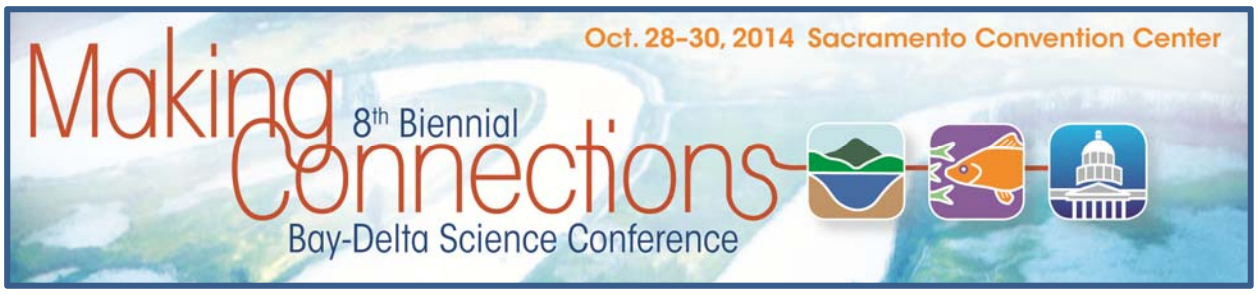

ORAL ABSTRACTS

2014 Bay-Delta Science Conference

Abstracts for oral sessions presented at the 2014 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 poster is submitted by a student and eligible for the student poster awards competition.

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Cooperative Ecological Investigations in the San Francisco Estuary: Science for a Changing State

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California is a state of change. Ongoing changes include its exceptional climatic and hydrological variability and the phenomenal growth of its human population since it became a state in 1850, from less than one million people to thirty-eight million today and fifty million projected by 2050. To sustain this growth, California has been and continues to be "terraformed" into a novel landscape. This rapid, transformational change can be viewed as a grand experiment with uncertain outcomes. But this experiment was not conceived in a scientific way; for much of California's statehood the relative likelihood of different potential outcomes was seldom evaluated before transformational actions took place, and actual outcomes were rarely tracked systematically and comprehensively. Science began to play a larger role when unintended and undesirable outcomes became more clearly visible. Individual government agencies started employing scientists to evaluate changes of interest to their agency's mission and how to best manage them. But it still took several decades before the realization took hold that these changes could neither be controlled nor understood one at a time. In the San Francisco Estuary (Bay-Delta), this realization eventually led to the long-term scientific cooperation of originally four and now nine State and Federal agencies in the Interagency Ecological Program (IEP). The IEP has been conducting cooperative ecological investigations in the Bay-Delta since 1970 and has provided consistent and comprehensive long-term data and information about changes in fish, flows, habitats, and many other important management targets and indicators of change. Perhaps even more importantly, the IEP has functioned as a stimulating, unbureaucratic "science space" for scientists from different agencies, universities and elsewhere to connect, exchange ideas, and work together to address scientific questions relevant to their own and other agencies and institutions. This interdisciplinary science collaboration that started with the IEP has since been expanded with the help of the Delta Science Program and others. Because of these efforts, we now know a lot not just about how the Bay-Delta has changed, but also about why it changed and how it might change in the future – more than ever before, we understand many of the complex connections between our actions, other drivers, and ecological outcomes. We also have a highly connected, vibrant science community adept at converting scientific data into usable knowledge. The challenge now is to better support and connect scientists with managers and policymakers so we can turn what started as an inadvertent grand terraforming experiment into a sustainable, adaptive management scheme for a changing state and world.

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

Six things the Delta Science Community Has Learned in the Past Two Years

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During the Town Hall meeting held during the 2012 Delta Science Conference, Directors of Agencies and leading scientists explored the challenges of integrating science and policy in several key areas. Some of the challenges expressed included how collaborative science could be achieved when one forum attempts to foster open collaborative science and another program is embroiled in litigation with many of the participants common to both activities. The complexity of the Bay-Delta was also discussed and the critical need to quantify uncertainty, the sensitivity of scientific projections to assumptions, and a continuing commitment to understanding the risks associated with management actions. The importance of viewing the Bay-Delta as a system where decisions made in one part of the state influence other regions were also used as examples to highlight the complexity of the system and the linkages that must be understood. During the past two years these issues have been addressed in multiple venues including several that are featured in the Delta Science Conference 2014, including the Collaborative Adaptive Management Team, the Inter-Agency Ecological Program and the preparation of the Delta Science Plan. The latter was completed in December 2013 and considered more than 1,000 comments received from over 100 organizations.

This presentation highlights some of the lessons learned during the past two years of collaborative science. The presentation will consider processes, emerging technologies, some examples of new discoveries as well as continuing critical barriers to knowledge discovery.

