of California's Mandatory Minimum Penalty Enforcement Program on Effluent Quality and Surface Water Quality in the Sacramento-San Joaquin Delta

Victor Vasquez, UCLA Environmental Science and Engineering Program, vrvasquez@ucla.edu
Michael Stenstrom, UCLA Department of Civil and Environmental Engineering, stenstro@seas.ucla.edu

Since 2000, California has issued mandatory minimum penalties (MMP) for violations of effluent limitations in National Pollution Discharge Elimination System (NPDES) permits for point-source facilities discharging to surface waters. California's water quality regulatory agencies issued MMPs through administrative civil liability (ACL) enforcement actions; however, whether MMPs improved effluent quality and ambient water quality has not been evaluated. A method is presented in this study to quantitatively estimate the impact of MMPs in improving effluent quality from wastewater treatment facilities (WWTFs) that discharge directly or indirectly to the Sacramento-San Joaquin Delta (Delta) and subsequently impact water quality within the Delta. Effluent monitoring results for total nitrogen (TN) and copper (Cu) and ACL enforcement action data for WWTFs inside and within 50 miles of the Delta between 2000 and 2012 were correlated using linear regression. The regression results suggest that effluent quality discharged from the WWTFs improved by as much 30 percent as a result of MMP ACLs, although there is a time lag between ACL issuance and effluent quality improvements. Quasi-physical models for effluent quality were determined from the regression analysis, and the amount of pollution prevented, apparently due to the issuance of MMPs, was calculated. Using a simple mixing model of the Delta and known flows of Delta rivers and tributaries, the reduction of TN and Cu concentrations at various points in the Delta, accounting for the pollution prevented due to MMPs, was calculated and compared with actual ambient monitoring results within the Delta. It is possible, however, that the pollution prevention impacts of MMPs may be obscured by other environmental processes. Difficulty in obtaining sufficiently complete data sets for analysis for this study highlights the need for comprehensive monitoring of effluent discharges and ambient waters across water quality regulatory programs, perhaps using a common water quality index.

Keywords: NPDES, wastewater treatment facilities, Sacramento-San Joaquin Delta, water quality
Session Title: Contaminant Issues in the Bay-Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 307

Is there a Toxic Algae Problem in San Francisco Bay?

Melissa Peacock, UC Santa Cruz, mdbpeacock@gmail.com
Zephyr Sylvester, San Francisco Estuary Institute, zephyrs@sfei.org
Corinne Gibble, UC Santa Cruz, corinnegibble@gmail.com
Raphael Kudela, UC Santa Cruz, kudela@ucsc.edu
David Senn, San Francisco Estuary Institute, davids@sfei.org
James Cloern, USGS, jecloern@usgs.org

San Francisco Bay (SFB) is an urbanized, nutrient-enriched estuary, and considered the most anthropogenically-altered estuary in the United States. SFB has historically resisted many classic symptoms of eutrophication; though recently, increased primary productivity and potential impairment is trending upwards. One indication of this impairment are the many toxin producing species of harmful algae that have been identified by microscopy and the recently documented trophic transfer of toxins to shellfish. A pilot program to identify toxin in SFB using particulate samples and Solid Phase Adsorption Tracking (SPATT) was conducted from 2011 - 2016 on bi-monthly USGS cruises. Results from each collection methods indicated persistent presence of both domoic acid and microcystin toxins throughout SFB., with periodic concentrations of high concern. This indicates the potential for persistent chronic toxin exposure in the marine food web from both toxins. In 2015-2016 this program was expanded to collect marine mussels from SFB, to identify any toxic impacts to the marine food web. In marine mussels, four toxins were consistently detected: domoic acid, microcystins, saxitoxins, and okadaic acid. Of particular concern was the detection of microcystins, a freshwater toxin, at concentrations 40-fold greater than the World Health Organization's Tolerable Daily Intake level for seafood. Currently, there is no regular monitoring of toxins in marine mussels in SFB. The findings of at least four toxins present in the marine food web indicates a need to not only monitor for these toxins in shellfish, which are consumed by humans and wildlife, but also to identify environmental factors that escalate the risk of exposure to the food web in order to provide a relevant management strategy for toxins in SFB.

Keywords: Domoic acid, Microcystin, Saxitoxin, Okadaic Acid, marine mussels, impairment, HAB
Session Title: Contaminant Issues in the Bay-Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 307

Disrupting Aquatic Communities from Bottom-Up: A Long-Term Assessment of Herbicides

Simone Hasenbein, School of Veterinary Medicine, Department of Anatomy, Physiology and Cell Biology, UC Davis, shasenbein@ucdavis.edu
Sharon P. Lawler, Department of Entomology and Nematology, UC Davis, splawler@ucdavis.edu
Richard E. Connon, School of Veterinary Medicine, Department of Anatomy, Physiology and Cell Biology, UC Davis, reconnon@ucdavis.edu

Problem statement: Herbicides, used in both agricultural and urban areas, are found in the Sacramento-San Joaquin Delta watershed at concentrations that are potentially toxic to phytoplankton. Furthermore, herbicides are directly applied to control invasive aquatic vegetation. Consequently, there is increasing concern over direct effects on primary production, and indirect effects on zooplankton and other aquatic invertebrates.

Approach: Here we assessed long-term effects of five applications over 30 days of binary mixtures of the herbicides diuron and hexazinone at 'low' and 'high' concentrations as typically found in the Sacramento-San Joaquin Delta watershed. Phytoplankton, chlorophyll-α, zooplankton and macroinvertebrate communities were monitored over four months.

Results: In the mesocosm study, 16 of 95 phytoplankton taxa, 3 of 18 zooplankton taxa, and 6 of 14 macroinvertebrate taxa responded negatively to contaminant exposures. Herbicide applications significantly altered the phytoplankton community structure. Relative abundance of Cyanophyceae decreased following five applications from 52.1% in the control to 37.3% in the 'low' and to 25.9% in the 'high' treatment, while Chlorophyceae increased to 50.6% in the 'low' and 61.7% in the 'high' treatment compared to the control (39.7%). Chlorophyceae had the greatest number of affected species (8), while one species within the Cyanophyceae was negatively affected on more than one sampling day. Further, chlorophyll *a* was reduced on 4 and 5 days out of the 8 total sampling days in the 'low' and 'high' treatment, respectively, compared to the control.

Relevance: These results highlight that herbicides can cause long-term effects that can affect multiple levels of organisms disrupting population structure from bottom-up. Integrating multiple taxa and contaminants with long-term exposures in ecological risk assessments of herbicides can facilitate the ability to make predictive and mechanistic generalizations about the role of herbicides in shaping patterns of species abundance in natural systems.

Keywords: mesocosm, macroinvertebrate, herbicides, zooplankton, ecotoxicology, diuron, hexazinone
Session Title: Contaminant Issues in the Bay-Delta I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 307

Mixtures of Current-Use Pesticides Detected in Surface Waters of the Sacramento/San Joaquin Delta Watershed

James Orlando, U.S. Geological Survey, jorlando@usgs.gov
Michelle Hladik, U.S. Geological Survey, mhladik@usgs.gov
Megan McWayne, U.S. Geological Survey, mmcwayne@usgs.gov
Corey Sanders, U.S. Geological Survey, csanders@usgs.gov
Matt De Parsia, U.S. Geological Survey, mdeparsia@usgs.gov
Sean Stout, U.S. Geological Survey, sstout@usgs.gov

Current-use pesticides pose a potential threat to aquatic organisms, highlighting the need for up-to-date and robust data characterizing inputs of these contaminants to the Sacramento/San Joaquin Delta. Over the past three years, the USGS Pesticide Fate Research Group has conducted multiple research projects focused on understanding the occurrence of current-use pesticides in surface waters within the Delta watershed. Each of these studies employed consistent analytical methods and provide data for a suite of over 150 current-use pesticides and pesticide degradates. Locations sampled during these studies included small watercourses receiving runoff from adjacent agricultural lands or suburban neighborhoods, larger streams and rivers with direct input to the Delta, as well as sites located within sensitive habitats within the Delta. Although specific objectives varied from project to project, the use of common analytical methods and sampling procedures allows the data to provide a more complete perspective of pesticide inputs to the Delta.

Analysis of data acquired during these projects shows that waters entering the Delta contain mixtures consisting of a wide variety of both agricultural and urban use pesticides, with a total of over 70 different fungicides, herbicides, insecticides, and their degradates detected. The exact makeup of these pesticide mixtures varies seasonally due to changes in pesticide application patterns, as well as in response to rainfall and irrigation runoff events. Overall pesticide concentrations tend to be higher in the smaller, near-source tributary sites and lower in the tidally-mixed Delta sites. Through the use of common analytical methods, these data can provide valuable information to scientists and resource managers working to understand the role of contaminants in the Sacramento/San Joaquin Delta.

Keywords: water quality pesticides contaminants
Session Title: Contaminant Issues in the Bay-Delta I
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An Investigation of Pesticide Input to the Bay-Delta Area

Dan Wang, California Department of Pesticide Regulation, Dan.Wang@cdpr.ca.gov
Yuzhou Luo, California Department of Pesticide Regulation, Yuzhou.Luo@cdpr.ca.gov
Robert Budd, California Department of Pesticide Regulation, Robert.Budd@cdpr.ca.gov
Nan Singhasemanon, California Department of Pesticide Regulation, Nan.Singhasemanon@cdpr.ca.gov
Kean Goh, California Department of Pesticide Regulation, Kean.Goh@cdpr.ca.gov

This study evaluated recent pesticide input to the Bay-Delta area through physical modeling and comparison to environmental monitoring data. The model estimated pesticide mass loading to the area by assuming that all pesticides applied in the contributing hydrological areas would immediately travel toward the nearby waterways and degrade following first-order kinetics through the stream network. Pesticides were ranked after normalizing the estimated mass loading by its toxicity benchmark value. The pesticides that ranked the highest based on their use in 2012-2014 include 15 insecticides (6 pyrethroids, 4 organophosphates, diflubenzuron, etoxazole, fenpyroximate, fipronil, and pyriproxyfen), 4 herbicides (atrazine, oxyfluorfen, paraquat dichloride, and pendimethalin) and a fungicide (mancozeb). Monitoring data exist for all the pesticides listed above, except etoxazole, fenpyroximate, pyriproxyfen, and mancozeb, in the Department of Pesticide Regulation's SURF database. The limit of quantification values for several pyrethroids, organophosphates, fipronil and atrazine were sometimes above their benchmarks, which hindered the evaluation of exceedance. If only the samples with reportable concentrations are counted, bifenthrin, cyfluthrin, permethrin, chlorpyrifos, and diazinon exceeded acute and chronic benchmarks for aquatic animals; deltamethrin, lambda-cyhalothrin, dimethoate, and fipronil exceeded the chronic benchmark for aquatic animals; atrazine exceeded the acute benchmark for aquatic plants. The database also contains monitoring data for an additional 143 pesticides; only diuron had one exceedance. These findings indicate the necessity to prioritize the monitoring target and reduce the analytical methods' reporting limit.

Keywords: pesticide input, modeling, environmental monitoring
Session Title: Contaminant Issues in the Bay-Delta I
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Comprehensive Organic Contaminant Assessment and Link to Effects on Invertebrates in the Cache Slough Ecosystem

Christoph Moschet, University of California, Davis, cmoschet@ucdavis.edu
Bonny Lew, University of California, Davis, bmlew@ucdavis.edu
Simone Hasenbein, University of California, Davis, shasenbein@ucdavis.edu
Don Weston, University of California, Berkeley, dweston@berkeley.edu
Helen Poynton, University of Massachusetts, Boston, Helen.Poynton@umb.edu
Richard Connon, University of California, Davis, reconnon@ucdavis.edu
Thomas Young, University of California, Davis, tyoung@ucdavis.edu

The Cache Slough complex in the Sacramento–San Joaquin River Delta is an important habitat for endangered fish species. In order to assess toxicity towards important fish prey, the present study involved deployment of a sensitive amphipod, *Hyalella azteca*, combined with a comprehensive pesticide/organic contaminant screening of water samples during storm events. The use of high-resolution mass spectrometry allowed detection of target chemicals, but also facilitated a broad screening for suspect chemicals without reference standards. Grab samples were taken during two rain events in January and March 2016. Extracted water samples and suspended solids were analyzed by both gas chromatography high-resolution mass spectrometry (GC-TOF-MS) and liquid chromatography high-resolution mass spectrometry(LC-TOF-MS). Nearly 50 target pesticides were evaluated and the samples were screened for additional pesticides using two large spectral libraries containing over 2000 compounds. Data of the first (small) rain event showed low acute toxicity towards *H. azteca*, but more than 30 target pesticides were detected. The second (large) rain event showed high toxicity which suggests a much higher pesticide load. Obtained data are providing crucial information about chemicals that were the cause of observed toxicity, which will represent a valuable resource for future watershed management.

Keywords: toxicity, pesticides, pyrethroid insecticides, Hyalella azteca, Cache Slough, nontarget analysis
Session Title: Contaminant Issues in the Bay-Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 307

A New Approach to Identifying the Substance Causing Mortality in Bay-Delta Toxicity Monitoring

Donald Weston, University of California Berkeley, dweston@berkeley.edu
Helen Poynton, University of Massachusetts, Boston, Helen.Poynton@umb.edu
Kaley Major, University of Massachusetts, Boston, kaley.major@gmail.com
Gary Wellborn, University of Oklahoma, gwellborn@ou.edu
Michael Lydy, Southern Illinois University, mlydy@siu.edu
Cristoph Moschet, University of California Davis, cmoschet@ucdavis.edu
Richard Connon, University of California Davis, reconnon@ucdavis.edu

Problem: Monitoring programs often rely upon toxicity testing, and when toxicity is found, efforts to mitigate it require identifying the chemical(s) responsible. The approach generally used is a Toxicity Identification Evaluation (TIE) in which the sample is subjected to physical or chemical manipulations. This approach often only identifies the toxicant to major class (e.g., metal), and identification is often suggestive, rather than definitive.

Approach: We have found that the amphipod, *Hyalella azteca*, when collected from waterways routinely exposed to pyrethroid pesticides, is often resistant to them due to a mutation that prevents binding of the pyrethroid to its target site. This finding suggests a novel "biological TIE" approach in which both resistant and wild-type *H. azteca* are simultaneously exposed. Greater survival of those pyrethroid resistant would provide strong evidence that these pesticides are the agents responsible for toxicity to the wild type strain lacking the mutation.

Results: The approach was tested in Cache Slough following two rain events. Four samples were found to be toxic to the wild type strain when they were held in situ in Cache Slough throughout the rain. However, two other strains bearing the pyrethroid resistance mutation were simultaneously exposed yet unaffected. Similar results were obtained in six other waterbodies in the Bay-Delta. In all cases, the biological TIE indicates that pyrethroids were responsible for the toxicity.

Relevance: Our approach provides evidence, consistent with chemical and conventional TIE data, that pyrethroids are often the substances responsible for toxicity to the common testing species, *H. azteca*, and that toxicity is widespread throughout the Bay-Delta. As monitoring and regulatory efforts are increasingly focused on this group of pesticides, the biological TIE approach may be the best approach yet developed to establish causality. We are exploring its application to other pesticides, for which the technique also holds promise.

Keywords: Pesticides, Pyrethroids, Hyalella, Toxicity Identification Evaluation, Stormwater runoff
Session Title: Contaminant Issues in the Bay-Delta II
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Pyrethroid Insecticide Resistance is Widespread in the Non-Target Crustacean *Hyalella azteca*

Kaley Major, School for the Environment, University of Massachusetts Boston, kaley.major@gmail.com
Donald Weston, Department of Integrative Biology, UC Berkeley, dweston@berkeley.edu
Michael Lydy, Department of Zoology, Southern Illinois University, Carbondale, IL, mlydy@siu.edu
Gary Wellborn, Department of Biology, University of Oklahoma, Norman, OK, gwellborn@ou.edu
Helen Poynton, School for the Environment, University of Massachusetts Boston, helen.poynton@umb.edu

Pyrethroid insecticides are prevalent in sediments throughout the Bay-Delta Region. These pesticides are extremely toxic to aquatic invertebrates, the base of the food web for many important and declining fish species within the delta. However, our research shows that highly exposed populations of the crustacean *Hyalella azteca* have evolved resistance, with up to 550-fold increased tolerance to pyrethroids compared to base-line sensitivity of all other natural populations including those commonly used for laboratory toxicity testing. Resistance results from mutations in the target site for pyrethroids, the voltage-gated sodium channel (*VGSC*). The *VGSC* resistance mutations in wild *H. azteca* populations represent the first identified in a non-target aquatic organism, suggesting previously undescribed environmental impacts associated with pyrethroid use. Determining the extent of resistance and its correlation with pesticide levels is necessary to quantify this impact.

Approach: We sampled sixteen populations of *H. azteca* throughout California including many areas of the Bay-Delta system. Nine populations were from residential or agricultural areas with suspected insecticide use and seven populations were collected from pristine areas. Pyrethroid use was determined by measured sediment concentrations of insecticides, and 96-h toxicity bioassays were used to determine each population's sensitivity to pyrethroids. The *VGSC* was sequenced in twenty individuals from each population to determine the extent of genetic resistance.

Results: All populations collected from areas with elevated insecticide concentrations in sediments showed reduced sensitivity. Preliminary results from our genetic analysis suggests that these populations have developed resistance through genetic mutations.

Relevance: Insecticide resistance is widespread in *H. azteca* populations throughout California and is highly correlated with insecticide use. As resistant *H. azteca* could be vectors for the trophic transfer of insecticides to fish, or may be more susceptible to other climate related stressors, the widespread occurrence of insecticide resistance is concerning for the health of the delta ecosystem.

Keywords: insecticides, *Hyalella azteca*, toxicity testing, resistance
Session Title: Contaminant Issues in the Bay-Delta II
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Toxicity, Bioaccumulation and Tropic Transfer of Permethrin in Pyrethroid-Resistant *Hyalella azteca*

Michael Lydy, Southern Illinois University, mlydy@siu.edu
Kara Huff-Hartz, Southern Illinois University, khuffhar@siu.edu
Sam Nutile, Southern Illinois University, snutile@siu.edu
Andrew Derby, Southern Illinois University, derbya@siu.edu
Jennifer Heim, Southern Illinois University, heimjen@siu.edu
Leslie Muggelberg, Sage College of Albany, lmuggs123@yahoo.com
Amanda Harwood, Alma College, Amandaharwood@gmail.com
Helen Poynton, University of Massachusetts, Helen.Poynton@umb.edu
Kaley Major, University of Massachusetts, kaley.major@gmail.com
Donald Weston, U.C. Berkeley, dweston@berkeley.edu

Problem Statement: Some field populations of the freshwater amphipod, *Hyalella azteca*, from pesticide-exposed waterbodies demonstrate resistance to pyrethroid insecticides. However, there is a debate whether these populations will retain their resistance if held in the lab without continued pyrethroid exposure. In addition, if resistant *H. azteca* experience pyrethroid exposure, one of the possible consequences is bioaccumulation, which increases the potential for transfer of pyrethroids from the resistant individuals to higher trophic level organisms.