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

Making Science Actionable

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Many of the world's large estuarine ecosystems are severely stressed due to population growth, water quality and quantity problems, vulnerability to flood and drought, and the loss of native species and cultural resources. Consequences of climate change and accelerated sea level rise further increase uncertainties about the future. The availability of information and improved communication of scientific and engineering issues is raising the level of dialogue at the science-policy interface. However, severe challenges persist since scientific discovery does not occur on the same timeframe as management actions, policy decisions or at the pace sometimes expected by elected officials. Common challenges include the need to make decisions in the face of considerable uncertainty, ensuring research results are actionable and preventing science being used by special interests to delay or obsfucate decisions.

The major societal challenges facing the California Bay-Delta system require innovations in governance, policy, and ways of implementing management strategies. Transformative change is very difficult to achieve with history in other systems showing that these transformations are difficult to achieve, with benefits only being widely recognized years or decades into the future. The innovators are sometimes heavily criticized and attacked professionally at the time of change.

Understanding the magnitude of water challenges facing California and the Bay-Delta system, the California State Legislature passed the landmark legislation in 2009 (CA Water Code SS 85054) that established "*Coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem*". The legislation also stated that "*The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place*." Further, the State of California and Federal Agencies have stated that management decisions should be based on the best-available science. This presentation describes the challenges of integrating policy, management and scientific research and progress and the importance of supporting public servants tasked with major management decisions as well as supporting the science that inform these difficult decisions.

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

Habitat Quality: A Fish's Perspective

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One of the fundamental challenges in ecology is to predict species distributions in an environment and to evaluate the consequences of that distribution to survival, reproductive success and overall production. Understanding habitat quality is at the very core of our ability to predict a species' persistence in an ecosystem. How do we define the habitat quality that an ecosystem affords a particular species? Is there a way to look at a habitat and quantitatively evaluate and, indeed, map the habitat quality and quantity for a given species? Moreover, how well can a species exploit that prevailing habitat?

Habitat quality must be defined from the perspective of an individual species or life stage of a species since the physiological and behavioral requirements differ across species. Habitat quality must also be a function of both abiotic and biotic factors that prevail in a particular ecosystem. But, how do we weigh biological and abiotic characteristics of the environment in a meaningful way from the fish's perspective? Fish Growth Rate Potential (GRP) is used as an example of a quantitative, species-specific measure of fish habitat quality. GRP is the expected growth rate of a fish of given size if placed in a specified volume of water with known physical and biological conditions. This bioenergetics metric is not only a robust and integrative measure but it is also a nonlinear response to the combined physical and biological habitat. Illustrative examples will be drawn from hypoxic areas in the Chesapeake Bay, Northern Gulf of Mexico and the Great Lakes.

A new concept is introduced as a measure of the ability of the fish to use the habitat quality it is afforded. The purposeful separation of habitat quality potential and habitat use provides an innovative way to address habitat issues and might provide new insights and lines of research for the Bay Delta.

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

Is Flow the Cure for the Summertime Blues? A 12-Year Record of Summer Growth for Delta Smelt

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Problem statement: The delta smelt, as well as several other pelagic species that occupy the Low-Salinity Zone in summer have declined. Growth in the early life has been linked to recruitment success and year-class strength in many estuarine species from around the world. Freshwater flow has been hypothesized to be the key driver. In this study we investigate inter-annual variability of delta smelt growth for fish collected in summer months.

Approach: We use the otolith increment widths as a proxy of growth during in the early life stages of delta smelt collected in the Summer Tow-net Surveys from 1999 to 2013. This study covers the period prior to the pelagic organism decline and includes several periods of dry conditions as well as an extreme wet year.

Results: Summer growth rate varied between dry years and wetter periods and exhibited a greater than 30% decline in growth rate during the pelagic organism decline. Growth during 2011, when freshwater outflow was the second highest in the past 30 years was significantly faster than prior years and dry years following 2011.

Conclusions/Relevance: This study documents a significant change in vital rates of juvenile delta smelt associated with freshwater outflow and suggests dry conditions are correlated with slow growth. Slow growth is likely to lead to reduced recruitment success and year-class strength.

Keywords: Delta Smelt, otoliths, growth, recruitment, POD, freshwater flow
Session Title: Delta Smelt Ecology
Session Time: Tuesday 1:35PM – 3:15PM Room 306

Winter Food-Limitation: Impacts on Adult Delta Smelt Reproduction and Health

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The delta smelt (*Hypomesus transpacificus*) is endemic to the San Francisco Bay Estuary (Bay-Delta), and is listed federally as an endangered species. The Bay-Delta is a highly dynamic system, with natural and anthropogenic factors acting to change and impact the habitat of pelagic fish species, such as the delta smelt. One hypothesis of the cause of the decline observed in the delta smelt population is that limited food-availability, caused by changes in the species composition and abundances in phytoplankton and zooplankton communities, has affected resources available to sustain healthy numbers of fish in the population. To test the effects of food-limitation on the reproduction and general health of the delta smelt, an experiment was conducted in which fish were fed a ration reduced by 40% compared to controls for eight weeks. The experiment was conducted in the winter months just prior to the spawning season. Preliminary results show that test females experienced delays in spawning and had higher ratios of Omega-6/Omega-3 fatty-acid in eggs than control fish. Omega-3's are essential fatty-acids for growth and neural development and a higher ratio of Omega-6/Omega-3 fatty acids has shown to negatively affect embryo development. Although preliminary, the results indicate that food-limitation can play a significant role in partitioning energy resources for gonadal maturation, which can negatively impact adult reproduction and progeny produced. Additional analysis of health and reproductive biomarkers (i.e. triglycerides, histology, hormonal assays) and fecundity indices (i.e. egg size, number of clutches) are a work in progress and will be presented.

Understanding the factors affecting delta smelt population abundances and the viability of successive generations, would help Bay-Delta managers understand the ecological relevance, and impact, of changes to the community food-web and food-availability in the Bay-Delta.

Keywords: Delta Smelt, Food-limitation, Reproduction, Fecundity, Health
Session Title: Delta Smelt Ecology
Session Time: Tuesday 1:35PM – 3:15PM Room 306

Organismal and Mechanistic Sensitivity to Elevated Temperature and Salinity in Delta Smelt

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The delta smelt (*Hypomesus transpacificus*) is an endemic fish in the San Francisco Bay–Delta and is an important indicator of ecosystem health. Delta smelt have been rapidly declining in the past 30 years due to a variety of physiological and ecological stressors, and climate change is expected to further impact this species by altering regional temperatures and salinities. The delta smelt is also an annual migratory species that encounters differential thermal and salinity regimes across ontogenetic stages. Some studies have investigated whole organism tolerance to these stressors in adults, but little is known about how tolerance thresholds or their mechanistic drivers vary through development. We sought to understand thermal and salinity impacts on delta smelt by conducting a series of exposures on both chronic and acute timescales. We assessed temperature and salinity tolerance limits, and proportional survival, as well as changes in gene expression to evaluate sublethal stress responses. Larval stages (30 and 60 days post-hatch, dph) of delta smelt exhibited higher thermal tolerance relative to juvenile (150 dph) and adult stages (200 dph), but were more sensitive to salinity than these older stages. We associated tolerance data with gene response profiles, and detected induction of osmotic, oxidative, and other sublethal stress responses with increasing temperatures and salinities; which varied among lifestages. Genomic responses were induced at Critical Thermal Maxima (CTMax)-4◦C, and higher, but not CTMax-6◦C, suggesting a sublethal threshold for heat stress. Our results demonstrate the importance of understanding mechanistic thresholds, as well as considering ontogeny, when evaluating sensitivity to environmental stressors. Results highlight mechanistic and whole organism thresholds for Delta Smelt thermal and salinity sensitivity, data that is highly relevant to ecosystem management in the face of climate change, as it relates to this and other species.

Keywords: Delta Smelt, Temperature, Salinity, Sensitivity, Mechanisms, Gene Expression, CTMax, Sublethal
Session Title: Delta Smelt Ecology
Session Time: Tuesday 1:35PM – 3:15PM Room 306

Environment Parameters: The Choices of Delta Smelt

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Natural and anthropogenic variability in the Delta change the habitat of Delta Smelt with time making it difficult to predict their behavior. Developing a better understanding of the Delta Smelt's response to water temperature, salinity, and turbidity under controlled conditions may help predict fish location in the field. Therefore, in the present study we investigated the behavioral response of Delta Smelt to a wide range of thermal and salinity conditions using a shuttle box system (two tanks connected by a narrow passage) in which the temperature differed by two degrees and salinity by three ppt. By monitoring the fish's movement and residence time in each tank, we can learn about sensitive temperature and salinity ranges, e.g. ranges unfavorable for them.