Approach: These issues were addressed in the current study by conducting toxicity tests with the standard laboratory-cultured *H. azteca* and resistant populations. Resistant and non-resistant *H. azteca* also were exposed to ^{14}C-labeled permethrin, and bioaccumulation and proportion biotransformed were quantified. Finally, the trophic transfer potential of permethrin via resistant *H. azteca* was demonstrated by daily feeding of permethrin-exposed *H. azteca* to fathead minnows.

Results: Toxicity tests in water with permethrin showed the 96-h LC50 of resistant *H. azteca* was 53 times higher than that of non-resistant *H. azteca*, even after the resistant animals had been held in the lab without pyrethroid exposure for 16 months. Resistant *H. azteca* were shown to bioaccumulate increasing amounts of permethrin as exposure concentrations increased. Since resistant organisms can survive in habitats that have higher pyrethroid concentrations, our results indicate they are able to accumulate more of these compounds in their tissues than their non-resistant counterparts. In the current study, fathead minnows were shown to bioaccumulate permethrin after consumption of contaminated resistant *H. azteca*.

Relevance: These results suggest that that the mutation responsible for conferring resistance in these organisms is retained within the population for many generations after exposure to pyrethroids has ceased. In addition, we found consumption of pyrethroid-resistant individuals may increase fish exposure to permethrin and its biotransformation products, which may impact wild fish populations.

Keywords: Pyrethroid-resistant Hyalella, Bioaccumulation, Permethrin, Mutation
Session Title: Contaminant Issues in the Bay-Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 307

Multiple Stressors over Multiple Generations: Assessing the Combined Risk of Endocrine Disruptors and Climate Change

Bethany DeCourten*, UNC Wilmington, bmd5520@uncw.edu
Susanne Brander, UNC Wilmington, branders@uncw.edu

Understanding anthropogenic impacts such as climate change and pollution on aquatic ecosystems is critical for preserving biodiversity and maintaining water quality. The pyrethroid pesticide bifenthrin is a known endocrine disrupting compound (EDC) found in biologically active concentrations in the San Francisco Bay-Delta estuary. Little is known about how elevated temperatures associated with climate change may affect the estrogenic activity of bifenthrin, particularly in species that exhibit temperature-dependent sex determination (TSD), such as the introduced species Menidia beryllina. This study investigated the effects of temperature and bifenthrin exposure on reproductive output in M. beryllina across multiple generations. Fish in the parental generation were exposed to bifenthrin, ethinylestradiol (EE2 - positive control) and methanol (solvent control) at 22°C and 28°C for 14 days prior to spawning. Embryos in the F1 generation were exposed to EDCs as larvae (until 21 dph) and then reared to adulthood (8 months) in clean water at experimental temperatures. In all F1 treatments, elevated temperature resulted in fewer viable offspring. At the time of maturity, the F1 generation underwent spawning trials to assess reproductive output and offspring viability following larval exposure. Sex ratios of the F1 generation were influenced by elevated temperature and EDCs, resulting in alteration of adaptive TSD. Fish exposed to bifenthrin during development exhibited developmental deformities. Tissues were collected from each generation to assess the effects of these stressors on the expression of genes involved in reproduction and growth. Findings from this study will be useful in determining how EDCs will impact organisms and community structure in the face of global climate change.

Keywords: Endocrine disruptors, multigenerational, ecotoxicology, multiple stressors, menidia, bifenthrin, pesticides, temperature
Session Title: Contaminant Issues in the Bay-Delta II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 307

Bridging the Divide: Communicating Science Synthesis to Meet Decision Makers' Needs

Cliff Dahm, Independent Lead Scientist, Delta Science Program, cliff.dahm@deltacouncil.ca.gov

Synthesis in an integral part of communicating science to policy makers, as this process integrates components of a complex system to provide a clear overview of the current state of knowledge. Presented in a manner that informs decision makers, synthesis can facilitate more effective policy-science interactions, forming the basis for science-based policy. Effective synthesis of scientific knowledge is especially needed in the Delta, where much of this information is in a fragmented state, housed separately in several databases, agencies, and research institutions. This talk will provide an overview of how science synthesis is used in communicating knowledge and how the outcomes from the mercury workshop series (January and June, 2016) will be integrated into future Delta plans and programs. An overview of how the Delta Science Program will use the outcomes from the mercury synthesis workshops to advance the understanding of mercury issues in the Delta will be discussed and how this communication of knowledge in turn provides decision makers with the best scientific information and tools to use when confronted with challenging decisions related to mercury in the Delta and beyond. The discussion will also provide a road map of the various collaborative efforts and agencies that will benefit from this updated knowledge on mercury sources, cycling, and biotic effects.

Keywords: Mercury, environmental management, synthesis, Delta Science Program
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 307

Building a Scientific Foundation to Manage the Mercury Threat in the San Francisco Estuary

Jacob Fleck, United States Geological Survey, jafleck@usgs.gov
Joshua Ackerman, United States Geological Survey, jackerman@usgs.gov
Collin Eagles-Smith, United States Geological Survey, ceagles-smith@usgs.gov
Lisamarie Windham-Myers, United States Geological Survey, lwindham@usgs.gov
Roger Fujii, United States Geological Survey (Emeritus), rfujii727@gmail.com

Mercury contamination is a primary threat to environmental health across the San Francisco Bay-Delta Estuary. In January 2016, we assembled a diverse group of scientists, managers and policy makers to participate in a series of technical workshops designed to integrate and discuss the current understanding of mercury contamination and the processes that influence its cycling and bioaccumulation across the region. This scientific assessment was conducted within the context of informing management strategies to minimize mercury risk in the region. We found strong evidence that mercury contamination poses an ongoing threat to wildlife that forage within the Estuary and human health through fish consumption. Methyl mercury exposure was most strongly related to habitat. Wetlands, tidal wetlands, lakes, and riverine habitats all showed significant biotic exposure, but wetlands harbored biota with the greatest exposure. Differences between habitats were primarily attributed to differences in their propensity for methylmercury production, physical transport processes, and food web characteristics. Biota mercury exposure was also related to their proximity to mining-related mercury sources, but mercury source effects were localized and imposed little effect at the regional scale. Advances in our understanding of the relative availability of different mercury sources for methylation has improved vastly, but further characterization remains a focus for future research efforts. Recent efforts have focused on testing and developing strategies for managing mercury methylation and removal mechanisms to control biotic mercury exposure, mostly through the reduction of surface water loadings to open waters. Results of these efforts have yet to produce any widespread implementation of management actions but have been profoundly helpful in refining our conceptual model of mercury cycling in the estuary and have highlighted the challenges to modeling mercury exposure.

Keywords: mercury, methyl mercury, wetlands, ecosystem risk, bioaccumulation, synthesis, contaminants
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 307

The Delta Doughnut: A Persistent Pattern for Methylmercury Metrics

Lisamarie Windham-Myers, U.S. Geological Survey, lwindham@usgs.gov
Lisa Lucas, U.S. Geological Survey, llucas@usgs.gov
Jacob Fleck, U.S. Geological Survey, jafleck@usgs.gov
Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov
Rosanne Martyr, U.S. Geological Survey, rmartyr@usgs.gov
Mark Marvin-DiPasquale, U.S. Geological Survey, mmarvin@usgs.gov

Concerns regarding human and wildlife health posed by mercury contamination in the food web has led to the development of numerous fish-consumption advisories and regulatory policies in the San Francisco Bay-Delta watershed (SFBDW). A comprehensive understanding of processes driving observed spatial patterns of fish mercury concentrations is necessary to effectively develop strategies to predict and potentially manage for lower fish mercury throughout the system. We evaluated the spatial patterns of fish, water, and sediment mercury and methylmercury in open water habitats across the SFBDW and found a persistent pattern of low methylmercury concentrations in the central delta, and higher concentrations in all matrices in the delta periphery. Four untested hypotheses suggested for this commonly observed phenomenon include: a) closer proximity to legacy mining-related Hg sources in the periphery, b) more mercury methylation in the seasonal wetlands of the periphery, c) more degradation and settling of tributary-sourced methylmercury in the open waters of the central delta, and d) more tidal dispersion and rapid flushing in the central delta. Preliminary evaluation of field data and transport of conservative tracers using D3D-FM/Delwaq modeling platform suggests that the observed spatial trends could be explained by any one of these proposed processes, but likely reflect a combination of several or all. A more complete assessment of the primary factors driving the observed spatial distribution of mercury in fish and water will necessarily include more direct measurements of methylmercury production and degradation across dominant habitat types, hydrodynamic mixing and transport models, and a more complete food web characterization. Management options to decrease mercury bioaccumulation in fish are evaluated. The information provided by this analysis will inform future efforts to control mercury exposure, such as the Delta methylmercury total maximum daily load (TMDL) implementation.

Keywords: mercury, methylmercury, biogeochemistry, hydrodynamics, water quality, tidal dispersion, wetland, tributary
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 307

Using Recent Science to Advise the Delta Methylmercury TMDL

Janis Cooke, Central Valley Regional Water Quality Control Board, Janis.Cooke@waterboards.ca.gov

The Central Valley Regional Water Quality Control Board is looking toward review and possible revisions of the Delta Mercury Control Program or Total Maximum Daily Load (TMDL) after 2018. The TMDL, approved in 2011, relied significantly on source and process information collected prior to 2008. This information included mass balances for mercury and methylmercury entering and leaving the Delta and measurements of mercury in ambient water, fish, and sediment within the Delta.

Mercury studies and syntheses completed after the TMDL was approved can form the basis of changes to the implementation approaches and, in a few years, the TMDL itself. To fully benefit the Delta methylmercury TMDL, however, new data and scientific understanding need to be focused to answer particular management questions. Management questions relevant for advising the Delta methylmercury TMDL will be introduced. Topics include the following:

- Criteria leading to prioritization of locations and seasons in which exposure of wildlife to mercury is of greatest concern;
- Certainty in our understanding of relative reactivities of mercury from atmospheric and legacy sources; and
- Degree of understanding of factors affecting methylmercury cycling and transport that can be further utilized in management.

Keywords: methylmercury, mercury, TMDL
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond I
Session Time: Thursday 1:15 PM – 2:55 PM, Room 307

Mercury Studies in the Cache Creek Settling Basin, Yolo County: Preliminary Results from 2010–2014

Charles N. Alpers, U.S. Geological Survey, California Water Science Center, cnalpers@usgs.gov
Mark Marvin-DiPasquale, U.S. Geological Survey, National Research Program, mmarvin@usgs.gov
Joshua T. Ackerman, U.S. Geological Survey, Western Ecological Research Center, jackerman@usgs.gov
Jacob A. Fleck, U.S. Geological Survey, California Water Science Center, jafleck@usgs.gov
Lisamarie WIndham-Myers, U.S. Geological Survey, National Research Program, lwindham@usgs.gov
Kevin J. Brown, California Department of Water Resources, kevin.brown@water.ca.gov

The 3600-acre Cache Creek Settling Basin partially traps sediment to minimize the volume reaching the Yolo Bypass floodway. The Cache Creek watershed is contaminated with mercury (Hg) from several sources including historical Hg mines; historical gold mines where Hg was used for amalgamation; rocks and soils with high-Hg natural background from hydrothermal activity; and active hot and cold springs. Water-quality and discharge of Basin inflows and outflows have been monitored starting in Water Year (WY) 2010 by the U.S. Geological Survey to assess suspended sediment and Hg loads, and to determine trap efficiency (TE). The spatial variability of total mercury (THg) and methylmercury (MeHg) in sediment, biota, and surface water within the Basin are being assessed across dominant habitat types to improve understanding of Hg methylation and MeHg bioaccumulation.

During WYs 2010–2014, the Basin's TE was 70% for suspended sediment, 59% for whole-water (ww) THg, and 55% for ww MeHg. Loads of filter-passing MeHg increased from inflow to outflow by 20% to 34%. Concentrations of MeHg were higher in bed sediment from organic-carbon-rich floodplain and riparian habitats compared with organic-carbon-poor agricultural and open-water habitats. Bed sediment MeHg increased in the direction of flow within the Basin (west to east) and decreased with time during dry periods. Concentrations of THg in house-wren and tree-swallow eggs were higher during 2012 (relatively wet) than 2013 (relatively dry). House-wren egg THg increased with distance downstream along the Cache Creek channel within the Basin during 2012, but not in 2013. In both caged and wild mosquitofish collected in March-April 2013, THg concentrations increased with distance downstream within the Basin. THg and MeHg concentrations in surface water collected at fish-cage sites also increased with distance downstream.

Ongoing analysis of data collected during 2010–16 will further assist the California Department of Water Resources with Basin management.

Keywords: mercury, methylmercury, Cache Creek, trap efficiency, bioaccumulation, bed sediment, loads
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 307

In Situ Control of Methylmercury Production in Sediments Using Redox-Buffering Mineral Amendments

Dimitri Vlassopoulos, Anchor QEA LLC, dvlassopoulos@anchorqea.com
Masakazu Kanematsu, Anchor QEA, mkanematsu@anchorqea.com
Jessica Goin, Anchor QEA, jgoin@anchorqea.com
Alexander Leven, University of California Merced, aleven@ucmerced.edu
Elizabeth Henry, Anchor QEA, bhenry@anchorqea.com
David Glaser, Anchor QEA, dglaser@anchorqea.com
Peggy O'Day, University of California Merced, poday@ucmerced.edu

Environmental risk from mercury contaminated sediments derives mainly from methylmercury production, exposure and bioaccumulation. Methylmercury is produced predominantly by heterotrophic sulfate-reducing bacteria. Our research is evaluating the ability of redox-buffering mineral-based amendments to suppress mercury methylation by inhibiting microbial sulfate reduction near the sediment surface, with the objective of reducing methylmercury exposure and food web bioaccumulation. Laboratory sediment-water "aquarium" microcosms, in which manganese(IV) oxide minerals (pyrolusite or birnessite) were either directly mixed into the upper 5 cm of sediment or applied in a thin-layer cap, have documented a substantial reduction in methylmercury production and efflux from sediment to overlying water. CO2 respirometry experiments show that the amendments stimulate microbial activity and microbial community census by PCR and DNA sequencing indicates that the addition of the manganese oxides did not significantly alter the indigenous sediment microbial community structure, although a small increase in abundance of iron and manganese reducers was observed after a 2 week incubation period. The mechanism of methylmercury suppression therefore most likely involves a shift from sulfate reduction to manganese reduction as the energetically favorable redox process, which was also confirmed by microelectrode voltammetry profiling of the sediment microcosms. Manganese X-ray Absorption Near Edge Structure (XANES) spectra of amended sediment document the gradual conversion of Mn(IV) oxide amendments to Mn(III) oxides (bixbyite), mixed-valence Mn(II/III) oxides (hausmannite) and rhodochrosite over time. This solid phase assemblage is expected to continue to buffer redox to inhibit sulfate reduction and suppress mercury methylation in the surficial sediment. The retention of the added manganese in sediment solid phases also has interesting implications for in situ self-regeneration of Mn(IV) oxides in dynamic settings where soils and sediments experience periodic water level and redox fluctuations (e.g. in intertidal zones, tidal marshes, seasonal wetlands, reservoirs), as this would prolong the effective lifetime of the amendments.

Keywords: methylmercury, mercury, sediment, water quality, remediation, in situ, reactive amendments
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 307

An Experiment to Decrease Methylmercury Export from Managed Wetlands

Mark Marvin-DiPasquale, U.S. Geological Survey, mmarvin@usgs.gov
Lisamarie Windham-Myers, U.S. Geological Survey, lwindham-myers@usgs.gov
Jacob Fleck, U.S. Geological Survey, jafleck@usgs.gov
Harry McQuillen, U.S. Bureau of Land Management, hmcquill@blm.gov

Wetlands are critical for wildlife and healthy ecosystem function, and yet are also important areas for methylmercury (MeHg) production and export to adjacent water bodies. Therefore, preserving or restoring wetland habitat, while limiting MeHg export, provides a unique challenge to wetland managers. This two-year study examined how wetland design could influence MeHg export. The study area consisted of eight ~10 hectare managed wetlands, annually flooded (4-20 cm) during mid-September thru late April to provide habitat for winter migratory waterfowl. The four 'treatment' wetlands were constructed with two distinct cells separated with a narrow berm. Eighty percent of the wetland was maintained shallow for waterbird habitat, where 20% of the area (~2 hectare) at the outflow end was excavated to a depth of ~1 m. The four 'control' wetlands were shallow and uniform in depth. Treatment wetlands were operated in a semi-continuous flow-through mode, while control wetlands were operated in a 'fill-and-hold' mode, where water was only released at the end of the managed flood period. We quantified three MeHg removal mechanisms (particulate settling, benthic demethylation, and photo-demethylation) in the deep-water treatment cells. During Year-1, mean whole-water MeHg load (by mass) decreased 41% from the in-flow to the outflow in the deep cells. Photodegradation accounted for 19% of the mass removed, while particle flux to the benthos accounted for the remainder. Benthic MeHg degradation was exceeded by MeHg production, and was thus not a major loss term. While deep-cells within the treatment wetlands served as net sinks for MeHg, overall the net MeHg export from the flow-through treatment wetlands (20±12 mg) exceeded export from the fill-and-hold control wetlands (2±4 mg). The use of deep cells in wetland design was effective in lowering MeHg exports under flow-through conditions, but further optimization of flow rates is needed prior to widespread implementation.

Keywords: mercury, methylmercury, methylation, demethylation, wetlands
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 307

Methylmercury and Total Mercury Imports and Exports of Two Tidal Wetlands in the Yolo Bypass and Suisun Marsh

Petra Lee, California Department of Water Resources, petra.lee@water.ca.gov

Mercury (Hg) has been a contaminant of concern in the Bay-Delta Region, based on elevated concentrations of methylmercury (MeHg) in fish and wildlife, particularly in areas of frequent wetting and drying, such as wetlands. Because future tidal wetland restorations are planned, determining loads from tidal wetlands is imperative.

Because of the potential of tidal wetlands to be methylmercury sources, the Department of Water Resources (DWR), under a regulatory obligation by the Central Valley Regional Water Quality Control Board, is characterizing and quantifying imports and exports of total mercury (THg) and MeHg of 3-4 tidal wetlands, and has already completed one-year studies of two of those wetlands, one in the Yolo Bypass (YB) and one in Suisun Marsh (SM).

DWR began the YB study in May 2014, and the SM study in June 2015, and completed one-year load studies at both sites. Staff collected samples for flood and ebb tides of 10 tidal cycles at both sites over the course of the year, generally more frequently in the warm months, and less frequently in the cold months.

The preliminary data at the tidal wetland in the Yolo Bypass indicate that the tidal wetland was always a sink for water, and generally a sink for THg and MeHg. The Suisun Marsh tidal wetland was more variable in whether it was a source or sink of water, as well as being a source or sink of THg and MeHg. Data from two more freshwater wetlands will be collected, and compared to the existing data to determine if any trends exist and whether it may be possible to manage methylmercury imports and exports from tidal wetlands.