The Delta Smelt appear to show a consistent behavior in avoiding warm temperatures starting at a specific temperature level, which was 23°C for fish acclimated to 14°C and 25°C for fish acclimated to 17°C. Increased mortality was found at 28°C in both cases, which indicates the lethal temperature for Delta Smelt is the same no matter what temperature they were acclimated to. In the salinity trials, in which the salinity was slowly increased at a rate of 5 ppt per three hours, the proportion of fish that stayed in the tank with higher salinity declined as salinity increased, indicating they are tolerant of high salinity but will consistently move to a lesser salinity given the choice. The enzymatic biomarker (AChE) activities in the brain of tested fish increased slightly with increasing temperature and remained high when the fish were held in high temperature (27- 28°C) for six hours, but the activities started to decrease after that. Fish experiencing the increase in salinity from 0 to 23 ppt in fifteen hours, the AChE decreased slightly but not significantly ($P>0.05$).

Keywords: Shuttle box, Delta Smelt, stimulus, behavioral response, enzymatic biomarker
Session Title: Delta Smelt Ecology
Session Time: Tuesday 1:35PM – 3:15PM Room 306

Spawning Behavior of Cultured Delta Smelt in a Conservation Hatchery

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Understanding reproductive behavior of cryptic species is crucial for their conservation. The Delta Smelt, *Hypomesus transpacificus*, is a federally threatened, state endangered fish, whose reproductive behavior is poorly understood. We used genetic techniques to investigate the spawning behavior of cultured delta Smelt at a conservation hatchery for Delta Smelt. We conducted a "natural tank-spawning" experiment in a total of four separate tanks during two spawning seasons. Tanks holding adult Delta Smelt were allowed to spawn on their own in order to investigate spawning patterns using genetic parentage analysis of fry produced. In total, 2,474 fry were assigned parents with >80% likelihood. We found that many adults were not assigned any offspring. Males spawned proportionally more than females, and were generally assigned offspring on more dates than females. We also found high variance in family size, leading to reduced N_e and increased inbreeding. Finally, we found no evidence that Delta Smelt preferred to mate with unrelated individuals. This study improves our understanding of how reproductive information informs conservation of cryptic species such as Delta Smelt.

Keywords: delta smelt, genetics, parentage, conservation, hatchery
Session Title: Delta Smelt Ecology
Session Time: Tuesday 1:35PM – 3:15PM Room 306

Sampling Uncharted Waters: Examining Longfin Smelt and Delta Smelt Rearing Habitat in Fringe Marshes of the Low Salinity Zone

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Despite a rich monitoring history (> 40 years) for invertebrates and fish in the San Francisco Estuary, very little is known about how invertebrates and fish use tidal marshes along the axis of the low salinity zone. Our study investigated the abundance and distribution of larval fish communities in fringe marshes and shallow waters of Suisun Bay (between Antioch and Benicia) that have been overlooked by the long-term monitoring programs. Ichthyoplankton were sampled every two weeks between February and June in 2013 and 2014 using a 505 µm mesh net towed from the stern of a small boat. Zooplankton and water quality (salinity, turbidity, DO, PH, Chl *a*) were sampled concurrently to determine what factors affected abundance and distribution of key species of interest. Our results show longfin smelt larvae are widely distributed in shallow waters and tidal marshes of the low salinity zone. During some sampling periods, longfin smelt densities in tidal marshes were similar or higher than densities observed in the channel stations of the California Department of Fish and Wildlife Smelt Larval Survey. Delta smelt were also observed in shallow habitats, but their densities were far lower than longfin smelt densities. Striking differences in water quality was observed between open water and tidal marsh habitats, which appear to be driven by wind and hydrodynamic residence times and exchange. Our study indicates that tidal marshes from the Suisun Bay area provides key rearing habitat for longfin smelt. Information from our study could be used to guide future restoration in the area, design additional monitoring stations for the larval fish surveys, and understand the role of food generated within marshes to support secondary production in adjacent open waters.

Keywords: Tidal Marsh, Longfin smelt, Suisun Bay, Delta Smelt, Larval Fish
Session Title: Native Fish Ecology: From the Rivers to the Bay
Session Time: Tuesday 3:35PM – 5:15PM Room 306

Ancient Fish and Recent Invaders: White Sturgeon (*Acipenser transmontanus*) Diet Response to Invasive Species-Mediated Changes in a Benthic Prey Assemblage

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Invasive organisms can have significant impacts on native species and the San Francisco Estuary, California (SFE) is one of the world's most invaded estuaries. Decline of native white sturgeon (*Acipenser transmontanus)* in the SFE has been acknowledged, but is poorly understood. Invasion by the overbite clam (*Potamocorbula amurensis*) drastically altered the SFE benthic prey community yet little is known about how this change has affected sturgeon. Elucidating feeding ecology response to this invasion is essential to future white sturgeon management. This study investigated the effect of the overbite clam invasion and subsequent shift in the SFE benthic prey assemblage on the feeding ecology of white sturgeon. Gut content analysis was used to compare prey composition and dietary importance between the pre- and post-invasion periods. Additionally, stable isotope analysis was employed to estimate the assimilation of prey items to sturgeon biomass. Overbite clams dominated diets in the post-invasion period accounting for > 80% of total volume. Stable isotope analysis confirmed the importance of this prey item, although their contribution to sturgeon biomass was estimated to be less (~73%) than gut contents indicated. The frequency of fish increased in the post-invasion period and isotopic analysis indicated relatively large contributions of fish to sturgeon biomass (8 to 25%). The trophic adaptability of white sturgeon has allowed them to exploit this new prey source. Future conservation and restoration efforts must consider a potentially destabilized food web given the large importance of a single prey item, coupled with the potential transfer of toxins to sturgeon.

Keywords: stable isotopes, white sturgeon, food web, diet, invasion
Session Title: Native Fish Ecology: From the Rivers to the Bay
Session Time: Tuesday 3:35PM – 5:15PM Room 306

Connectivity and Effective Size of the Two Splittail (*Pogonichthys macrolepidotus)* Populations in the San Francisco Estuary

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The discovery of two genetically distinct splittail populations within the San Francisco Estuary, one that spawns in the rivers of the Central Valley and another in the Petaluma and Napa Rivers, prompted the need to assess their degree of connectivity and relative sizes. We genotyped multiple age-0 splittail cohorts using 19 microsatellite loci to monitor spatiotemporal changes in the distribution of the two populations and estimate their respective effective population size (Ne). Genetic population assignments demonstrated that while age-0 splittail of the two populations generally remain spatially segregated from one another, substantial geographical overlap may occur during years of high precipitation. However, nearly a decade with similarly wet years has passed since the original discovery of the two populations and yet their level of genetic differentiation remains stable. This indicates that the observed population structure will likely persist in the near future due to a certain isolating mechanism (e.g. strong philopatry and/or adaptive differences). We also found that Ne estimates were generally lower for the Petaluma-Napa population than the Central Valley population, which is consistent with the relative amount of habitat availability in the two locations and previous genetic diversity indices. The relative isolation and apparent lower Ne of the Petaluma-Napa splittail population indicate the need of a closer monitoring for this less studied population.

Keywords: effective population size, population genetics, splittail, population structure
Session Title: Native Fish Ecology: From the Rivers to the Bay
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Metapopulation Structure of a Semi-Anadromous Migratory Fish (Sacramento Splittail, *Pogonichthys macrolepidotus*) Shaped by Climate-Induced Dynamic Habitat Fragmentation

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The Sacramento splittail, *Pogonichthys macrolepidotus,* is a relatively large (400mm) and long-lived (8 years) demersal cyprinid of conservation importance that is endemic to the San Francisco Estuary (SFE). The species exhibits a semi-anadromous life cycle in that it spends the majority of its adult life in low to moderate salinity (0-12) habitat and migrates into upstream freshwater rivers and inundated floodplains for spawning during late winter and spring. The species persists as two genetically distinguishable populations—one dominant and one subordinate—separated by discrete spawning habitats resembling an island-mainland metapopulation structure. The two populations overlap in distribution in the SFE yet segregation is maintained at multiple scales, with individuals tending to aggregate/school with others of similar population heritage and natal origin. The two populations are connected via dispersal of the dominant population into the subordinate population's spawning habitat when climate patterns produce enough rainfall and associated freshwater outflow to form a bridge of suitable low-salinity habitat across the upper SFE in Suisun and San Pablo Bays. Habitat affinities of the two populations, hydrodynamic modeling studies, and historical outflow records together suggest such climatic conditions occur with a frequency of 1 out of 3 years and with an irregular frequency. This dynamic pattern of connectivity controlled by climate variability may drive demographically-meaningful gene flow. The future trajectory of splittail evolution and population structure likely will be shaped by future climate conditions, providing a unique example in an estuary of how metapopulation models must consider climate variability as a driver of habitat fragmentation and population structure.