Keywords: Methylmercury, Mercury, Tidal Wetlands, Blacklock, Yolo Bypass, Suisun Marsh
Session Title: Assembling the Puzzle Pieces: Synthesis of Mercury Science in the San-Francisco Bay Delta and Beyond II
Session Time: Thursday 3:15 PM – 4:55 PM, Room 307

Oh Give Me a Floodplain: Comparison of Food Web and Juvenile Salmon Growth across Four Central Valley Floodplains

Louise Conrad, California Department of Water Resources, Louise.Conrad@water.ca.gov
Lynn Takata, California Department of Water Resources, Lynn.Takata@water.ca.gov
Ted Sommer, California Department of Water Resources, Ted.Sommer@water.ca.gov
Eric Holmes, University of California, Davis, ejholmes@ucdavis.edu
Carson Jeffres, University of California, Davis, cajeffres@ucdavis.edu
Naoaki Ikemiyagi, California Department of Water Resources, Naoaki.Ikemiyagi@water.ca.gov
Jacob Katz, CalTrout, jkatz@caltrout.org
Miranda Bell-Tilcock, University of California, Davis, mirbell@ucdavis.edu

Floodplain restoration is a management priority in the Sacramento-San Joaquin Delta region because floodplains provide critical growth benefits to juvenile salmon. However, Central Valley floodplains include various landscape types, from farmland to wildlife areas. These habitats may provide a range of benefits for fish, but little work has been done to evaluate variability among habitats in their capacity to support juvenile salmon. In February 2015, we compared food web and juvenile salmon growth among six floodplain sites located in Sutter and Yolo Bypasses, Cosumnes River Preserve, and Dos Rios Ranch at the confluence of the San Joaquin and Tuolumne Rivers. These sites produced rice or wheat, or had natural vegetation during non-flooded periods. During managed inundation, we collected weekly zooplankton samples at each site. We held juvenile fall-run Chinook Salmon in replicated cages at Sutter, Yolo, and Dos Rios locations to compare growth rates. We observed diverse invertebrate assemblages across all sites in a broad range of densities (~25,000 – 175,000 total organisms/m^3). Rice fields in the Yolo Bypass were dominated by cladocera, while an adjacent fallow site in the Yolo Bypass had a mix of ostracods and midges. Sites in Sutter, Cosumnes, and Dos Rios locations had a higher presence of copepods. Salmon diets were variable, with some suggestion of selectivity for midges. Despite the variation in land use and food web, juvenile salmon growth rates (0.72 – 0.89 mm/day) were comparable among locations, and all were exceptional compared to reports from Central Valley riverine environments.

Statement of Relevance: This work suggests that farmlands and natural floodplain landscapes alike can provide functional and essential nursery habitat for juvenile salmon. For floodplain restoration efforts, focusing on improving access, rather than providing a specific habitat, may be the right emphasis for rapid support to the freshwater rearing phase of juvenile salmon.

Keywords: floodplain, salmon, habitat, growth, food web
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 308-310

The Knaggs Study – Comparing Food Resources and Growth of Juvenile Salmon between Flooded Agricultural Fields, the Toe Drain and the Sacramento River

Carson Jeffres, UC Davis Center for Watershed Sciences, cajeffres@ucdavis.edu
Jacob Katz, California Trout, jkatz@caltrout.org
Ted Sommer, DWR, ted.sommer@water.ca.gov
Louise Conrad, DWR, louise.conrad@water.ca.gov
Miranda Tilcock, UC Davis Center for Watershed Sciences, mirbell@ucdavis.edu
Eric Holmes, UC Davis Center for Watershed Sciences, ejholmes@ucdavis.edu

Floodplains have been shown to provide high quality rearing habitat, but due to difficulty in sampling, very few studies have been able to directly compare water quality, food resources and growth of juvenile salmon between river and floodplain habitats. From 2012 to 2016 juvenile fall run Chinook salmon have been reared in flooded rice fields on the Yolo Bypass showing prolific growth rates. To look at a direct comparison between riverine and flooded agriculture lands, in the winter of 2016, juvenile Chinook salmon were reared across a transect of the Yolo Bypass, Toe Drain, and Sacramento River to compare water quality, food resources and growth rates between the habitats. Water temperatures were warmer on the rice fields and Toe Drain compared to the river site for lower flows, but during a storm the last week of the study water temperature were similar. Food resources (invertebrates and zooplankton) were 130 times more abundant in the flooded agricultural fields than in the river habitat. Fish were placed in cages within all three habitats for a total of three weeks. During the three-week study, growth rates diverged greatly between the habitats. Growth rates were five times and three times higher in the flooded rice fields compared to the Sacramento River location and Toe Drain respectively. This direct comparison of food resources and individually marked fish allows for a better understanding of the potential benefits of juvenile salmon rearing on flooded agricultural habitats.

Keywords: floodplain, juvenile Chinook, growth, food web, agriculture, productivity, Yolo Bypass
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 308-310

Mimicking Hydrologic Process to Restore Ecological Function

Jacob Katz, California Trout, jkatz@caltrout.org
Carson Jeffres, UC Davis Center for Watershed Sciences, cajeffres@ucdavis.edu
Louise Conrad, DWR, Louise.Conrad@water.ca.gov
Ted Sommer, DWR, Ted.Sommer@water.ca.gov
Lynn Takata, DWR, Lynn.Takata@water.ca.gov
Miranda Tilcock, UC Davis Center for Watershed Sciences, mirbell@ucdavis.edu
Eric Holmes, UC Davis Center for Watershed Sciences, ejholmes@ucdavis.edu

Floodplain-sourced carbon is made available to aquatic food webs when floodplains activate as rivers flood. Today, levees cut off 95% of the Central Valley's floodplains from river channels. So that Central Valley aquatic ecosystems no longer recruit the carbon (stored solar energy) needed to support a robust aquatic food web and sustain abundant fish and wildlife populations. **Put simply, levees are starving salmon and smelt.**

Recovery of endangered fish populations will likely be impossible without first recovering the ecological processes which once supported historic abundances. Each winter and spring flooding in the pre-development Central Valley created a vast mosaic of productive floodplain habitats teeming with fish and wildlife. Nineteenth and twentieth-century investments in a network of dams, canals, and levees transformed the Central Valley into one of the world's most productive agricultural regions. This transformation has also led to the threatened and endangered status of numerous species.

This presentation will explore how managing floodplains to create prolonged shallow inundation mimics the Central Valley historical flood patterns to which California's native fish species are adapted. The presentation will synthesize 5 years of results from the Nigiri Project which seasonally manages for the creation of floodplain habitat for native fishes and waterbirds during winter and spring on fields that remain in agricultural production in summer and fall. The presentation will demonstrate how multi-species, multi-benefit land uses can cultivate ecological solutions on working agricultural landscapes while sustaining biodiversity and fostering resilience to climate change.

Keywords: salmon, floodplain, food web, fish, rice, levees, process based reconciliation
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 308-310

Evidence that Seasonal Floodplain-Tidal Slough Complex Could Support Improved Life History Diversity and Population Resilience

Pascale Goertler, DWR, Division of Environmental Services (DES), Env. Water Quality & Estuarine Studies Branch, Aquatic Ecology Section, Pascale.Goertler@water.ca.gov
Ted Sommer, DWR, DES, Ted.Sommer@water.ca.gov
William Satterthwaite, Southwest Fisheries Science Center, NMFS, NOAA, will.satterthwaite@noaa.gov
Brian Schreier, DWR, DES, Env. Water Quality & Estuarine Studies Branch, Aquatic Ecology Section, Brian.Schreier@water.ca.gov

Habitat restoration practitioners are faced with a knowledge gap when rehabilitating aquatic landscapes for species resilience. Population diversity is a mechanism for resilience and has been identified as an issue for the management of fisheries resources, but restoration ecologists lack evidence for specific features or processes that can be rehabilitated to promote diversity. Since habitat complexity may affect population diversity, it is important to understand how population diversity is partitioned across landscapes and among populations. In this study, we examined life history diversity based on size distributions of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) within the Yolo Bypass, a remnant transitional habitat from floodplain to tidal sloughs in the upper San Francisco Estuary (SFE). We used a generalized least squared model with an AR1 correlation structure to describe the distribution of variation in size from 1998 to 2014, and tested the effect of four possible drivers of the observed variation: (1) environmental/seasonal drivers, (2) prey resources and (3) sampling effort within the Yolo Bypass, and (4) the juvenile Chinook population at large within the Sacramento River and north SFE. We found that the duration of floodplain inundation, water temperature variation, season and sampling effort were influencing the observed size distribution and timing of juvenile salmon. Both floodplain inundation and thermal heterogeneity are features of hydrologic complexity, which is severely limited in the channelized lower Sacramento River and SFE. Data is not available to test if size variation within the Yolo Bypass contributes to population–level life history diversity or resilience, but given the minimal inundation and reduced thermal heterogeneity in adjacent habitats, these mechanisms of juvenile size and timing diversification are primarily available to salmon utilizing the Yolo Bypass. Therefore, enhancement of river floodplain tidal slough complexes and inundation regimes through habitat restoration may affect the resilience of Central Valley Chinook Salmon.

Keywords: juvenile Chinook Salmon, Yolo Bypass, habitat complexity, resilience, habitat restoration
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 308-310

Yolo Bypass: Potential Refuge for Delta Smelt?

Naoaki Ikemiyagi, Department of Water Resources, Naoaki.Ikemiyagi@water.ca.gov
Brain Mahardja, Department of Water Resources, Brian.Mahardja@water.ca.gov
James Hobbs, UC Davis Department of Wildlife, Fish and Conservation Biology, jahobbs@ucdavis.edu
Brian Healey, UC Davis Department of Wildlife, Fish and Conservation Biology, bmhealey@ucdavis.edu
Brian Schreier, Department of Water Resources, Brian.Schreier@water.ca.gov

The Yolo Bypass, the primary flood basin of the Sacramento River, has been shown to provide valuable habitat for various native fish species such as the Sacramento Splittail (*Pogonichthys macrolepidotus*) and Chinook Salmon (*Oncorhynchus tshawytscha*). However, recent data from the Yolo Bypass Fish Monitoring Program (YBFMP) indicates that the Yolo Bypass may also be an important habitat for the imperiled Delta Smelt (*Hypomesus transpacificus*) during non-flood periods via the perennially wetted Toe Drain. We examined Delta Smelt catch data from the YBFMP to identify changes in the distribution and abundance of Delta Smelt within the Yolo Bypass. We found that although Delta Smelt have been captured on an annual basis by the YBFMP since its inception in 1998, the annual Delta Smelt catch for our rotary screw trap has increased nearly ten-fold from pre-Pelagic Organism Decline years (POD) to post-POD years. Unexpectedly, we also observed relatively high annual catches of Delta Smelt during the recent drought years (2012-2015). Moreover, we found that juvenile Delta Smelt caught in the Yolo Bypass appear to be larger earlier in the year than those collected by other monitoring programs within the Interagency Ecological Program. Otolith growth increment data suggest that the larger size of juvenile Delta Smelt in the Yolo Bypass was due to higher growth rates in the region relative to the rest of the San Francisco Estuary. Our results suggest that the Yolo Bypass may provide high quality habitat even during drought conditions and could play a crucial role in the future persistence of this imperiled species.

Keywords: Yolo Bypass, Delta Smelt, Pelagic Organism Decline, Floodplain, Fish Monitoring
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains I
Session Time: Thursday 8:20 AM – 10:00 AM, Room 308-310

Survival and Travel Time of Acoustically Tagged Juvenile Chinook Salmon in Yolo Bypass during the "Godzilla" El Niño of 2016

Russell Perry, USGS Western Fisheries Research Center, CRRC, rperry@usgs.gov
Jason Romine, USGS Western Fisheries Research Center, Columbia River Research Center (CRRC), jasongrr@gmail.com
Adam Pope, USGS Western Fisheries Research Center, CRRC, apope@usgs.gov
Jon Burau, USGS California Water Science Center, jburau@usgs.gov

The Yolo bypass is a highly productive floodplain in the Sacramento River valley that consists of wildlife areas and agricultural land. The bypass is accessible to fishes in most years, but not all. Emigrating juvenile salmon that enter the bypass have accelerated growth rates due to increased prey abundance and density; however juvenile fishes have limited access to the Yolo bypass during low flow years or when the Fremont Weir does not overtop. In addition to contributing to growth, access to the bypass may improve survival of emigrating fishes relative to other emigration routes in the Delta such as the interior Delta. During the moderate flow spring of 2016 we evaluated survival and travel time of acoustically tagged juvenile Chinook salmon as they emigrated down the Sacramento River from the Tisdale Weir during different stages of spring floods. Five releases consisting of 240 fish each were made during the study. Fish were released prior to, during, and after the overtopping of the Fremont Weir. Data obtained from the study will provide a comparison between survival and travel times in the Yolo bypass versus the Sacramento River from release to Chipps Island. This comparison will inform management decisions regarding whether and to what extent to make the Yolo bypass more accessible to emigrating juvenile salmonids during drought or low flow years.

Keywords: Yolo bypass, survival, Chinook salmon, telemetry, Fremont weir
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 308-310

Hydrodynamics in a River Bend Adjacent to the Fremont Weir: Implications for Design of Fish Passage Structures

Paul Stumpner, USGS, pstump@usgs.gov
Jon Burau, USGS, jrburau@usgs.gov
Aaron Blake, USGS, ablake@usgs.gov

A fish passage structure (or notch) has been proposed at the Fremont Weir to partially inundate the Yolo Bypass at lower stages and with greater frequency. Evidence suggests that the Yolo Bypass may provide better habitat and increase through Delta survival of out-migrating juvenile salmon. In WY2016 we collected discharge and secondary circulation measurements near the Fremont Weir on the Sacramento River over a range of flows. These data suggest several salient features relevant for making estimates of fish entrainment into the proposed notch.

First, the discharge in the Sacramento River relative to the notch flow is critical in determining entrainment rates. Yet there is a non-linear relationship between stage and velocity at this location due to backwater effects from the Sutter Bypass and the Feather River, suggesting discharges calculated based on stage at this location will be inaccurate at higher flows, prior to the weir overtopping. Secondly, strong secondary circulation occurs at the apex of the bend increasing the cross-channel velocities downstream of the peak in the secondary circulation, suggesting notch location is critical in maximizing the number of fish entrained for a given amount of water entering the notch. Lastly, we estimate the location of the flow split in the river over a range of measured Sacramento River discharge and notch design flows. When design flows are low, relative to the Sacramento River flows, the flow split is closer to the outside of the bend relative to the fish distribution leading to minimal entrainment for a given volume of water entering the notch.

To integrate these results, we developed an individual-based model based on velocity fields interpolated from data and impose simple behaviors in a particle tracking model. We show that measured fish spatial distributions can be reasonably predicted based on a simple model of behavior.

Keywords: Hydrodynamics, Yolo Bypass, Entrainment, Particle Tracking
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 308-310

Techniques for Estimating Entrainment Rates in Riverine Junctions under Future Engineering Scenarios

Aaron Blake, USGS, CWSC, ablake@usgs.gov
Paul Stumpner, USGS, CWSC, pstump@usgs.gov
Jon Burau, USGS, CWSC, jrburau@usgs.gov

Recent mark-recapture survival modeling has shown that route-specific survival of emigrating salmonids varies between migration corridors in the Sacramento–San Joaquin River Delta. As a result, through Delta survival can be improved with engineering solutions that change route selection probabilities at channel junctions by increasing entrainment into high-survival routes. Two such solutions under consideration are a Bio Acoustic Fish Fence (BAFF) installed at the mouth of Georgiana Slough, and modifications to the Fremont Weir to allow fish passage into the Yolo Bypass at lower Sacramento River discharges.

Although the Georgiana Slough BAFF and the Fremont Weir modifications are being implemented independently, these projects present similar technical challenges with regard to predicting the route selection probabilities that will result from proposed engineering solutions. Individual-based modeling (IBM) shows promise for predicting the behavior of salmonids under proposed scenarios, but the inherent Lagrangian nature of these techniques can amplify errors in the underlying hydrodynamic data and behavioral abstractions driving the models. In order to quantify the cumulative effect of these errors, we present techniques for spatially explicit quantitative calibration and validation of individual-based model results using measured fish tracks. In addition, we present a general technique for estimating future entrainment probabilities using hydrodynamic and biologic data that can be collected prior to junction modifications and can then be used to calibrate and validate IBM predictions. Finally, we apply this technique to estimate future entrainment rates of emigrating salmonids for potential modifications to Sutter Slough and the Fremont Weir.

Keywords: Route Selection Probability, Juvenile Chinook salmonid, Fremont Weir, IBM Modeling
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 308-310

Integrating Hydrodynamics and Fish Physiology to Estimate Entrainment Rates for Fremont Weir Notch

David Smith, USACE-ERDC, david.l.smith@usace.army.mil
R. Andrew Goodwin, USACE-ERDC, Andy.Goodwin@usace.army.mil
Josh Israel, USBR, JAIsrael@usbr.gov
James Newcomb, CA DWR, James.Newcomb@water.ca.gov
Josh Urias, CA DWR, Joshua.Urias@water.ca.gov
Edmund Yu, CA DWR, Edmund.Yu@water.ca.gov
Manny Bahia, CA DWR, Maninder.Bahia@water.ca.gov
Yong Lai, USBR, ylai@usbr.gov

Floodplains are important features of rivers that influence interlinked morphological and ecological processes. The Sacramento River cannot access its floodplain due to levees except during high flows at engineered overflow weirs. The 3200 meter Fremont Weir conveys a maximum of 9300 m3/s, which is approximately 80 percent of the flood waters in the Sacramento River. When inundated downstream migrating fish readily pass over the weir onto the floodplain (Yolo Bypass). We used an integrative approach to assess effectiveness of 9 proposed Fremont weir notch alternatives in entraining fish from the Sacramento River and onto the Yolo Bypass. The proposed notches are designed to allow water to access the floodplain at much lower river flows thereby providing consistent and long term floodplain access for migrating juvenile salmon. We used multidimensional hydrodynamic models of the notches built with a combination of engineering drawings, topographical and bathymetric data to describe notch influence on river flow fields. We use measured fish positional data (winter and late fall run Chinook salmon) and multidimensional hydrodynamic models to calibrate modeled fish movement to speed over ground and spatial distribution. We found entrainment is a function of speed over ground, fish swimming capacity, influence on river streamlines and notch design. Through examination of different fish sizes and behaviors we explored alternative fish response to the proposed notches. We conclude the proposed notches vary in terms of entrainment rates and that through an integrated modeling approach we can refine and enhance the overall entrainment rates. The long-term relevance of this work impacts the survival of endangered salmon in the Sacramento through provision of an important habitat component, floodplains, that are largely inaccessible in the Sacramento system.