Keywords: population ecology, metapopulation, otolith, genetics
Session Title: Native Fish Ecology: From the Rivers to the Bay
Session Time: Tuesday 3:35PM – 5:15PM Room 306

Fall Run Chinook Pre-Smolt Outmigration to Alternate Rearing Areas in the Sacramento-San Joaquin Valley

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Numerous pre-smolt fall run Chinook leave their natal rivers to rear in floodplains, the delta, and bays of the Sacramento-San Joaquin River system. Both the number migrating and the timing of migration vary interannually, though the underlying cause of this migration has not been established. The objective of this study was to relate river outmigration to environmental variables. A generalized linear mixed model framework was used to develop a predictive model of river outmigration. Many environmental covariates were found to be significantly related to Sacramento River pre-smolt river outmigration. Of these covariates, the probability of migration increased with photoperiod and flow, and decreased with water temperature. Pre-smolt outmigration from the Stanislaus River responded to different covariates; change in temperature was more relevant than temperature and positively related to outmigration probability, whereas flow was no longer significant. Photoperiod was the most substantial term followed by change in temperature, with larger, parr-sized individuals more influenced by photoperiod and smaller, fry-sized fish by change in temperature. Outmigration to floodplain, delta, and bay rearing habitats results in dissimilar survival rates of pre-smolts, which may affect the number of returning adults. Photoperiod is rather constant with time, while temperatures and flows in these rivers are regulated, allowing for estimates of river outmigration and the survival consequences. These processes will ultimately be simulated in a full life cycle model of Central Valley fall run Chinook, with the goal of aiding management.

Keywords: Central Valley, Chinook, fall run, fry, GLMM, migration, parr, pre-smolt
Session Title: Native Fish Ecology: From the Rivers to the Bay
Session Time: Tuesday 3:35PM – 5:15PM Room 306

Assessing Food Quality of Non-Algal Particles in the San Francisco Bay Estuary and Delta

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Estuarine food web dynamics are complicated by multiple organic carbon sources, including riverine dissolved (DOC) and particulate organic carbon (POC), DOC and detritus from wetlands, algal primary production, and an influx of marine organic carbon. A decline in food quantity and quality inevitably leads to declines in native fish stocks, but predicting impacts cannot be made by simply quantifying changes in the total bioavailable organic carbon in the system, as trophic transfers to preferred prey also must be considered. The decline in native fish in the San Francisco Bay Estuary/Delta (SFBE/Delta) is likely tied to a similar decline in their primary feedstock, i.e. zooplankton, which in turn is likely declining because of decreases in the quantity and quality of the POC on which they feed. Among the many debated issues on Delta ecology, carbon cycling, and foodweb dynamics, the relative importance of algal-derived POC vs. riverine non-algal POC as feedstock for zooplankton is not well-constrained. However, from a mass balance consideration, it seems clear that algal POC alone is not sufficient to support zooplankton abundance, and that both algal and non-algal POC must have a quantitatively important role. This study investigates the detrital/non-algal component of particles in the SFBE/Delta to assess whether increased detrital production from future restored wetlands can be quantitatively large enough to increase zooplankton production, and hence native fish populations. We sampled particles monthly at numerous stations over the course of two years in conjunction with annual fish trawls, and our carbon quality analyses include elemental carbon and nitrogen, lignin, and optical characteristics. Relationships between lignin parameters and total suspended sediment suggests that as the quantity of non-algal POC increases, the quality likely does as well. Thus the benefits of increased particles in the Delta toward zooplankton production is greater than simply higher concentrations of POC.

Keywords: Food web, particulate organic carbon, lignin, optical characterization
Session Title: Food Webs I: Where the Plankton Are
Session Time: Tuesday 1:35PM – 3:15PM Room 307

Limnology of the Sacramento Deepwater Ship Channel

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The Sacramento Deepwater Ship Channel (SDSC) supports relatively high fish densities, including all life stages of the endangered delta smelt (*Hypomesus transpacificus*) population. And yet, little is known about how its temperature, specific conductance, turbidity, suspended solids, nutrients, and the abundance and taxonomic composition of its plankton community vary spatially and seasonally. This talk will present information on these and other limnological properties of the SDSC using data collected monthly during 2012-2013. These data will be used to inform and provide a baseline for experiments focused on increasing the food supply of the North Delta.

Keywords: Delta, food, Sacramento Ship Channel, nitrogen limitation
Session Title: Food Webs I: Where the Plankton Are
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Estimating Mass Flux of Dissolved Inorganic Nitrogen and Chlorophyll-*a* at Blacklock Marsh, a Restored Site in Suisun Marsh