Keywords: Fremont weir, Yolo bypass, hydrodynamic models, notch, fish movement models
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 308-310

Ecological Importance of Fall Flows in Yolo Bypass

Jared Frantzich, Department of Water Resources, jfrantzi@water.ca.gov
Ted Sommer, Department of Water Resources, tsommer@water.ca.gov
Brian Schreier, Department of Water Resources, bshreie@water.ca.gov

Historically, Yolo Bypass lower trophic level research has focused on the benefits of the inundated floodplain habitat during the winter and spring months. However, in 2011, Department of Water Resources (DWR) began a year-round monitoring effort for a suite of lower trophic metrics that include the collection of biweekly: chlorophyll *a* (chl *a*), zooplankton and invertebrate drift samples. The timing of this increased monitoring effort was fortuitous, as it overlapped with significant phytoplankton blooms in fall 2011 and 2012 that occurred downstream of the Yolo Bypass in the lower Sacramento River. Substantial evidence from within region water isotopic studies, ongoing water quality data collection, and Yolo Bypass lower trophic monitoring suggested that these phytoplankton blooms were supported, in part, by elevated fall agricultural drainage flows from the Yolo Bypass. These phytoplankton blooms were unprecedented and of great importance to the Sacramento-San Joaquin Delta, as phytoplankton blooms like these have become increasingly rare in the Delta in recent decades. More importantly, declines in primary productivity have been linked to decreases in both zooplankton and pelagic fish abundance. Since 2013, DWR has been investigating the spatial and temporal trends of phytoplankton (chl *a*), zooplankton, nutrients, flow and water quality conditions before, during, and after increased fall agricultural flows in the Yolo Bypass. The initial results from this study show that the Yolo Bypass in all years has significantly higher chl *a* concentrations (Kruskal Wallis $p < 0.001$) in summer and fall compared to other regions of the Delta. In addition, results showed a significant correlation (Pearson Correlation $p < 0.001$) between increased Yolo Bypass calanoid copepod abundance and summer/fall flow pulses. Our hope is that continued investigation into the processes that facilitate increased fall phytoplankton biomass could yield new water management tools to benefit the Delta pelagic food web.

Keywords: Yolo Bypass, phytoplankton, zooplankton, flow
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass and other Central Valley Floodplains II
Session Time: Thursday 10:20 AM – 12:00 PM, Room 308-310

Measuring the Delta as a Place: A Regional Opportunity Index and Economic Indicators

Jonathon London, UCD Center for Regional Change, jklondon@ucdavis.edu
Alejo Kraus-Polk, UC Davis, akrauspolk@ucdavis.edu

The Delta Protection Commission's 2012 Economic Sustainability Plan (ESP) projected a 5 percent shift of Delta land towards higher-value vineyards and truck crops, assuming that land and water resources were protected. Proposed infrastructure (CalWaterFix) and ecosystem restoration projects could significantly alter the Delta's economy and the region's character. To gauge the pace and direction of change, and to understand the current socio-economic conditions of Delta residents and the communities in which they live, the DPC commissioned two projects from the Center for Regional Change at UC Davis.

1. A Report on the Delta, using the Center's Regional Opportunity Index (ROI), which is a comparative analysis of 33 key indicators that measure relative opportunity for both people and the places in which they live. The ROI focuses on six domains: education, economy, housing, transportation/mobility, health/environment, and civic engagement. The 2015 Report was based on a comprehensive analysis of these conditions within the Delta, comparing them to state averages. Overall, the ROI analysis presents a picture of a region struggling economically, with significant challenges related to health conditions as well. Further research and development efforts might include improving school quality, job quality and diversity, and health care, as well as expanding access to broadband internet.
2. A set of Economic Indicators for the Delta, including measures of economic, political, and social security, including the agricultural economy, labor market and job quality measures, and education. The indicators will be repeatable measures that can be examined every five years to document change across the region. The project will begin by interviewing stakeholders in the summer 2016, and will have draft indicators in tabular and map forms by late 2016.

Keywords: Socio-economic, economic opportunity, education, health care, agricultural economy, economic trends
Session Title: Delta as an Evolving Place
Session Time: Thursday 1:15 PM – 2:55 PM, Room 308-310

What Do We Know About Recreation in the Delta?

Greg Shaw, CSU Sacramento, sac14077@saclink.csus.edu
Dave Rolloff, CSU Sacramento, Rolloff@csus.edu
Amy Mickelson, CSU Sacramento, mickela@csus.edu
Beth Davidson, CSU Sacramento, Erickson@csus.edu

Boating, hunting, and fishing are long-standing contributors to the Delta's economy. However, recreational trends suggest increasing demand for non-motorized boating, agritourism, wildlife watching, and other non-consumptive activities. There is no current, regularly updated data about the demand for and economic impact of recreation in the Delta. The Delta Protection Commission (DPC) commissioned CSU Sacramento to study Delta recreation to support policy development and identify areas for potential investment.

Recreational Boating Needs Assessment: CSUS surveyed Delta boaters to identify patterns of boating use and spending, as well as infrastructure needs. The survey included law enforcement officers to identify areas of concern, facility issues, and trends in law enforcement. Public workshops offered an opportunity for the public to participate. Interim results will be available in late 2016, the final report will be available in June 2017.

Delta Recreation Research Strategy: CSUS will develop three research proposals to identify the socioeconomic dimensions of recreation in the Delta. The Strategy, scheduled for completion in July 2016, consists of a research prospectus for each of the following:

Non-motorized Watercraft Usage

Study the rapidly growing area of paddleboard, wind surfing, and kayak use in the Delta. Examine preferred locations, conflicts with other recreation groups, information needs, facilities, and calculate the economic impact of such recreation.

Economic Impact of Cultural Tourism and Agri-tourism

Study the economic impact, visitation preferences, information sources for people visiting farms, museums, wineries, historic buildings, and festivals in the Delta. Examine what they do, where they go, where they stay, and desired additional tourism infrastructure.

Barriers to Positive Tourism Development

Study potentially negative aspects of visitation in the Delta, such as traffic/infrastructure congestion, invasive species, litter, miscreant recreation styles, and water quality as factors that detract from the current recreation/tourism opportunities, or that create challenges for tourism growth.

Keywords: Boating, marinas, recreation, non-motorized watercraft, cultural heritage, tourism, wineries, museums

Session Title: Delta as an Evolving Place
Session Time: Thursday 1:15 PM – 2:55 PM, Room 308-310

Exploring the Creation of Food Hub in the Delta: The Sacramento-Yolo Rural-Urban Connections Strategy

David Shabazian, Sacramento Area of Council of Governments, dshabazian@sacog.org

The Delta Protection Commission's Strategic Plan seeks to stimulate agricultural-based economic development in a manner that protects and enhances the Delta's cultural, ecological and agricultural values. As part of this effort, the Commission funded a Sacramento Area Council of Governments (SACOG) case study on potential strategies to preserve and enhance the long-term viability of agriculture in the Delta portion of Sacramento and Yolo counties. SACOG utilized tools developed from the Rural-Urban Connections Strategy project, which presumes that resource conservation is bolstered by strategies that leverage and enhance the value of these assets.

The case study assessed current agricultural conditions by developing a field-level model of the study area and investigated emerging market opportunities to stimulate further economic development. A finding was that Delta agriculture is well positioned to capitalize on the rapidly expanding demand for locally grown food in the Sacramento and Bay Area regions.

Infrastructural barriers, particularly the lack of mid-scale facilities, could impede the expansion of the Delta local food system. The case study conducted an in-depth financial analysis of expanding and creating new agricultural infrastructure through a food hub facility, which would offer aggregation, packing, processing, storage, marketing, and distribution capacity. The project team found the food hub model to be financially feasible for the hub operator and supplying farmer.

Finally, the case study conducted a range of agricultural scenarios to detail the magnitude of economic, environmental, and other impacts from potential cropping pattern changes. The three scenarios—continuing recent trends, advancing a food hub investment, and supporting agritourism – demonstrate possible strategies that Delta stakeholders may explore to accelerate growth in the local food system.

This research is important to Bay-Delta management by demonstrating that these strategies can help preserve open space habitat in areas vulnerable to urban development by making agriculture a viable economic driver.

Keywords: History, culture, education, transportation, communication, reclamation, restoration, communities, economics, arts
Session Title: Delta as an Evolving Place
Session Time: Thursday 1:15 PM – 2:55 PM, Room 308-310

Delta Narratives: Highlighting the Delta's Cultural and Historic Resources

Bob Benedetti, CSU Sacramento, rbenedetti@pacific.edu
Blake Roberts, Delta Protection Commission, Blake.Roberts@delta.ca.gov

Despite the environmental, economic, and political importance of the Delta, the human history of the region has been obscure and poorly understood. Funded by the Delta Protection Commission, Delta Narratives was a collaborative project involving a team of scholars and museum professionals that communicated the importance of the Delta region in California's - and America's – history by developing a cultural and historical framework for multi-format educational exhibits.

Humans have occupied the Delta continuously for over 10,000 years. The Gold Rush brought thousands to the Delta's water highways as they traveled to inland mines. Many saw the potential of the Delta's rich soil and soon the region became an agricultural destination. The Delta later attracted those who would relax or hide out in its labyrinth of sloughs. Today, the Delta's environmental significance has been recognized and its water resources hotly debated.

The diversity of team skills and resources was critical in recovering the stories behind these events. Five scholars related Delta narratives to larger trends in California and American history by preparing essays on transportation and communication, reclamation and restoration, ethnic and economic communities, and writers and visual artists. The scholars utilized the archives and artifacts of local historical societies, museums, and libraries in their research. Museum professionals worked with the scholars to propose a series of exhibition strategies to help the public become aware of the history and the many cultural institutions serving the region.

The final report recommended the distribution of Delta stories through electronic media, integration into California's educational curriculum, and organizing of regular Delta Days to celebrate the region's cultural and historical riches. The Commission is currently pursuing these recommendations.

This research is important to Bay-Delta management by providing a greater historical understanding of human interaction with the Delta ecosystem and a context for policy decision-making.

Keywords: Agriculture, infrastructure, economics, economic development, local food, food hub, agritourism
Session Title: Delta as an Evolving Place
Session Time: Thursday 1:15 PM – 2:55 PM, Room 308-310

Resilient Landscapes: A Science-based Approach to Creating Recommendations for How to Return Desired Functions to Highly Altered Ecosystems.

Letitia Grenier, San Francisco Estuary Institute, letitia@sfei.org
Robin Grossinger, San Francisco Estuary Institute, Robin@sfei.org
Erin Beller, San Francisco Estuary Institute, Erin@sfei.org
April Robinson, San Francisco Estuary Institute, April@sfei.org
Sam Safran, San Francisco Estuary Institute, sams@sfei.org
Erica Spotswood, San Francisco Estuary Institute, Ericas@sfei.org
Ruth Askevold, San Francisco Estuary Institute, Ruth@sfei.org
Scott Dusterhoff, San Francisco Estuary Institute, Scottd@sfei.org
Jeremy Lowe, San Francisco Estuary Institute, Jeremyl@sfei.org
Carolyn Doehring, San Francisco Estuary Institute, Carolynd@sfei.org
Micha Solomon, San Francisco Estuary Institute, micha@sfei.org

The Bay Area faces environmental challenges that include rapid climate change, extinctions, natural systems stressed to the breaking point, and increasing human population. The necessity of addressing these issues creates an opportunity to re-envision our landscapes so they can support prosperous human and wildlife populations. Urbanization and natural resource exploitation occurred in particular patterns related to regional history. These patterns can now be revised over the coming decades to reflect new science, new stressors, and new societal values. This presentation details one approach to such a revision, which is based in a landscape resilience framework that we synthesized from the academic literature of resilience theory. To support desired functions (like support of native wildlife or delivery of clean drinking water) over the long term, landscapes must continue to provide the function in the face of gradual change and pulse disturbances.

Our approach to developing recommendations for achieving resilient landscapes starts with understanding how the landscape functioned in the relatively recent history of California prior to significant European development. This investigation into historical ecology illuminates the natural physical and chemical processes of the land and water and how they interacted with biological processes to support habitat types and wildlife populations. Then we analyze contemporary data to quantify landscape change related to loss of desired ecological functions. Finally, we identify opportunities and constraints to returning functions by restoring or emulating key physical and biological processes. This approach takes a large-scale, long-term view, which allows for different parts of the landscape to provide different functions and for actions to be implemented in phases over decades. Examples of how this approach is being applied through the Delta Landscapes Project and Resilient Silicon Valley will be briefly mentioned and more fully discussed in the "Resilient Silicon Valley" presentation and the "Re-envisioning the Delta" special session.

Keywords: Ecosystem Restoration, Reconciliation Ecology, Landscape Ecology, Resilience
Session Title: Restoring Resilient Landscapes
Session Time: Thursday 3:15 PM – 4:55 PM, Room 308-310

Restoration Tells a Story: Mapping of Delta Habitat Projects, Data and Science

Martina Koller, Delta Stewardship Council, martina.koller@deltacouncil.ca.gov
Megan Brooks, Delta Stewardship Council, Megan.Brooks@deltacouncil.ca.gov
Lita Brydie, Delta Stewardship Council, Lita.Brydie@deltacouncil.ca.gov

Where are habitat restoration projects in the Delta and what are we learning from them? In order to answer these questions in a compelling way, we find maps to be a great tool of expression. Also, maps are most powerful when they tell a story. Combining geospatial data with interactive maps, research findings with multimedia (photos, videos, text, 3d images), and habitat projects with environmental datasets, provides an engaging way to communicate and deliver a message about habitat restoration in the Bay-Delta system. We used story map technology to develop narratives about past Delta restoration projects by incorporating locations of restored, managed and historical wetlands, floodplain and flooded islands. We then linked restoration projects to geospatial datasets such as land elevation, channel network, levees infrastructure, vegetation cover and land use. We reviewed relevant research, published studies and available literature and linked the collated information to project locations. What has emerged is a visual story connecting restored areas to environmental datasets, research findings and lessons learned. The restoration story map presents acquired knowledge from past restoration projects and identifies remaining challenges that stand in the way of achieving better restoration success in the Delta and Suisun Marsh. The Delta restoration projects story map is one of many possible ways to effectively visualize, communicate and deliver habitat restoration information to Delta restoration practitioners, decision makers and the public. This tool can also complement the last phases of the Delta Plan adaptive management framework, “communicate current understanding and adapt.”

Keywords: gis, story map, restoration, interactive, communication
Session Title: Restoring Resilient Landscapes
Session Time: Thursday 3:15 PM – 4:55 PM, Room 308-310

Southport Levee Setback Project: Ecologically Functional Floodplains Under Construction on the Sacramento River

Chris Bowles, cbec eco engineering, c.bowles@cbecoeng.com
John Stofleth, cbec eco engineering, j.stofleth@cbecoeng.com
Douglas Shields, cbec eco engineering, d.shields@cbecoeng.com
Kenric Jameson, Reclamation District 900, wsrd@pacbell.net
Sergio Jimenez, HDR, Sergio.Jimenez@hdrinc.com

The presentation focuses on a 4-mile reach of the Sacramento River downstream of the City of Sacramento, where a major levee setback is schedule for construction starting in 2016 as a part of a multi-objective flood control and habitat restoration effort. This project represents an important step towards combining flood risk reduction with significant ecological enhancement.

An update is provided on the multi-disciplinary approach employed to integrate hydrodynamic modeling with geomorphic interpretation to maximize the restoration benefits that were incorporated into the design of this levee setback project. The approach utilized a 2-dimensional hydrodynamic and morphological model as an analytical tool for assessing the dynamics of floodplain inundation under existing and design conditions for a 12-mile reach of the Sacramento River. The assessment was used to support recommendations for ecosystem enhancement actions that optimized both geomorphic and ecologic function. The analysis provided insight into the geomorphic evolution of the study reach under the design condition and this insight was used to develop strategies for long-term floodplain management. The benefits of using a 2-dimensional hydrodynamic / sediment transport model as a tool to describe geomorphic processes and inform restoration design is emphasized.

A discussion is provided relating to how these types of levee setbacks represent of a significant opportunity for the future; as means of achieving both increased flood protection and habitat restoration and in turn, providing multiple benefits to society. This floodplain management approach is illustrative of one of the most promising solutions to the current levee integrity/ flood management crisis in California.

Keywords: Levees, setbacks, hydrodynamic and mgnrpologic modeling, restoration.
Session Title: Restoring Resilient Landscapes
Session Time: Thursday 3:15 PM – 4:55 PM, Room 308-310

Resilient Silicon Valley: Increasing Landscape Resilience through Interdisciplinary Science and Multi-Sector Collaboration

Robin Grossinger, San Francisco Estuary Institute, robin@sfei.org
Letitia Grenier, San Francisco Estuary Institute, letitia@sfei.org
Erin Beller, San Francisco Estuary Institute, erin@sfei.org
April Robinson, San Francisco Estuary Institute, april@sfei.org
Erica Spotswood, San Francisco Estuary Institute, erica@sfei.org

Famously referred to as the “Urbanized Estuary," the San Francisco Bay-Delta Estuary is largely surrounded by cities. As we work to create a healthier estuary in the face of climate change and other stressors, we are increasingly recognizing the importance of redesigning our urban landscapes to support prosperous human and wildlife populations. The urban margins must provide more habitat and connectivity for wildlife, offer transition zones for sea level rise migration, treat runoff, and deliver sediment to sustain the estuary. Fortunately, trends towards urban greening, Low Impact Development, bayside redevelopment, and green transportation present opportunities to redesign these landscapes to better sustain physical and biological processes. However, the positive effects of these diverse activities are currently limited by the lack of technical guidance, multi-partner coordination, and successful demonstration examples.

To address this need, we are working with multiple sectors in Santa Clara Valley to develop an integrated, multi-benefit approach to ecological resilience. In its first year, Resilient Silicon Valley produced a vision for landscape resilience that connects objectives across the Baylands, Valley, Streams, and Hills. The RSV Vision applies the Landscape Resilience Framework, which synthesizes current resilience science and theory into a holistic framework for improving resilience at the landscape scale (and is discussed in the Resilient Landscapes presentation). The initial RSV vision is being applied through collaborations with Google, Santa Clara Valley Water District, and other agencies and NGOs. Using this foundation, more detailed visions are being developed for specific portions of the valley and specific strategies to translate the technical guidance into local policies, plans, and projects. RSV and similar integrative, catalytic efforts have the potential to transform our urban areas to increasingly support the natural processes underlying the health and resilience of both people and wildlife.

Keywords: Ecosystem Restoration, Reconciliation Ecology, Landscape Ecology, Resilience
Session Title: Restoring Resilient Landscapes
Session Time: Thursday 3:15 PM – 4:55 PM, Room 308-310

Improving Habitat Along Delta Levees

Jessica Davenport, Delta Stewardship Council, Jessica.Davenport@deltacouncil.ca.gov
Darcy Austin, Delta Science Program, Darcy.Austin@deltacouncil.ca.gov
Jahnava Duryea, Delta Science Program, jahnava.duryea@noaa.gov
Daniel Huang, Delta Stewardship Council, daniel.huang@deltacouncil.ca.gov
Daniel Livsey, Delta Science Program, Livsey.daniel@gmail.com

Most of the historical riparian habitat along Delta waterways has been lost, as 1,100 miles of levees were erected, many armored with riprap. These modifications to the Delta helped establish and protect the Delta's productive farmland, but also greatly reduced the channels' ability to support native fish and wildlife. Recognizing this problem, the Legislature required the Delta Levees Program achieve a "net long-term habitat improvement." Additionally, the Delta Reform Act calls for improving river corridors for fish, birds and other animals.