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Constructed breaches in levees that surround land, previously used for agriculture or duck ponds, have been increasing in the San Francisco Bay-Delta. Often the restoration goals are to improve water quality and to create highly productive habitats for species of concern like the delta smelt. With higher residence times for phytoplankton in tidal marshes, these autotrophs may assimilate high concentrations of dissolved inorganic nitrogen (DIN) into labile organic matter. Still, few studies have quantified the contribution of phytoplankton of individual restored marshes that may be augmenting the base of the pelagic food web. A detailed investigation of tidal variability in water quality parameters including DIN and phytoplankton biomass took place over two summers in a restored site, Blacklock Marsh, in Suisun Marsh. The objective was to determine if this restored site serves as a sink or source for DIN and chlorophyll-*a*. High frequency sampling was conducted over four flood-ebb cycles and two 14-day tidal periods. The concentrations of constituents in the sampled water, along with volumetric changes, were used to calculate the individual net mass fluxes. During all monitored cycles, ammonium, chlorophyll-*a* and suspended sediment concentrations fluctuated inversely with the tides suggesting that the benthos may have contributed significant amounts of these constituents. For the first fortnightly sampling period, preliminary calculations suggest that DIN may be exported and imported depending on the nitrogen species. Results from this study will determine how the marsh is serving as a sink or source of phytoplankton (i.e. organic matter) to neighboring waters. High frequency sampling and net mass flux calculations at restoration sites like Blacklock Marsh will increase understanding of nutrient cycling and help managers predict how future wetland restoration efforts affect nutrient and organic matter loads on a regional scale.

Keywords: wetlands, breach, chlorophyll-a, nitrogen, restoration, water quality
Session Title: Food Webs I: Where the Plankton Are
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Vertical Distributions of Phytoplankton in San Francisco Bay

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Temperate lakes and oceans become stratified in spring when heat input creates a warm (low density) surface layer overlaying a cool (high density) bottom layer. Phytoplankton biomass grows in the sunlit surface layer as long as nutrients are available. Once the nutrient stocks are depleted phytoplankton growth becomes nutrient limited in the surface layer and remains light limited in the bottom layer. The interface between the surface and bottom layer can be a narrow zone that provides sufficient light and nutrients to support phytoplankton growth, leading to formation of a subsurface chlorophyll maximum (SCM). A substantial fraction of the primary production of stratified lakes and oceans occurs in the SCM, so it is ecologically significant. What about estuaries like San Francisco Bay that have high nutrient concentrations and intermittent stratification – do SCMs form in these kinds of environments? We analyzed vertical profiles of calibrated chlorophyll fluorescence (a proxy for phytoplankton biomass) collected in San Francisco Bay from 1990-2014 to answer the following questions: (1) do SCMs form in the Bay; (2) are there characteristic depths where SCM's are found; (3) is there a seasonal pattern to SCM formation; (4) are there patterns of change in the occurrence of SCMs over time? Answers to these questions have important implications for designing sampling programs to measure phytoplankton biomass in the Bay.

Keywords: Phytoplankton, Vertical Distribution, Subsurface Chlorophyll Maximum, Stratification, San Francisco Bay
Session Title: Food Webs I: Where the Plankton Are
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High Frequency Variability of Phytoplankton and Zooplankton Communities in the San Francisco Estuary

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Estuarine fishery production in San Francisco Estuary is low and has declined over the past decade. It is hypothesized that the decline in fishery production was partly caused by poor production at the base of the food web. However, the production at the base of the food web is poorly known due to low frequency spatial sampling. To address this gap in knowledge, high frequency variation of phytoplankton and zooplankton community composition and biomass in relation to water quality conditions was determined by discrete sampling at 31 stations, spaced t 1.5 km apart, along a 46.5 km transect in the Sacramento and San Joaquin Rivers between May and November in 2013. At each station, water samples were taken at 1 m depth for phytoplankton community composition and water quality analysis, while zooplankton community composition was determined from vertically integrated pumped samples. Continuous measurements of water quality parameters and photosynthetic efficiency were also collected with an YSI sonde and Phytoflash fluorometer. Transects were characterized by high spatial variability, with large shifts in chlorophyll *a* concentration and species composition within only a few km. Water quality variables varied at a low frequency along transects, but were correlated with the biological patterns. For both rivers, chlorophyll *a* concentration increased with water temperature and light availability. Seasonal variation was high, but many of the species shifts occurred at the same location across months. The high frequency spatial variation of phytoplankton, zooplankton and water quality variables in the Sacramento and San Joaquin Rivers suggested there are “hot spots” of production in the estuary that support local estuarine production, and that understanding mechanisms associated with these “hot spots”, may provide guidance for future fishery management.

Keywords: phytoplankton, zooplankton, high frequency distribution, water quality, transect study
Session Title: Food Webs I: Where the Plankton Are
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Biomass and Grazing Rates of Two Exotic Bivalves, *Corbicula fluminea* and *Potamocorbula amurensis*, Show Surprising Variability Over 20-30 Year Sampling Period: What Does it Mean for Future Food Webs?