The Delta Stewardship Council recently released the report *Improving Habitats Along Delta Levees* to support the development of the Council's Delta Levee Investment Strategy. Since this Strategy primarily focuses on prioritizing State investments in Delta levees to reduce flood risks, this report provides guidance so those investments can also contribute to long-term improvement of river corridors.

Through review of monitoring reports and interviews with experts for 15 levee habitat improvement projects in and near the Delta, we learned that most monitoring focused solely on vegetation performance and few projects evaluated species' response to habitat improvements. We also recognized the challenges that small, local reclamation districts face, maintaining their levees while also trying to improve habitat. Although we couldn't draw firm conclusions about effectiveness of past projects, we summarize lessons learned about which habitat designs may provide greater benefits to native species. The report also includes recommendations about how to better assess project effectiveness in the future. One recommendation is creating a standardized regional monitoring program to make it easier to compare results of habitat improvements across levee projects and relieving the direct responsibility of implementing a scientifically-robust monitoring program from reclamation districts. Another recommendation is for monitoring of levee projects to incorporate appropriate performance measures, including fish and wildlife response, to assess effectiveness of projects to benefit target species.

Keywords: Adaptive Management; Levees; Channel Margin Habitat; Riparian Habitat; Effectiveness Monitoring
Session Title: Restoring Resilient Landscapes
Session Time: Thursday 3:15 PM – 4:55 PM, Room 308-310

Changes in Phytoplankton Community Composition and Biovolume during Prolonged Drought

Tiffany Brown, Department of Water Resources, Tiffany.Brown@water.ca.gov
Mary Xiong, Department of Water Resources, Mary.Xiong@water.ca.gov

Phytoplankton are an important component of the San Francisco Estuary, comprising the base of the food web and sometimes forming nuisance blooms. Their community composition can vary widely under differing flow and nutrient conditions. Phytoplankton biovolume and biomass as chlorophyll-*a* represent what is directly available for consumption by higher trophic levels, and can vary by orders of magnitude among different taxa. DWR's Environmental Monitoring Program collects phytoplankton samples monthly to track changes in phytoplankton community and biomass. During the recent drought, the phytoplankton community in the Delta and Suisun Bay shifted dramatically to one dominated by small-celled cyanobacteria, considered a poor food source for zooplankton. Biovolume, however, varied widely between sites and years, with some large taxa such as diatoms representing over 50% of the biovolume but less than 10% of the organisms per milliliter. Possible reasons for these changes include changes to nutrient concentrations, fluctuations in temperature, and long residence times due to decreased flow.

Statement of Relevance: Drought is becoming the new normal for California and for the San Francisco Estuary in particular. Ongoing, multi-year droughts require understanding of how these conditions affect the phytoplankton community so that management tools can be developed to minimize nuisance blooms while maintaining a productive food web.

Keywords: phytoplankton, drought, community composition, biomass, biovolume
Session Title: Ecosystem Impacts of Drought: Detailing the Response from Phytoplankton to Fish
Session Time: Thursday 8:20 AM – 10:00 AM, Room 311-313

The Impact of Two Years of Successive Drought on *Microcystis* Blooms in San Francisco Estuary

Peggy Lehman, California Department of Water Resources, Peggy.Lehman@water.ca.gov
Tomofumi Kurobe, University of California at Davis, tkurobe@ucdavis.edu
Sarah Lesmeister, California Department of Water Resources, Sarah.Lesmeister@water.ca.gov
Sarah Blaser, San Francisco State University, sarahblaser@gmail.com
Dolores Baxa, University of California at Davis, dvbaxa@ucdavis.edu
Maxwell Mizel, University of California at Davis, Mmizel@ucdavis.edu
Chelsea Lam, University of California at Davis, chylam@ucdavis.edu
Tim Hollibaugh, University of Georgia, aquadoc@uga.edu
Alex Parker, California State University Maritime Academy, aparker@csum.edu
Frances Wilkerson, San Francisco State University, fwilders@sfsu.edu
Swee Teh, University of California at Davis, sjteh@ucdavis.edu

Future climate change is expected to increase the frequency and intensity of drought in California and associated toxic cyanobacteria blooms in San Francisco Estuary. The droughts in 2014 and 2015 were the third and fourth most severe drought years in San Francisco Estuary, and provided the opportunity to test the hypothesis that successive drought years create environmental conditions that promote larger and more toxic *Microcystis* blooms in the estuary, than a single drought year. Field samples were collected at 10 stations semi-monthly during the bloom season in 2014 and 2015. Physical, chemical and biological factors were measured using a combination of YSI sonde and laboratory analyses of water samples. *Microcystis* colonies were quantified by surface net tow and their growth rate was measured by carbon uptake. Nitrogen sources were determined using stable isotope concentration and diffusion studies. Contrary to expectations, the more severe drought in 2015 was not associated with a larger *Microcystis* bloom than in 2014. Median chlorophyll *a* concentration for all stations was three times greater in August and September in 2014 than 2015. Most physical and chemical conditions and processes in the water column were similar in 2014 and 2015, including the presence of excess nutrients and use of ammonium as the primary nitrogen source. The difference in bloom magnitude between years was most closely associated with changes in the seasonal variation in streamflow and water temperature. Elevated water temperature extended the duration of the bloom into December in 2014, but only into October in 2015. Relatively high primary producer growth rate, in combination with low inflow and agricultural export, also enhanced the accumulation of bloom biomass more in 2014 than 2015. Knowing how drought impacts toxic cyanobacteria blooms can lead to better management of fishery resources in San Francisco Estuary.

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The Effect of Drought on Smelt: The Long-Term Ecological Response of Native Smelt in the San Francisco Estuary

James Hobbs, UC Davis, jahobbs@ucdavis.edu

Problem Statement: In the San Francisco Estuary, two native osmerids, the Delta Smelt (*Hypomesus transpacifics*) and the Longfin Smelt (*Spirinchus thaleicthys*), have experienced population collapse, garnering significant attention by managers and spurring largescale ecological studies to determine the causes of decline. Approach: In this paper we examine the potential effects of drought on distribution, abundance and life history responses to gain a better understanding of how environmental variability influences the population response of these endangered fish. Results: Since the early 2000's we've documented changes in freshwater flows, temperature and food abundance for these fish. Concomitantly, we've observed a phenological shift in the spatial and temporal distribution, reduction in growth rates and declines to near zero abundance in recent monitoring surveys. Conclusions: Delta Smelt and Longfin Smelt respond rapidly to episodic drought conditions in the estuary, experiencing slower growth during the critical juvenile lifestage and poor recruitment success. Long-term trends suggest symptoms of an ecological syndrome is occurring, which is likely related to climate change. Significant changes to the management of freshwater flows is needed to provide population resilience to avoid extinction.

Keywords: Delta Smelt, Longfin Smelt, Drought, Climate Change, Extinction, Flow, Phenology
Session Title: Ecosystem Impacts of Drought: Detailing the Response from Phytoplankton to Fish
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Evidence of Regime Shift and Drought Impacts in the Sacramento-San Joaquin Delta Littoral Fish Community

Brian Mahardja, California Department of Water Resources, Division of Environmental Services (DES), brian.mahardja@water.ca.gov
M. J. Farruggia, California Department of Water Resources, DES, mary.farruggia@water.ca.gov
Brian Schreier, California Department of Water Resources, DES, brian.schreier@water.ca.gov
Ted Sommer, California Department of Water Resources, DES, ted.sommer@water.ca.gov

Various estuarine and freshwater ecosystems worldwide have undergone substantial changes in their ecological community due to multiple stressors that are often anthropogenic in origin. Over the past two decades, the Sacramento-San Joaquin Delta (Delta) saw a severe decline in pelagic fishes, a shift in zooplankton species composition, and rapid expansion of invasive aquatic vegetation. To evaluate whether major changes have also occurred in the littoral fish assemblage, we analyzed beach seine survey dataset collected regularly from 1995 to 2015 from 26 sites within the Delta. We examined changes in the littoral fish assemblage at three different ecological levels: species, community, and biomass, using clustering analysis, trend tests, and change-point analyses. We found that the annual catch for many introduced species and some native species have increased since 1995, while only a few have experienced decline. A consistent pattern of change over time in annual species community composition was also observed; a pattern which was primarily defined by a consistent increase in Centrarchid species abundance. However, the amount of freshwater input to the Delta also helped explain some of the interannual variation. Drought years were characterized by increased numbers of Mississippi Silverside *Menidia audens* and reduced catch of native cyprinid fish species such as the Sacramento Splittail *Pogonichthys macrolepidotus*. Lastly, we demonstrated that littoral fish biomass has essentially doubled over the 21-year study period, with Mississippi Silverside and the Centrarchidae family driving most of this increase. Overall, our results showed that drought years favor invasive species to the detriment of native species, and that a regime shift has occurred in the Delta littoral fish community. Furthermore, they indicated that the factors causing the decline in the pelagic food web could have been beneficial to the littoral community productivity.

Keywords: Regime Shift, Fish Community, Biomass, Time Series, Drought
Session Title: Ecosystem Impacts of Drought: Detailing the Response from Phytoplankton to Fish
Session Time: Thursday 8:20 AM – 10:00 AM, Room 311-313

Winter-Run Chinook Salmon Responses to Drought: Impacts on Population Viability Criteria

Joshua Israel, Reclamation, jaisrael@usbr.gov
Brett Harvey, Department of Water Resources, Brett.Harvey@water.ca.gov
Daniel Kratville, California Department of Fish and Wildlife, Daniel.Kratville@wildlife.ca.gov
William Poytress, U.S Fish and Wildlife Service, bill_poytress@fws.gov
Kevin Reece, Department of Water Resources, Kevin.Reece@water.ca.gov
Jeff Stuart, National Marine Fisheries Service, J.Stuart@noaa.gov

The effects of the 2014-2016 drought on viability of Winter-run Chinook Salmon (WRCS) is of intensive concern to agencies and stakeholders. During this period, unprecedented hydrometeorological challenges forced multiple temporary changes to CVP/SWP operational plans and state and federal regulations protecting environmental qualities and ESA-listed species. We performed a review of monitoring data from the Sacramento River and Bay Delta to evaluate the effects of the drought on the viable salmonid population criteria of WRCS. When reliable monitoring data were available, analyses were based on predictions from a conceptual model of drought operations and impacts on WRCS. By linking monitoring data with hypothesized mechanisms causing biological response, we integrated the droughts impact across life stages and habitats into a clearer picture of the plight of WRCS. We assessed various metrics for consideration of impacts from the drought's environmental and management drivers for brood years 2007 through 2012, between Water Year (WY) 2008 and 2013, of WRCS. We compared these years' measures with regard to the environmental conditions and operational events in their freshwater and estuarine life stages with similar measures from Brood Year (BY) 2013-2015 to determine if the salmon population was affected by the drought and management actions implemented during the drought period. Compilation of monitoring data showed measureable metrics reflecting abundance, distribution, and diversity were affected through the drought period and the degradation of these criteria will have consequences of the population's viability. A reduction in viability accelerates the need for greater management intervention to reduce endangerment of Winter-run Chinook Salmon.

Keywords: salmon, drought, temperature, outflow, viability criteria, monitoring, water operations
Session Title: Ecosystem Impacts of Drought: Detailing the Response from Phytoplankton to Fish
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Bathymetric Mapping for the 2015 False River Barrier: Solving Problems with Better Data

Shawn Mayr, California Dept. of Water Resources, North Central Region Office, sdmayr@water.ca.gov

Bathymetric monitoring was an integral part of the planning and construction of the False River drought barrier. The primary goal of the monitoring was to allow for the identification of sediment movement impacts in nearby channels. The Department of Water Resources, North Central Region Office made multiple river bed measurements in these channels before, during, and after the barrier was in place. Additionally, the data was useful for underwater hazard identification, hydrodynamic computer modeling, barrier site planning, engineering design, construction monitoring, flow monitoring, levee stability monitoring, and sediment impact evaluations. Some unexpected findings may change the way we think about the Delta's waterways.

Keywords: Bathymetry, drought barrier, False River, Multibeam, scour, sedimentation, monitoring, hydrodynamics
Session Title: Evaluating an Emergency Response: False River Drought Barrier Efficacy and Effects
Session Time: Thursday 10:20 AM – 12:00 PM, Room 311-313

Salinity Response, Hydrodynamic Change and Performance Limiters under the EDB and 2015 Hydrology

Kijin Nam, DWR, Kijin.Nam@water.ca.gov
Eli Ateljevich, DWR, Eli.Ateljevich@water.ca.gov

This presentation describes changes in the Bay-Delta induced by the Emergency Drought Barrier and associated 2015 low flow hydrology. We describe the hydrologic setting for the year and review the tidal pumping mechanism targeted by the EDB to reduce salinity intrusion. Through a synthesis of 3D modeling and data analysis we demonstrate that the EDB was successful in shutting down tidal pumping, preventing salinity increase landward of the barrier after closure. It also changed net and tidal flow patterns around Franks Tract. Conditions at closure have a persistent influence on barrier performance for several months. Although the mid-Delta experienced further subsequent freshening, the pace was slow. We show how the rate of freshening is modulated by pumping and by very limited lateral mixing in eastern Franks Tract and between Old and Middle Rivers. An episode of increased pumping in early September demonstrates how slightly higher pumping rates accelerate freshening. The limited lateral mixing in Franks Tract is explainable by wind and submerged aquatic vegetation, their contributions being confounded but dependable seasonally. We conclude by describing monitoring that would help assess a future EDB effort and confirm some of the nuanced flow features around Franks Tract. We describe how the unknowns we have identified affect the robustness of early season design support.

Keywords: Hydrodynamic Modeling, Salinity Intrusion, Emergency Drought Barrier
Session Title: Evaluating an Emergency Response: False River Drought Barrier Efficacy and Effects
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High Speed Mapping of Water Isotopes with Simultaneous Water Quality Measurements to Determine Effects of the Emergency Drought Barrier

Bryan Downing, US Geological Survey, bdowning@usgs.gov
Brian Bergamaschi, US Geological Survey, bbergama@usgs.gov
Carol Kendall, US Geological Survey, ckendall@usgs.gov
Tamara Kraus, US Geological Survey, tkraus@usgs.gov

Installation of the Emergency Drought Barrier (EDB) in West False River in 2015 to limit salinity penetration into the Central Delta and thus to water intakes in the south Delta also affected other water quality parameters with repercussions on food web dynamics. For example, the hydrologic change impacted water residence time, nutrient gradients and phytoplankton productivity. To investigate potential impacts of the EDB, we used high-speed boat transects designed to continuously measure nitrate, chlorophyll, dissolved organic matter fluorescence, and ancillary water quality parameters (temperature, pH, specific conductance, dissolved oxygen, turbidity) at high frequency (1 second) sampling rates. Measurements were made both with the EDB in place and after its removal. High frequency water isotope measurements (δ^2H, $\delta^{18}O$) were also collected simultaneously to assess the distribution of water residence times. High speed mapping was particularly useful in understanding the tidally complex area surrounding the EDB, because measurements made over relatively short time scale (hours) over a broad spatial scale (tens of miles) are required to resolve tidally associated changes (flood tide, ebb tide, slack tide). Here, we present preliminary results from our high speed mapping efforts, and discuss how high speed mapping helped to distinguish linkages between physical and biogeochemical processes. We demonstrate how data generated by this approach provide information useful to other monitoring programs, such as existing fixed monitoring stations, discrete sampling programs, and remote sensing efforts.

Keywords: Water quality, nutrients, isotope hydrology, high speed mapping, biogeochemical gradients
Session Title: Evaluating an Emergency Response: False River Drought Barrier Efficacy and Effects
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Characterization of the Impacts of the Emergency Drought Barrier on Nutrients and Phytoplankton in the Lower San Joaquin River

Alexander Parker, California State University Maritime Academy, aparker@csum.edu
Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@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
Jamie Lee, Romberg Tiburon Center, San Francisco State University, jamielee00@gmail.com
Tricia Lee, Romberg Tiburon Center, San Francisco State University, tricialee113@gmail.com

As a result of extreme drought conditions, an emergency drought barrier (EDB) was installed at False River between May and October 2015 to manage saltwater intrusion to the Delta. This action also altered water input to and circulation within Franks Tract. The potential ecological impact of the management action on nutrient concentrations and lower trophic levels in Franks Tract was uncertain however the barriers had the potential to create conditions that support algal blooms and promote harmful algal species. Franks Tract is generally characterized by relatively high water clarity, low inorganic nutrients and low chlorophyll, between 2 and 4 µg/L. Episodes of elevated phytoplankton, with chlorophyll >10 µg/L were documented in Sept 2011 and Oct 2012, dominated by *Microcystis* or a long-chain diatom, suggesting the potential for blooms to establish in the flooded island. We hypothesized that the EDB would alter source water, nutrients, and residence time in Franks Tract, creating favorable conditions for either slow growing *Microcystis* or long chain-forming diatoms. We carried out a series of cruises at stations located in the lower San Joaquin River, Mokelumne River, and Franks Tract between September and November (with the EDB in place and after its removal) and measured nutrients and chlorophyll, primary production and nutrient uptake, and assessed phytoplankton functional groups with diagnostic phytopigments. Nutrients and chlorophyll concentration in Franks Tract were remarkably similar to historical ranges with no clear effect of the EDB. *Microcystis* was noted in low to medium densities throughout the study area. Two remarkable differences in our observations were elevated chlorophyll at locations in the Mokelumne River and dense stands of submerged aquatic vegetation, including *Stuckenia pectinata* and *Potamogeton crispus* within Franks Tract. Our results suggest no large-scale alteration in nutrients or lower trophic levels as a result of the EDB operations.

Keywords: Emergency Drought Barrier, Franks Tract, Microcystis, Nutrients, San Joaquin River
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Effects of the Emergency Drought Barrier on the Transport of Zooplankton to Delta Smelt Habitat

Wim Kimmerer, Romberg Tiburon Center, San Francisco State University, kimmerer@sfsu.edu
Anne Slaughter, Romberg Tiburon Center, San Francisco State University, aslaught@sfsu.edu
Edward Gross, RMA, Inc., ed@rmanet.com
Steve Andrews, RMA, Inc., steve@rmanet.com

The dispersive transport mechanisms that move brackish water landward in the western Delta also move freshwater seaward; therefore the rock barrier installed on False River west of Franks Tract in 2015 was expected to reduce dispersive fluxes in both directions. The copepod *Pseudodiaptomus forbesi* is important food for the endangered delta smelt in the low-salinity zone (LSZ) to the west of the rock barrier, but the population is most abundant in freshwater to the east. Therefore the barrier may have reduced transport to delta smelt habitat and thereby reduced abundance. In 2010–2012 we conducted field surveys of copepod abundance and developed a box model to estimate exchange rates among regions of the Delta and to estimate mortality of the life stages of *P. forbesi*. Mortality of nauplii (larvae) in the LSZ was very high and sufficient to eliminate the copepod population there, but was offset by the subsidy of copepods from freshwater. In fall of 2015 we repeated the field surveys to determine copepod distributions, modeled hydrodynamic conditions with and without the barrier, and used the box model to examine how transport changed with installation of the barrier. As expected, tidal exchange between Franks Tract and the LSZ was reduced in 2015. Abundance gradients across the Delta were steeper than those from earlier years, consistent with reduced dispersion (or higher mortality) in the LSZ than in earlier years. This steepening may have offset the reduction in exchange rate due to the barrier, because abundance in the LSZ was not markedly lower than in previous dry years.

Relevance: manipulation of flow patterns in the Delta through alteration of its physical structure can have unintended consequences for species of concern. Plans for such alterations should include investigations into hydrodynamic consequences and how they cascade to ecological responses.

Keywords: Drought barrier, copepod, particle tracking model, hydrodynamics, spatial distributions
Session Title: Evaluating an Emergency Response: False River Drought Barrier Efficacy and Effects
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Hydrology of the Recent California Drought and Comparison with Past Droughts

Maurice Roos, CA Dep't of Water Resources, mroos@water.ca.gov

Multiyear droughts place a lot of stress on the Bay -Delta system. Water years 2012-15 turned out to be a severe 4 year drought in California. Other notable droughts of the past 100 years included 1918-20, 1924-26, 1929-34, 1976-77, 1987-92, and 2007-9. Using the Sacramento-San Joaquin 8 river runoff as a base, water year 2015 was the 4th driest of the historical record. Water year 2015 was about 20 percent better than 2014 on the Sacramento, but worse on the San Joaquin river system where 2015 was the 2nd driest, exceeded only by the severe 1977 water year. For the combined 8 river runoff, the recent 2015 water year was the 6th driest in a record of 110 years. The 4 year runoff, WY 2012-15, for the 8 river system was the driest 4 year set of record, exceeding slightly the previous record of 1931-34. However, on the southern group, the 4 rivers of the San Joaquin river system, the 4 year runoff was by far the worst in a 115 year historical record and about 20 percent drier than any 4 years in a reconstructed record of over 1000 years estimated from tree rings. The drought was most severe over central California, including the Central Coast, San Joaquin Valley, and southern Sierra. Figure 1 compares multi-year droughts of the Sacramento and San Joaquin River basins. Other charts will show precipitation deficits, reservoir storage comparisons, State Water Project supply deficits and the April 1 snowpack history. 2015 was notable with a new record low snowpack of only 5 percent on April 1.

Keywords: Drought, Water Supply, Sacramento and San Joaquin Rivers
Session Title: Climate, Drought and Water Management
Session Time: Thursday 1:15 PM – 2:55 PM, Room 311-313

Drought Water Right Curtailment

Wesley Walker*, UC Davis - Center for Watershed Sciences, wfwalker@ucdavis.edu
Jay Lund, UC Davis - Center for Watershed Sciences, jrlund@ucdavis.edu
Brad Arnold, UC Davis - Center for Watershed Sciences, barnold@ucdavis.edu
Andrew Tweet, UC Davis - Center for Watershed Sciences, atweet@ucdavis.edu
Bonnie Magnuson-Skeels, UC Davis - Center for Watershed Sciences, brmagnuson@ucdavis.edu
Chad Whittington, UC Davis - Center for Watershed Sciences, ccwhittington@ucdavis.edu

California's water rights system allocates water based on priority, where lower priority, "junior" rights are curtailed first in a drought. The Drought Water Rights Allocation Tool (DWRAT) was developed to integrate water right allocation models with legal objectives to suggest water rights curtailments during drought. DWRAT incorporates water right use and priorities with a flow-forecasting model to mathematically represent water law and hydrology and suggest water allocations among water rights holders. DWRAT is compiled within an Excel workbook, with an interface and an open-source solver. By implementing California water rights law as an algorithm, DWRAT provides a precise and transparent framework for the complicated and often controversial technical aspects of curtailing water rights use during drought. DWRAT models have been developed for use in the Eel, Russian, and Sacramento river basins. In this study, an initial DWRAT model has been developed for the San Joaquin watershed, which incorporates all water rights holders in the basin and reference gage flows for major tributaries. The San Joaquin DWRAT can assess water allocation reliability by determining probability of rights holders' curtailment for a range of hydrologic conditions. Forecasted flow values can be input to the model to provide decision makers with the ability to make curtailment and water supply strategy decisions. Environmental flow allocations will be further integrated into the model to protect and improve ecosystem water reliability.

Keywords: water rights, drought, modelling, curtailment, allocation, supply, law, reliability, forecast
Session Title: Climate, Drought and Water Management
Session Time: Thursday 1:15 PM – 2:55 PM, Room 311-313

An Innovative Ensemble Modeling System for Improved Water Supply Forecasts in the Sacramento-San Joaquin Delta

Minxue He, California Department of Water Resources, Kevin.He@water.ca.gov
Brett Whitin, California-Nevada River Forecast Center, Brett.Whitin@noaa.gov
Arthur Henkel, California-Nevada River Forecast Center, Arthur.Henkel@noaa.gov
Robert Hartman, California-Nevada River Forecast Center, Robert.Hartman@noaa.gov
Mitchel Russo, California Department of Water Resources, Mitchel.Russo@water.ca.gov

Problem Statement: The Sacramento-San Joaquin Delta receives a substantial portion of its water supply from upstream reservoirs to meet its water quantity and quality objectives and thus maintain a healthy ecosystem. Increasing water demand, increasing occurrence of hydroclimatic extremes, and warming climate pose great challenges to the reliability of water supply to the Delta. Providing reliable water supply forecasts with lead time up to months remains to be a practical solution to these challenges.

Approach: This study describes an innovative ensemble water supply forecasting system, the Hydrologic Ensemble Forecast Service (HEFS), currently employed at the California-Nevada River Forecast Center (CNRFC). The system provides ensemble streamflow forecasts up to one year by digesting the meteorological forecasts from the Global Ensemble Forecast System (GEFS). This study further assesses the forecast skill of the system for eight reservoirs draining into the Delta.

Results: The system provides satisfactory water supply forecasts for the Delta. On April 1st, the bias of median forecasts varies from -7.8% (Pine Flat) to 1.6% (Millerton Lake). The skill shows high sensitivity to extreme conditions but low sensitivity to ensemble size, forcing data, and the length of the study period.

Conclusions/Relevance: From a scientific perspective, the HEFS constitutes a significant step in the transition from traditional regression-based forecasting to ensemble forecasting in operations. As the skill of the meteorological (GEFS) forecasts continues to increase, the forecast skill of the HEFS will increase accordingly. Additionally, as skill develops in longer-range climate forecasts, that skill can be leveraged in this process as well. From a practical standpoint, the system serves a viable tool in providing critical information for water resources managers. They can capitalize on the ensemble nature of the products of this system and make uncertainty-informed, timely and effective decisions in maximizing the reliability of water supply for the Delta.

Keywords: Water Supply Forecast; Sacramento-San Joaquin Delta; Hydrologic Ensemble Forecast Service
Session Title: Climate, Drought and Water Management
Session Time: Thursday 1:15 PM – 2:55 PM, Room 311-313

Comparing Methods to Estimate Consumptive Use in the Sacramento-San Joaquin Delta: Preliminary Findings

Josue Medellin-Azuara, Center for Watershed Sciences, UC Davis, jmedellin@ucdavis.edu
Kyaw Tha Paw U, Land Air and Water Resources Department, UC Davis, ktpawu@ucdavis.edu
Yufang Jin, Land, Air and Water Resources Department, UC Davis, yujin@ucdavis.edu
Quinn Hart, Center for Watershed Sciences, UC Davis, qjhart@ucdavis.edu
Eric Kent, Land Air and Water Resources, UC Davis, erkent@ucdavis.edu
Jenae Clay, Land Air and Water Resources, UC Davis, jmclay@ucdavis.edu
Andrew Wong, Land Air and Water Resources, UC Davis, ajywong@ucdavis.edu
Andrew Bell, Center for Watershed Sciences, UC Davis, ambell@ucdavis.edu
Martha Anderson, USDA-ARS, Martha.Anderson@ars.usda.gov
Daniel Howes, ITRC, California Polytechnic State University, San Luis Obispo, djhowes@calpoly.edu
Forrest Melton, NASA-Ames Monterey, Forrest.S.Melton@nasa.gov
Tariq Kadir, Department of Water Resources, Tariq.Kadir@water.ca.gov
Morteza Orang, DWR, Morteza.Orang@water.ca.gov
Michelle Leinfelder-Miles, UC Cooperative Extension, ANR, mmleinfeldermiles@ucanr.edu
Jay Lund, Center for Watershed Sciences, UC Davis, jrlund@ucdavis.edu

Understanding consumptive use (CU) in the Sacramento-San Joaquin Delta (the Delta) is critical for water rights administration, management and operations, agricultural water management, and environmental and water quality protection. This research presents preliminary findings of a comparative study to improve understanding of consumptive water use in the Delta by coordinating modeling, measurement and other information from a variety of independent research and estimation efforts. Methods compared include CalSIMETAW, DETAW, METRIC, Priestley Taylor, SIMS and DisALEXI. In addition, direct field measurements of ET from bare soil were taken at several fields using eddy covariance and surface renewal stations. Preliminary findings indicate that the median estimates from the ensemble is broadly consistent with the 2013 California Water Plan, around 1.5 MAF. Summaries by crop, month and region are also part of the report. In addition, preliminary findings show that bare soil evapotranspiration at the end of the irrigation season was close to zero in four locations selected for field measurements during September-October of 2015. A final report on the 2014-2016 water years will be available in the spring of 2017. Improving quantitative understanding of CU in the Delta has the potential of increasing transparency and accuracy of models and reducing costs of water accounting statewide.

Keywords: evapotranspiration, consumptive use, remote sensing, field measurement, land use, management
Session Title: Climate, Drought and Water Management
Session Time: Thursday 1:15 PM – 2:55 PM, Room 311-313

Multi-Year Persistence of the 2014-15 West Coast Marine Heat Wave

Nate Mantua, NOAA, Southwest Fisheries Science Center, nate.mantua@noaa.gov
Emanuele Di Lorenzo, Georgia Inst. of Technology, School of Earth & Atmospheric Sci., edl@gatech.edu

Between the winters of 2013/14 and 2014/15 during the strong North American drought, the northeast Pacific Ocean experienced its largest marine heatwave ever recorded. Here we combine observations with an ensemble of climate model simulations to show that teleconnections between the North Pacific and the weak 2014/2015 El Niño linked the atmospheric forcing patterns of this event. These teleconnection dynamics from the extra-tropics to the tropics during winter 2013/14 and then back to the extra-tropics during winter year 2014/15 are a key source of multi-year persistence of the North Pacific atmosphere and ocean. The corresponding ocean anomalies map onto known patterns of North Pacific decadal variability, specifically the North Pacific Gyre Oscillation (NPGO) in 2014 and the Pacific Decadal Oscillation (PDO) in 2015. A large ensemble of climate model simulations predicts that the winter variance of the NPGO- and PDO-like patterns increases under greenhouse forcing, consistent with other studies suggesting an increase in the atmospheric extremes that lead to drought over North America.

Keywords: warm blob, marine heat wave
Session Title: Climate, Drought and Water Management
Session Time: Thursday 1:15 PM – 2:55 PM, Room 311-313

Before and After: Evaluating Spring Freshwater Inflow Regulations for the San Francisco Bay Estuary

Christina Swanson, Natural Resources Defense Council, cswanson@nrdc.org

Fresh water flowing into California's San Francisco Bay Estuary is highly contested and tightly managed. The current regulations for spring inflows were established in 1995, following a severe multi-year drought, lawsuits, fish population declines and several Endangered Species Act listings. These new standards were designed to provide inflows that reflected variation in hydrological conditions, prevent extreme low inflows, and improve low salinity habitat. However, since then, both fish populations and spring inflows (as a percentage of estimated unimpaired inflows) have continued to decline. I investigated the implementation and effects of the 1995 spring inflow standards. I found that, although the standards had been met in most years, they were waived in the two driest years (2014 and 2015) and, based on publicly available flow and EC data, apparently violated in a few other below median hydrology years. Comparison of pre-standard (1970-1994) and post-standard years (1995-2015) showed that implementation of the standards had little effect on seasonal flow amounts, although the frequency of extreme low inflows was reduced. Low salinity habitat quality and quantity showed slight improvement in some dry years, but not in the driest years when the standards were waived. Overall, this analysis suggests that the 1995 flow standards provided little if any improvement in inflow or ecological conditions in the estuary, information that should be informative for the State Water Board's review of the standards that is currently underway.

Keywords: Freshwater inflow, regulations, estuary, habitat, WQCP, SWRCB, spring, X2
Session Title: Ecological Flows and Flood Control
Session Time: Thursday 3:15 PM – 4:55 PM, Room 311-313

Assessing Functional Flows at a Global Scale: Implications for Environmental Flow Management Strategies in California

Jenny Ta, University of California, Merced, jta22@ucmerced.edu
Daniel Nover, University of California, Merced, dnover@ucmerced.edu
Joshua Viers, University of California, Merced, jviers@ucmerced.edu

The number of hydropower dams in the world is expected to more than double by 2030, a projection that does not include construction of dams for other purposes like flood protection, water supply, navigation, or recreation. This is one of many factors indicating that river systems throughout the world have been and will continue to be modified through water management practices resulting in impaired flow regimes critical to supporting hydrogeomorphic processes and ecological functionality of riverscapes. A functional flows paradigm – emphasizing process-based hydrograph components – has emerged as a guide for developing environmental flow frameworks in heavily managed river systems. Recent case-studies have explored Mediterranean-montane rivers in the western United States to identify key flow regime components, such as wet-season initiation flows, peak magnitude flows, recession flows, dry-season low flows, and interannual variability. The work presented here expands this framework to identify key hydrograph components in major hydroclimatic regions of the globe. Unimpaired natural flows were used to identify major hydrologic regions with distinct natural flow regimes and corresponding functional flow components specific to biophysical needs. Identification of these functional flow components enables comparison between a Mediterranean-montane river system, such as the Sacramento-San Joaquin, and other hydroclimatic regions. Our global-scale functional flow typology has been developed with an eye toward informing water resource managers on environmental flow requirements in different regions. Results suggest that implementing environmental restoration through establishment of sustainable environmental flows requires distinct policies in different hydro-climatic regions. Furthermore, a global perspective on environmental flows may inform best management practices for California's heavily managed riverscapes.

Keywords: functional flows, environmental flows, water management, flow regime
Session Title: Ecological Flows and Flood Control
Session Time: Thursday 3:15 PM – 4:55 PM, Room 311-313

Improving Multi-Objective Ecological Flow Management with Flexible Priorities and Turn-Taking: A Case Study from the Sacramento River Basin and San Francisco Bay–Delta Estuary

Clint Alexander, ESSA Technologies Ltd., calexander@essa.com
Frank Poulsen, ESSA Technologies Ltd, fpoulsen@essa.com
Donald Robinson, ESSA Technologies Ltd., drobinson@essa.com
Brian Ma, ESSA Technologies Ltd., bma@essa.com
Ryan Luster, The Nature Conservancy, rluster@tnc.org

Problem: The Sacramento River Bay Delta system is highly regulated to meet the water needs of agriculture, human communities and a range of natural resources that includes endangered Chinook salmon, green sturgeon and Delta smelt. Hydro project and water conveyance operational plans are currently informed by simulation modeling that attempts to globally optimize water allocation over a vast array of location specific objectives.

Approach: We demonstrate an improved method for multiple objective allocation of water: “turn taking” optimization (TTO) within a coupled multi-model cloud computing framework. We apply TTO to an array of physical hydrologic models linked with the Ecological Flows Tool (EFT), a multi-species decision support framework for evaluating how specific components of the flow regimes can be "specialized" to promote and balance favorable habitat conditions for 13 representative species and 31 indicators within the Sacramento River and San Francisco Bay Delta. TTO incorporates the existing water delivery and socio-economic water management criteria, priorities and constraints and optimizes monthly water release patterns each water year using a dynamically shifting set of EFT indicators. As an individual EFT indicator is successful in a particular year, its priority weight in one or more subsequent years is reduced (depending on the life-history needs of each species). Rather than attempting to meet all criteria every year, "turn taking" creates additional flexibility and opportunities for other indicators to be successful in other years.

Results: Evaluating the overall number of EFT indicators that were successful over simulation years by comparing TTO to a business as usual reference case that did not use TTO, revealed 12 EFT indicators that were improved with TTO, 14 which showed no change and 5 which showed a reduction with TTO.

Relevance: TTO provides an innovative new optimization technique to assist water managers balance competing objectives.

Keywords: EFT, optimization, environmental flows, CALSIM, USRDOM, USRWQM, Ecological Flows Tool
Session Title: Ecological Flows and Flood Control
Session Time: Thursday 3:15 PM – 4:55 PM, Room 311-313

Basin Planning for Coldwater Functional Flows

Timothy Nelson, State Water Resources Control Board, Division of Water Rights, timothy.nelson@waterboards.ca.gov
William Anderson, State Water Resources Control Board, Division of Water Rights, wanderson@waterboards.ca.gov

Recent drought years have illustrated the shortcomings of the existing water regulations with regards to maintaining environmental functional flows and thermal conditions, particularly related to sustaining critical life stages of threatened and endangered anadromous fish species. Recent work at the State Water Board, as a part of the Bay-Delta basin planning process, has included temperature simulation of environmental flow alternatives for the lower San Joaquin River and its tributaries at various fractions of tributary unimpaired flow. Modeling results are used to show the effectiveness of flow releases in meeting temperature criteria in certain months for spawning, egg viability, rearing, and migration within the Stanislaus, Tuolumne, and Merced Rivers. In addition, the water supply costs of meeting these flow objectives can be demonstrated. The lower San Joaquin and its tributaries can be contrasted with other case studies in the American River, Sacramento River, and Mill Creek. There exists a gap between the annual focus of operational management structures established to implement Biological Opinions and drought emergencies, and long-term basin planning that includes the consideration and implementation of environmental flow objectives. Temperature and water supply modeling tools are useful to demonstrate likely outcomes of planning alternatives, but effective implementation of flow objectives requires evaluation and optimization of the water costs and temperature benefits, among other benefits to listed and other species.

Keywords: Temperature modeling, water supply, anadromous fish, flow objectives, functional flows
Session Title: Ecological Flows and Flood Control
Session Time: Thursday 3:15 PM – 4:55 PM, Room 311-313

Flood Control 2.0: Integrating Habitat Restoration into Flood Risk Management at the Bay Interface

Scott Dusterhoff, San Francisco Estuary Institute, scottd@sfei.org
Robin Grossinger, San Francisco Estuary Institute, robin@sfei.org
Lester McKee, San Francisco Estuary Institute, lester@sfei.org
Carolyn Doehring, San Francisco Estuary Institute, carolynd@sfei.org
Sarah Pearce, San Francisco Estuary Institute, sarahp@sfei.org
Julie Beagle, San Francisco Estuary Institute, julieb@sfei.org
Micha Salomon, San Francisco Estuary Institute, michas@sfei.org

Throughout the San Francisco Bay region, flood control channels at the Bay margin are aging and in need of replacement. Many of these channels do not pass flood waters and sediment loads effectively because they were designed decades ago when watersheds were less developed and the Bay elevation was lower. In addition, the building of these channels often resulted in the fragmentation, disturbance, or complete destruction of important bayland habitats as well as disruption of the physical processes that maintained these habitats over time. Flood control managers currently have a rare opportunity to redesign new flood control projects at the Bay margin that can help meet current and future flood control needs and improve bayland habitat conditions, provided they have the right tools and knowledge base to develop resilient, multi-benefit designs.

Flood Control 2.0 is an EPA-funded project involving several agency partners that is aimed at developing tools and providing information that can be used in designing multi-benefit flood control channels at the Bay margin. This presentation will provide an overview of work being done under Flood Control 2.0 to characterize key landscape features and sediment delivery characteristics of major flood control channels, and develop high level management concepts that could support flood risk management while supplying freshwater and sediment to existing and restored baylands habitats. In the coming decades, reconnecting flood control channels with adjacent tidal areas will be essential for protecting people and ensuring bayland habitats are able to keep pace with an increasing Bay water surface elevation.

Keywords: Flood risk management, Multi-benefit management, Bayland restoration, Sediment delivery
Session Title: Ecological Flows and Flood Control
Session Time: Thursday 3:15 PM – 4:55 PM, Room 311-313

Cost-Benefit Analysis of the California WaterFix

Jeffrey Michael, University of the Pacific, jmichael@pacific.edu

At $16 billion, the California WaterFix is the most expensive water infrastructure project ever proposed in California. However, the sponsoring agencies have not, as of yet, produced a feasibility study or benefit-cost analysis of the project. This is important not just because of the projects' large cost, but because of the operational constraints that may need to be placed on the project in order for it to receive various regulatory approvals. In addition, the policy change from building the tunnels as part of a habitat conservation plan, the BDCP, seeking a section 10 Endangered Species Act permit to the tunnels-only WaterFix seeking a section 7 ESA permit has implications for the projects' economics that are not well understood.

This paper applies standard benefit-cost methodology to the WaterFix using data from the RDEIR/RDEIS, draft biological assessment, and other official documents describing the project. It includes an optimistic scenario which uses values are derived from earlier BDCP reports, and a base scenario where benefit values are derived from other analysis from the Department of Water Resources and Bureau of Reclamation. The analysis uses a 3.5% discount rate recently recommended by the California Water Commission and calculates benefits for 100 years of operations following an estimated 15 year construction period. Preliminary results are in the table below.

	base	optimistic
Benefits		
Export Water Supply	$1,319,521,208	$2,822,409,124
Export Water Quality	$1,626,802,827	$1,626,802,827
Seismic Risk to Exports	$0	$435,796,554
Total Benefits	$2,946,324,035	$4,885,008,504
Costs		
Ecosystem	$700,616,872	$0
In-Delta Municipal	$100,000,000	$30,000,000
In-Delta Agriculture	$411,087,481	$164,610,904
Construction Costs	$11,676,474,531	$11,676,474,531
O&M Costs	$591,658,075	$591,658,075
Total Costs	$13,479,836,959	$12,462,743,510
Net Benefit	($10,533,512,924)	($7,577,735,006)
Benefit/Cost ratio	0.22	0.39

Policymakers need to be mindful of these benefit-cost relationships as they consider environmental constraints and conditions to approving the project or risk increasing future environmental-economic conflict in the Delta.

Keywords: economics, Delta Tunnels, WaterFix, benefit, cost
Session Title: Ecosystem Management Challenges
Session Time: Thursday 8:20 AM – 10:00 AM, Room 314

Adapting Information Management to Improve Natural Resource Adaptive Management

Tony Hale, San Francisco Estuary Institute - Aquatic Science Center, tonyh@sfei.org
Kathryn Kynett, Sacramento-San Joaquin Delta Conservancy, kathryn.kynett@deltaconservancy.ca.gov
Cristina Grosso, San Francisco Estuary Institute - Aquatic Science Center, cristina@sfei.org

Recent years have witnessed increased attention not just on landscape restoration in the Delta, but also on ways to optimize transparent decision-making by reconceptualizing the relationship between restoration projects and the landscape that they affect. The Sacramento-San Joaquin Delta Conservancy (Conservancy) and partners, including SFEI-ASC, have made collective strides in recent years to bring together landscape restoration projects, legacy and current water quality information, data visualization technologies, and performance measures through several US EPA-funded projects. By working closely with agency partners, researchers, and other stakeholders, the Conservancy has sought to address critical data gaps and information redundancies, advancing innovations, that have otherwise impeded effective adaptive management.

Starting in 2013, the Conservancy convened a workgroup to evaluate and perform the merger of several disparate landscape restoration and conservation databases into a unified whole. Coming together were representatives from key partner agencies to develop Project Tracker, a tool that has significantly improved the management of project-related information. Following from this effort, the Conservancy tackled the challenge of discovering, collecting, and formatting data -- both legacy and active -- that could address questions of nutrient enrichment and toxic contaminants in the Delta. This project, called DEDUCE, helped to expand the current Bay Area Regional Data Center to serve additional CEDEN-compatible data. To make visual sense of these data, the Conservancy launched a visualization project to bring additional detailed water quality information into EcoAtlas. Finally, the Conservancy has focused on restoration project performance metrics with a new project, conducted in collaboration with the Delta Stewardship Council.

These projects may be individually recognized as offering incremental progress toward greater information access, transparency, and visualization. However, the whole is greater than the sum of the parts, with each project filling gaps to build a framework that can, in effect, establish a strong basis for adaptive management.

Keywords: adaptive management, performance measures, water quality, data visualization, landscape restoration
Session Title: Ecosystem Management Challenges
Session Time: Thursday 8:20 AM – 10:00 AM, Room 314

Lessons learned as Chair of the Science Advisory Team for the Marine Life Protection Act Initiative

Stephen Barrager, Baker Street Publishing, steve.barrager@gmail.com

I was the non-scientist Chair of the Science Advisory Team for the Marine Life Protection Act Initiative. I was also a member of the Leadership Team. I would like to share the lessons I learned from that experience.

Keywords: Decision making, Collaboration
Session Title: Ecosystem Management Challenges
Session Time: Thursday 8:20 AM – 10:00 AM, Room 314

Assessing Extinction I: Extinction as a Process

Jason Baumsteiger, Center for Watershed Sciences, UC Davis, jbaumsteiger@ucdavis.edu
Peter Moyle, Center for Watershed Sciences UC Davis, pbmoyle@ucdavis.edu

When considering long-term values of restoration projects in places such as Suisun Marsh, the potential for extinction of native species should be assessed. But while extinction is often at the forefront of conservation concerns, the primary focus has been on prevention, not assessment. In this talk we discuss general aspects of extinction, followed by a talk relating this discussion to native fishes of the San Francisco Estuary, including delta smelt. Extinction is usually regarded as a yes/no state, but its determination can be quite complicated. Using previous and novel approaches, we propose six extinction categories (mitigated, regional, native range, wild, visual, and global) which reflect increasing conservation-reliance and/or decreasing habitat availability. We explain how dependence on artificial selection is tantamount to mitigated extinction and introduce a waiting period (visual extinction) based on generation time rather than a fixed number of years to prevent premature declaration of extinction. Guidelines are then outlined to ensure a practical assessment of extinction and maximize the conservation effectiveness of these categories. Using imperiled fishes in California as a model, we demonstrate how a number of currently endangered species are already conservation-reliant, reaching the initial levels of extinction proposed. With a number of fishes in the Delta and Suisun Marsh approaching extinction (e.g., delta and longfin smelt), our guidelines and categories should be useful for assessing the status of these lineages and developing more comprehensive management strategies.

Keywords: extinction, conservation reliance, endangered fishes
Session Title: Ecosystem Management Challenges
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Assessing Extinction II: Delta Fishes

Peter Moyle, Center for Watershed Sciences UCD, pbmoyle@ucdavis.edu
Jason Baumsteiger, Center for Watershed Sciences, UCD, jbaumsteiger@ucdavis.edu

Here we apply our general discussion of extinction in the previous talk to Suisun Marsh and Delta fishes. The thicktail chub is a classic example of global extinction, while the Sacramento perch is regionally extinct. Winter-run Chinook salmon are completely conservation-reliant and subject mainly to artificial selection, thus are an example of mitigated extinction. Delta smelt and spring-run Chinook salmon, despite intensive management, still maintain populations 'in the wild' subject to natural selection and so do not yet fit our extinction categories but are likely to qualify for mitigated extinction in the near future. Fall-run Chinook salmon are also arguably an example of mitigated extinction because of their nearly complete reliance on hatcheries, although there is the potential to reverse that status with an intensive program of managing for naturally spawning populations. Delta smelt may face wild extinction in the very near future. The use of cultured fish to 'restore' the population has its pros and cons and merits intense discussion. If delta smelt are supported largely through the use of cultured fish, are they still delta smelt or are they a domesticated lineage rapidly diverging from the original? We favor considering such fish as 'real' delta smelt as long as artificial selection is kept to a minimum and the long-term goal is to develop a population that is once again subject mainly to natural selection, albeit in a novel ecosystem.

Keywords: delta smelt, thicktail chub, Chinook salmon, Sacramento perch, extinction
Session Title: Ecosystem Management Challenges
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Supporting Decisions through Collaborative Science: How CSAMP Works

Bruce DiGennaro, The Essex Partnership, bruce@essexpartnership.com

The Collaborative Science and Adaptive Management Program (CSAMP) is an applied science program specifically designed to inform decisions regarding water project operations and species protection in the Delta. The Program was established in 2013 as an outgrowth of litigation and is intended to provide an alternative where parties can work together to address critical uncertainties and promote common understanding. The Program is explicitly structured to integrate science and decision making through early and active engagement of decision makers in the formulation of key management questions. Management questions are then used in an adaptive management framework to drive the development of studies and tools which can improve our understanding and inform future decisions. The Program represents a unique engagement of decision makers, managers, and scientists from state and federal resource agencies, environmental organizations, and public water agencies working together to solve difficult, contentious management issues in the Delta. By providing an overview of the Program, this presentation will set the stage for the four other presentations in the special session which will describe specific CSAMP science investigations.

Keywords: Integrated Science and Decision Making, Adaptive Management, Species Protection
Session Title: The Collaborative Science and Adaptive Management Program - Moving from Litigation to Collaboration
Session Time: Thursday 10:20 AM – 12:00 PM, Room 314

Collaborative Adaptive Management Team (CAMT) Investigations: Using New Modeling Approaches to Understand Delta Smelt State Salvage Patterns at the State Water Project and Central Valley Project

Lenny Grimaldo, ICF, lenny.grimaldo@icfi.com
Matt Nobriga, USFWS, matt_nobriga@fws.gov
Will Smith, USFWS, william_e_smith@fws.gov
Rob Latour, VIMS, robert.latour3@gmail.com

As part of the Collaborative Adaptive Management Team (CAMT) investigations, we examined historical (1993-2015) salvage data to determine what factors affected Delta Smelt salvage at the State Water Project (SWP) and Central Valley Project (CVP) fish facilities. Our objective was to determine if new approaches could be applied to the data to yield new insights about the factors that explain Delta Smelt salvage patterns within and across years. Generalized additive models (GAMs) and Boosted Regression Trees (BRTs) were applied to a suite of predicator variables at different time scales of management relevance. Model performance was compared using cross-validation metrics. Overall, our preliminary models explained up to 78 % of the annual variability in Delta Smelt salvage. Combined exports, turbidity, FMWT index, and net delta outflow variables were retained in most models as the best explanatory variables. Results from this study improve upon previous analyses of salvage data and provide a framework for understanding factors that best explain entrainment risk conditions. In conjunction with our other CAMT studies, this work can be used by management to develop actions to protect Delta Smelt during high risk scenarios when they are most vulnerable to entrainment.

Keywords: Delta smelt, salvage, adaptive management, entrainment
Session Title: The Collaborative Science and Adaptive Management Program - Moving from Litigation to Collaboration
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Evaluating Potential Swimming Behaviors of Adult Delta Smelt by Application of a Particle-Tracking Model with Alternative Behavior Rules

Edward Gross, Research Management Associates, ed@rmanet.com
Benjamin Saenz, Resource Management Associates, benjamin.saenz@rmanet.com
Richard Rachiele, Resource Management Associates, richard@rmanet.com
Stephen Andrews, steve@rmanet.com, steve@rmanet.com
Stacie Grinbergs, Resource Management Associates, stacie@rmanet.com
Josh Korman, Ecometric, jkorman@ecometric.com
Lenny Grimaldo, ICF, Lenny.Grimaldo@icfi.com
Peter Smith, USGS retired, pesmith07@comcast.net
Michael MacWilliams, Anchor QEA, LLC, mmacwilliams@anchorqea.com
Aaron Bever, Anchor QEA, LLC, abever@anchorqea.com

Multiple individual based models of delta smelt have been developed, with the long-term goal of providing a tool for evaluating entrainment risk in a real-time environment. Each model consists of a set of simple behavior rules indicating delta smelt swimming responses to environmental stimuli and a particle-tracking model. Environmental stimuli considered include current speed and direction, salinity, turbidity, water depth, and distance to shore. Particle-tracking methods are applied to estimate the paths of delta smelt for combined hydrodynamic velocity and swimming. Both a depth-averaged model (RMA2) and a three-dimensional model (UnTRIM) were applied to supply hydrodynamic velocity and other environmental conditions. Qualitative and quantitative comparisons of predicted and observed delta smelt distribution are performed with the goal of identifying one or more plausible behaviors that merit further study. The observations used in this study include Spring Kodiak Trawl observations and salvage for 2002 and other years and the observations of Bennett and Burau (2014) in December 2010 to January 2011. For the Spring Kodiak Trawl periods simulated, the predictions of movement for different hypothesized behaviors and the catch observations are compared in a fitting approach which has initial abundance, natural mortality and salvage efficiency as free parameters. In the Bennett and Burau observation period a more qualitative approach is applied in which initial distribution is assumed and subsequent distribution is predicted over the following weeks for several behaviors without accounting for mortality. Simple representations of some previously hypothesized behaviors lead to predicted distribution broadly inconsistent with observed distributions. Slightly more complex behaviors involving both turbidity triggers and some form of tidal migration provide predictions more consistent with observed distributions.

Keywords: delta smelt, particle tracking, hydrodynamic model, UnTRIM, RMA2
Session Title: The Collaborative Science and Adaptive Management Program - Moving from Litigation to Collaboration
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Effects of Water Project Operations on Juvenile Salmon Survival in the Delta: Literature and Data Review

Rebecca Buchanan, University of Washington, rabuchan@uw.edu
John Ferguson, Anchor QEA, LLC, jferguson@anchorqea.com
Chuck Hanson, Hanson Environmental, Inc., chanson@hansonenv.com
Barb Byrne, National Marine Fisheries Service, Barbara.Byrne@noaa.gov
Pat Brandes, U.S. Fish and Wildlife Service, pat_brandes@fws.gov
Brett Harvey, California Department of Water Resources, brett.harvey@water.ca.gov
Josh Israel, U.S. Bureau of Reclamation, jaisrael@usbr.gov
Sheila Greene, Westlands Water District, sgreene@westlandswater.org
Daniel Kratville, California Department of Fish and Wildlife, Daniel.Kratville@wildlife.ca.gov
Rene Henery, Trout Unlimited, rhenery@tu.org
Joe Miller, Anchor QEA, LLC, jmiller@anchorqea.com

The effects of water project operations (WPO) on survival of juvenile salmon migrating through the Delta is of high concern to managers. We performed a literature review on the survival effects of WPO, including exports (E), Delta inflow (I), the San Joaquin River (SJR) I:E ratio, and the Delta E:I ratio. We also compiled estimates of through-Delta survival from CWT and acoustic-telemetry (AT) studies of SJR fall-run Chinook salmon, and reach-specific survival estimates from AT studies, and compared them to measures of Delta inflow, exports, and I:E. Through-Delta survival of SJR Chinook has been low (<0.20) since 2002 regardless of flow and exports operations. Sacramento River (SR) Chinook survival has varied more, with 2014 estimates ranging from 0.00 to 0.30 for spring- and fall-run Chinook, and up to 0.35 for winter-run Chinook. The Head of Old River Barrier (HORB) is effective at diverting SJR fish away from the interior Delta, but consistently low survival in all routes limits its protective effect on through-Delta survival. For SJR Chinook, higher SJR flow is associated with higher survival particularly when the HORB is in place, and the flow effect is strongest in the upstream reaches; very low through-Delta survival has been observed even in high flow years or with the HORB in place. Evidence of an export effect on through-Delta survival was both weak and inconsistent for SJR Chinook. The relationship between Delta survival of SJR Chinook and I:E is variable but generally positive for lower I:E values (e.g., I:E < 3); statistical analysis suggests a weak but generally negative effect of increased Delta E:I on survival of SR Chinook. Large uncertainties remain in how WPO influences salmon survival in the Delta and in population-level effects, which will require cooperation between resource management/funding agencies and researchers to resolve.

Keywords: Chinook salmon, Delta, exports, inflow, barrier, water project operations
Session Title: The Collaborative Science and Adaptive Management Program - Moving from Litigation to Collaboration
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CAMT Salmonid Scoping Team – Recommendations for Future Salmonid Investigations

John Ferguson, Anchor QEA, LLC., ferguson@anchorqea.com
Chuck Hanson, Hanson Environmental, Inc., chanson@hansonenv.com
Sheila Greene, Westlands Water District, sgreene@westlandswater.org
Barbara Byrne, NOAA Fisheries, Barbara.Byrne@noaa.gov
Patricia Brandes, U.S. Fish and Wildlife Service, pat_brandes@fws.gov
Rene Henery, Trout Unlimited, RHenery@tu.org
Josh Israel, U.S. Bureau of Reclamation, jaisrael@usbr.gov
Brett Harvey, California Department of Water Resources, brett.harvey@water.ca.gov
Rebecca Buchanan, University of Washington, rabuchan@uw.edu
Dan Kratville, California Department of Fish and Wildlife, Daniel.Kratville@wildlife.ca.gov

Problem: Survival through the Sacramento-San Joaquin River Delta (Delta) has been low for San Joaquin River Chinook salmon, averaging approximately 5% since 2002, and variable for Sacramento River Chinook salmon; survival data are limited for steelhead. Water export operations contribute to salmonid mortality via direct mortality at facilities, but direct mortality does not account for the majority of Delta mortality; the contribution of various stressors to the high mortality is unknown.

Approach: A collaborative process involving technical experts participating on the CAMT Salmonid Scoping Team (SST) was initiated in 2013. The SST synthesized technical information regarding hydrodynamics, juvenile salmonid migration, and survival in the Delta related to operations of the State Water Project and Central Valley Project. In June 2016 the SST issued reports to CAMT that reviewed the available information, identified gaps in existing knowledge, provided recommendations for future actions, and addressed eight specific management questions.

Results: The SST provided CAMT with the following recommendations:

- Expand the analysis of existing survival data to address information gaps, management issues, and testable hypotheses as part of developing a long-term survival program
- Implement short-term actions to improve salvage facility operations
- Develop a long-term monitoring, research and adaptive management plan
- Implement the long-term monitoring, research and adaptive management plan

Conclusions/Relevance: Implementation of the long-term monitoring, research and adaptive management plan will allow water project operations to be assessed. It will reduce uncertainty, potentially identify the incremental role water projects operations have on salmonid survival through the Delta, and potentially lead to adjustments to water project operations that improve survival beyond current levels. Information developed through implementing the plan could be integrated with, and incorporated into, decision support tools used to better manage the system. The long-term plan could be integrated with other major monitoring programs in the Central Valley.

Keywords: Salmonid survival, Delta collaborative, adaptive management, water export operations
Session Title: The Collaborative Science and Adaptive Management Program - Moving from Litigation to Collaboration
Session Time: Thursday 10:20 AM – 12:00 PM, Room 314

Overview of the RIO-SFE Program and Remote Sensing with Landsat 8

Curtiss Davis, Oregon State University, cdavis@coas.oregonstate.edu
Nicholas Tufillaro, Oregon State University, nbt@coas.oregonstate.edu

We are conducting a three year NASA Interdisciplinary Science project on San Francisco Bay and Delta Ecosystem (RIO-SFE) developing data sets and a modeling framework for an ecosystem approach to the stewardship of the SFE including freshwater and marine resources within the SFE. Our SFE project combines four components: (1) satellite observations, (MERIS, HICO on the International Space Station, Landsat 8-OLI); (2) field observations (nutrients, phytoplankton, suspended sediments, CDOM and optical properties); (3) the CoSiNE ecological model integrated the SCHISM hydrological model of SFE, and (4) Coordination with Stakeholders. In this talk we give an overview of the remote sensing work and particularly highlight the use of Landsat-8 OLI data which has been particularly useful for work in the Delta. We use a newly developed ocean color processor for Landsat-8 to examine changes in the Northern San Francisco Bay. Product maps using panchromatic enhancement (~15 m resolution) and scene based atmospheric correction allow a detailed synoptic look every 16 days. We discuss how this and other satellite data is used together with in situ data to validate models and advance our understanding of the ecology of San Francisco Bay and help with the management of this complex system.

Keywords: Landsat-8, remote sensing, ecosystem modeling, RIO-SFE, ecosystem
Session Title: Remote Sensing and Predictive Modeling to Improve Decision Making in Managing San Francisco Bay and Estuary
Session Time: Thursday 1:15 PM – 2:55 PM, Room 314

In situ Measurements of Optical Properties and Lower Trophic Level Dynamics in the San Francisco Estuary, Made during Drought and El Niño Conditions (RIO-SFE Study)

Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Curtiss Davis, Oregon State University, cdavis@coas.oregonstate.edu
Nick Tufillaro, Oregon State University, nbt@coas.oregonstate.edu
Sarah Blaser, Romberg Tiburon Center, San Francisco State University, sarahbaser@gmail.com
Edmund Antell, Romberg Tiburon Center, San Francisco State University, edmund.antell@gmail.com
Jamie Lee, Romberg Tiburon Center, San Francisco State University, jamielee00@gmail.com

The San Francisco Estuary/Delta (SFE) region experienced extreme drought conditions in 2014 and 2015 followed by heavy precipitation during spring 2016 as a consequence of an El Nino. In situ measurements were made in 2014 (May, October), 2015 (March, May, October) and 2016 (March, May) to compare the effects of the different flow and climate conditions as part of a three-year NASA Interdisciplinary Science project on the SFE Ecosystem (RIO-SFE). The goals were to a) measure remote sensing reflectance and inherent optical properties and the pigment (chlorophyll-a) and suspended sediment concentrations that determine optical regimes within the system and b) measure nutrient concentrations, phytoplankton productivity and community composition. Our hypothesis was that there will be elevated nutrients accompanying the drought as a result of less dilution, with elevated chlorophyll and spring phytoplankton blooms enabled by longer residence times. The converse - lower nutrient concentrations and less chlorophyll with elevated turbidity and TSS might be expected with the high flow conditions. These data from the northern SFE, South Bay and the Sacramento River are compared with past more “normal” conditions for spring to test these hypotheses. Surprisingly in March 2016 there was elevated chlorophyll (> 10 ug/L) in the river accompanied by the lowest spring values of ammonium that we have observed, and extremely high chlorophyll of 80 ug/L measured near the confluence in May 2016. These types of data will become increasingly important to inform adaptive management of pelagic species of concern and water quality for ecosystem sustainability in a future changing estuary.

Keywords: phytoplankton, bloom, nutrients. primary productivity, water quality, El Nino
Session Title: Remote Sensing and Predictive Modeling to Improve Decision Making in Managing San Francisco Bay and Estuary
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Development, Implementation, and Validation of a Modeling and Forecast System for the San Francisco Bay

Yi Chao, Remote Sensing Solutions, ychao001@gmail.com
John Farrara, Remote Sensing Solutions, farraraj@yahoo.com
Carrie Zhang, UCLA, zhc216@gmail.com
Fei Chai, University of Maine, fchai@maine.edu
Curt Davis, Oregon State University, cdavis@coas.oregonstate.edu
Richard Dugdale, San Francisco State University, rdugdale@sfsu.edu
Frances Wilkerson, San Francisco State University, fwilkers@sfsu.edu
Joseph Zhang, VIMS, yjzhang@vims.edu
Eli Ateljevich, Department of Water Resources, Eli.Ateljevich@water.ca.gov

With the goal of monitoring and predicting environmental conditions in the Bay, a three-dimensional modeling system for the San Francisco Bay (SFB) has been developed and implemented. The system is based on the Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM), an open-source community-supported modeling code with unstructured grids. SCHISM is coupled to a ROMS-based regional coastal ocean model and forced by output from a regional atmospheric model. The importance of monitoring and prediction efforts in the Bay has been underscored recently by the unprecedented warming in the region during 2014-2015.

We will present a documentation of the SFB SCHISM model configuration and its performance during a multi-year (April 2004 - April 2015) hindcast. Validation against tide gauges sea surface heights demonstrates that the system can accurately reproduce the major tidal components observed in the Bay. Validation of the annual mean and mean seasonal cycle using USGS observations of temperature and salinity reveals very good agreement between the model and observations, especially for the Central Bay region. An analysis of the heat and salt budgets for the Central Bay aimed at determining the major forcing terms driving the annual and seasonal changes will be presented. Lastly, a discussion of the modeled interannual variability, including the 2014-15 warming, will be given.

Keywords: modeling, unstructured grid, circulation, heat & freshwater flux, river discharge
Session Title: Remote Sensing and Predictive Modeling to Improve Decision Making in Managing San Francisco Bay and Estuary
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Modeling the San Francisco Bay Ecosystem Dynamics

Qianqian Liu, School of Marine Sciences, University of Maine, liuqianqian0622@gmail.com
Fei Chai, School of Marine Sciences, University of Maine, fchai@maine.edu
Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Yi Chao, Remote Sensing Solutions, ychao001@gmail.com
Hongchun Zhang, Remote Sensing Solutions, zhc216@gmail.com

A coupled physical-biogeochemical model is used to study the nutrient and biomass cycles in San Francisco Bay. The hydrodynamical processes are simulated by Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM), and the biogeochemical processes use the Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE). As a measure of light attenuation and a key ecological parameter, turbidity is highly correlated with the biomass production in San Francisco Bay and has been incorporated into the CoSiNE model in the form of Suspended Particulate Matter (SPM). Measurements of chlorophyll and nutrients (Dugdale and Wilkerson), and turbidity (Tufillaro and Davis) are used to assess the model accuracy. This study investigates the ecosystem of San Francisco Bay and its response to different hydrological conditions in 2011 and 2012 by a series of process-oriented experiments.

Keywords: Ecosystem, Numerical Simulation, Turbidity, Chlorophyll, Nutrients, Wet and Dry Years
Session Title: Remote Sensing and Predictive Modeling to Improve Decision Making in Managing San Francisco Bay and Estuary
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Delta Dash: Bay-Delta SCHISM Operational Modeling

Eli Ateljevich, DWR, Eli.Ateljevich@water.ca.gov
Kijin Nam, DWR, Kijin.Nam@water.ca.gov

We describe prototype work on a 3D model of hydrodynamics, temperature and water quality for short and medium term operational decisions. The combination of higher fidelity modeling and data assimilation provides a more accurate picture of real-time conditions within the Delta than has previously been possible, and the injection of observations has allowed researchers to constrain complex biogeochemical systems sufficiently to study individual components. Data assimilation also yields an improvement in accuracy on simpler dynamics and here we focus on how these improvements tally with the requirements of operational decision support and water quality compliance. The 5-7 day horizon emerges an important time scale, characterizing the prediction window of synoptic events offshore and the routing time from Orville and Shasta reservoirs. As expected, longer-than-fortnight improvement persists for tracer transport and this improvement is particularly important for low export scenarios with longer residence times. As the prediction window is extended to months, we compare uncertainty from atmospheric, consumptive use and ocean forcing assumptions to the uncertainty associated with Delta operational response. The work described in this talk comes from a prototype for an always-running operational and emergency response modeling tool (Delta Dash), encompassing contributions from DWR and other authors in the session. Our conclusions concerning operational time scales are pertinent to the definition of outflow and salinity standards.

Keywords: Hydrodynamic Modeling, Real-time Decision Support, Data Assimilation, Water Quality Management
Session Title: Remote Sensing and Predictive Modeling to Improve Decision Making in Managing San Francisco Bay and Estuary
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SacPAS: A Real Time Decision Support System to Predict and Assess Operational Benefits and Risks to Central Valley Salmon

James Anderson, Columbia Basin Research, School of Aquatic and Fishery Sciences, University of Washington, jjand@uw.edu
Josh Israel, Bureau of Reclamation Mid Pacific Region, jaisrael@usbr.gov

Problem statement:

The volume of cold water is insufficient to protect all early life stages of temperature-sensitive Chinook salmon. Prior to the spawning season, Reclamation develops a water release schedule based on the weather forecasts. Currently, the forecasts and schedules are difficult to update over the fish spawning and rearing seasons and there are limited analytical tools and models to assess the impacts of their water schedules on fish survival and distribution.

Approach:

The work, funded by and in collaboration with Reclamation, is developing a decision support system that links a real-time data management system with models to forecast the progress and movement of salmon from spawning through smolt migration. Our immediate focus has been on winter-run Chinook salmon, but already there are applications which will be useful across multiple CVP-operated rivers. The web-accessible system has advanced through rapid prototyping and extensive interagency interaction to configure a system operating for Columbia River Salmon for over a decade.

Results:

In its first year, the project has established a website (http://www.cbr.washington.edu/sacramento/) with extensive operational queries and alert functions and models to predict egg emergence and smolt migration. Currently, forecasting complete egg to Delta movements is limited by the information available to define movement behavior of fish in fry and smolt stages. However, the current model will be able to identify critical uncertainties and their impact on forecasting fish movement and survival in their freshwater life stages.

Relevance:

This system provides a foundation for in-season predictions useful for adaptive management that will monitor fish response, integrate these new movement behavior data, and further quantify benefits and risks of management decisions on salmon populations.

Keywords: cold water management, Chinook salmon, forecast, spawning, rearing
Session Title: Environmental Models
Session Time: Thursday 3:15 PM – 4:55 PM, Room 314

Hydrodynamic Modeling of Flood Hazards for the Southern Eden Landing Portion of the South Bay Salt Pond Restoration Project

Megan Collins, AECOM, megan.collins@aecom.com
Phillip Mineart, AECOM, phillip.mineart@aecom.com

The former Cargill Salt Ponds at southern Eden Landing are being restored to a combination of tidal wetlands and managed ponds. The Project objectives include enhanced wetland habitats, flood control, and wildlife-oriented public access. The project site is bordered by the Old Alameda Creek to the north and the federal Alameda Creek Flood Control Channel (ACFCC) to the south. The commercial and residential properties to the east are in a FEMA flood hazard area. Unlike some of the other former salt ponds being restored in the Bay Area, these flood hazard zones are subject to significant flooding from both riverine and tidal sources. An understanding of flooding from both these sources is a key component of the 2,269-acre restoration.

AECOM used the 2-dimensional MIKE21 Flexible Mesh model to design restoration features including levee breaches and channel dimensions, levee raising and lowering heights, and culvert sizes and quantities. Modeling results showed an unanticipated flood path where the 100-year return period flooding overtops the farthest downstream mile of the federal ACFCC levees. Flood waters travel back upstream along the backside of the ACFCC levee through existing Alameda County-owned wetlands and ponds outside of the restoration boundaries. Levee improvement configurations were chosen to avoid funneling the riverine flooding through non-project wetlands onto Alameda County or Cargill property; instead, the future wetlands will support detention of large riverine events reducing upstream flooding depth and extent.

Hydraulic connectivity was balanced with flood control objectives, especially in the selection of culvert sizes and locations along the ACFCC levee. Breaching of the federal ACFCC levee is not an option without federal de-authorization; however, connection to the ACFCC is critical for fish passage to the wetlands. Natural-bottom culverts are proposed to maximize restoration success, while preventing high flood volumes from entering the ponds and overtopping back levees.

Keywords: hydrodynamic modeling wetland restoration flood control recreation public access levee
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Seismic Hazard in Sacramento-San Joaquin River Delta using UCERF3 Source Models and NGA-West2 Ground Motion Models

Paolo Zimmaro, University of California Los Angeles, pzimmaro@ucla.edu
Peter M. Powers, U.S. Geological Survey, pmpowers@usgs.gov
Jonathan P. Stewart, University of California Los Angeles, jstewart@seas.ucla.edu
Nico Luco, U.S. Geological Survey, nluco@usgs.gov
Allison M. Shumway, U.S. Geological Survey, ashumway@usgs.gov
Scott J. Brandenberg, University of California Los Angeles, sjbrandenberg@ucla.edu

The Sacramento-San Joaquin Delta Region is host to a variety of critical infrastructure that may fail during an earthquake, however, the most recent seismic hazard analyses performed for the region utilized source and ground motion models (GMMs) now recognized as outdated. These analyses were performed for the Delta risk management strategy project (DRMS, 2007 and 2009). They used seismic source models (WGCEP, 2003; Cao et al., 2003) and GMMs (Power et al., 2008) that have since been replaced. These studies present conflicting findings regarding the dominant seismic sources for Delta hazard, in one case (DRMS, 2009) reporting distant sources (e.g. Hayward, Calaveras and San Andreas =faults) as controlling the hazard, whereas in another case (DRMS, 2007) relatively local faults (Northern Midland zone, and Southern Midland fault) were also listed as major contributors. Since that time, a number of the local faults near the Delta region have been better characterized, and GMMs have been improved significantly through the NGA-West2 project (Bozorgnia et al. 2014).

We have re-computed the seismic hazard for this important region. Hazard is computed at various return periods for the intensity measures of peak ground acceleration (PGA) and velocity (PGV). We use the UCERF3 (Uniform California Earthquake Rupture Forecast) model of Field et al. (2014). UCERF3 considers several faults not included in previous inventories, including the Dunnigan Hills and Clayton faults. PGAs at selected locations, for the 500-year return period exceed those from prior studies by about 15%. We show that relatively proximate faults (e.g. Pittsburg-Kirby Hills, Midland, Green Valley, and Dunnigan Hills) dominate the PGA and PGV hazard at the 500-year return period. These results are relevant for engineers and policy makers involved in risk assessment and development of mitigation strategies for this critical region.

Keywords: Hazard map, UCERF3 Source Models, NGA-West2 Ground Motion Models
Session Title: Environmental Models
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Modification of the WARMF Model to Track Pollutant Sources from the Delta to their Upstream Sources

Scott Sheeder, Systech Water Resources, Inc., scott@systechwater.com
Joel Herr, Systech Water Resources, Inc., joel@systechwater.com
Katie van Werkhoven, Systech Water Resources, Inc., katie@systechwater.com
Nigel Quinn, U.S. Bureau of Reclamation, nwquinn@lbl.gov

Natural resource managers must manage pollutant loads within the Delta and its tributary watersheds to maintain the suitability of surface waters for their designated uses. The Watershed Analysis Risk Management Framework (WARMF) is a comprehensive watershed model and decision support system which has been used to track the loading of salinity, organic carbon, nutrients, phytoplankton, and suspended sediment from the upstream watersheds to the Delta. A shortcoming of this type of analysis is that it is often difficult to accurately quantify the contribution of individual pollutant sources to concentrations in the Delta. Tabulating the loading to the river at the source does not account for processes which attenuate or magnify load before it reaches the Delta. Between upstream sources and the Delta, pollutants can be removed by diversion, decay, and settling. Resuspension of sediment can increase loads. Upstream phytoplankton loading can be magnified by growth. The WARMF model was recently upgraded with a postprocessor, called Gowdy Output, to address this shortcoming. The Gowdy Output algorithms track pollutant loads from their individual sources (tributaries, land catchments, and point sources) to a downstream location specified by the user, allowing managers to assess the relative impact of upstream loading sources on Delta water quality for each day of the simulation. From upstream to downstream along a reach of river, the fractions of loading from each upstream source are tracked with a mass-weighted average for every day of the simulation. The load is then attenuated based on the model output for the river segment. The calculation is repeated for each downstream river segment. This approach focuses load reduction strategies on those sources which have the greatest impact on downstream water quality. The presentation will focus on the use of Gowdy Output as part of the ongoing San Joaquin River real-time salinity loading management.

Keywords: WARMF, Watershed Modeling, Watershed Management, Water Quality, Pollutant Source Assessment
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Integrated Environmental Modeling of Estuarine Systems

Peter Goodwin, University of Idaho, pgoodwin@uidaho.edu
Jay Lund, Center for Watershed Sciences, UC Davis, jrlund@ucdavis.edu
Josue Medellin-Azuara, Center for Watershed Sciences, UC Davis, jmedellin@ucdavis.edu
Christopher Enright, Formerly, Delta Stewardship Council, cnuchris@yahoo.com
Benjamin Bray, East Bay Municipal Utility District, ben.bray@ebmud.com

Models are essential in organizing scientific thinking and communicating the results in an unbiased and comprehensible way – with assumptions clearly stated and uncertainty quantified. Models encapsulate our current knowledge, give a framework for integrating new knowledge, aid in evaluating alternative futures, and should be regularly updated. This paper builds from a set of presentations, software demonstrations, and roundtable brainstorming during a three-day symposium on integrated modeling of estuarine systems. The symposium held in 2015 at UC Davis, brought expertise from around the world and across California. We explored how models could be advanced more rapidly, informing revisions of monitoring programs, accelerating knowledge discovery, and communicating model results to agencies and those responsible for making management decisions of large estuarine systems. The concept of a *collaboratory* is proposed that includes physical space, a virtual network and a structure that can draw together modeling experts from across disciplines, organizations and geographic areas to tackle identified problems. Examples could be refined algorithms, constructive comparisons of different modeling approaches or articulations of alternative futures.

Keywords: environmental modeling, data infrastructure, collaboratory, integration, hydrodynamics, estuarine systems management
Session Title: Environmental Models
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