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Understanding the biomass and grazing rate dynamics of the estuarine bivalve *Potamocorbula amurensis* and the freshwater bivalve *Corbicula fluminea* are important to our understanding of present day food web dynamics and habitat restoration potential within the San Francisco Bay and Delta. Historic benthic monitoring samples (Department of Water Resources Monitoring Program), some from as early as 1975, are providing insight into the long term changes in *C. fluminea* and more recent changes in *P. amurensis* biomass. These biomass data series show that the effects of benthic grazing on pelagic food resources have not been constant. *C. fluminea* populations at three stations located in the Central Delta (D16, D28) and near Clifton Court (C9), showed dramatic declines in biomass and average clam length in 2001-2002 concurrent with the decline of several fish species in the ecosystem. The cause of these biomass and size declines is unlikely to be a reduction in phytoplankton biomass as chlorophyll *a* declined in 1994 and has remained relatively constant since then. Either increased predation on the bivalves or a decline in another food resource could result in the biomass patterns observed. Bivalves at stations located on the Sacramento River (D24), on the San Joaquin River (P8), and at the confluence of the rivers (D4) showed very different patterns. Bivalve biomass greatly increased at D24, declined at D4, and remained consistently low at P8. Within the bay, the Grizzly Bay population of *P. amurensis* developed a regular seasonal pattern of biomass change about six years after its invasion and the San Pablo Bay (D41A) *P. amurensis* populations have begun to show great interannual variability in biomass. Variable timing in bivalve grazing may result in short windows of opportunity for phytoplankton to grow as has been observed in Grizzly Bay and San Pablo Bay.

Keywords: bivalve, food-limited, *Corbicula, Potamocorbula*, long-term, biomass, grazing
Session Title: Food Webs II: Understanding Consumers
Session Time: Tuesday 3:35PM – 5:15PM Room 307

Clam Grazing and Suisun Bay Blooms Modeled with Nitrogen as Currency.

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The invasive clam, *Potamocorbula amurensis*, has been cited as the cause of reduced phytoplankton biomass and productivity in Suisun Bay, CA. Comparison of *in situ* clam grazing rates, calculated from laboratory determined filtration rates, and the biomass of clams and phytoplankton, with calculated phytoplankton growth rates suggests that in Suisun Bay, phytoplankton blooms could only occur rarely. However, spring blooms do occur in Suisun Bay, quite regularly in the shoals of Grizzly Bay and occasionally in the deep-water channels, indicating that growth rates of the phytoplankton do exceed clam grazing rates at times. An alternative way to assess the role of clams in Suisun Bay primary production is by utilizing a nitrogen-based model. Spring phytoplankton bloom development in the Suisun Bay requires first improved irradiance conditions followed by a decline in ammonium concentrations (due to phytoplankton uptake) that enables phytoplankton to access the greater concentration of DIN, nitrate. If clam grazing removes phytoplankton biomass at an equivalent or greater rate than the ammonium uptake rate by phytoplankton, ammonium concentrations will not decrease and blooms are prevented. Calculations show that to allow blooms, the *in situ* clam filtration rate must be less than 10% of the published laboratory values. Simulations were made of the Grizzly Bay spring bloom with varying concentrations of clams to estimate threshold levels of clam populations that could control blooms. These results are relevant to the question of the importance of clams and elevated ammonium as major environmental factors holding primary productivity to low levels in Suisun Bay and serving as possible factors in the Pelagic Organism Decline. Effective management of the estuary will require a basic understanding of the regulation of primary production in the northern estuary.

Keywords: clam, phytoplankton, Susiun Bay, nutrients, model
Session Title: Food Webs II: Understanding Consumers
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Increased Algae Concentration Broadens the Tolerance of a SFE Copepod to Salinity

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Concentrations of phytoplankton have dropped substantially in the SFE, at least partially due to invasions by exotic bivalves. As salinity increases in the SFE with climate change, it is unclear how zooplankton will respond, and whether decreased food concentration will play a role. Here, we examined how algal concentration and salinity affect food consumption, growth, and survival of *Eurytemora affinis*—a key prey species for the delta smelt and other species of conservation concern. In a series of laboratory experiments, we found that increasing the concentration of algae substantially increased the tolerance of *E. affinis* to both high and low salinity. To determine whether this food by salinity interaction was due to an enhanced ability to osmoregulate at higher levels of food, we measured growth and food consumption of *E. affinis* at 4 and 8g/L salinity at low and moderate feeding rates. At the lower level of feeding, we found that growth rates were 2-fold higher at 4 than 8g/L, while rates of food consumption were similar. At the higher level of feeding, we found that growth rates were nearly identical between the two salinities, but the rate of food consumption was 3 times higher at 8g/L. Both of these results demonstrate that the energy requirements of *E. affinis* increase dramatically at non-optimal salinities, likely due to the energetic costs associated with osmoregulation. When food is limited, growth is sacrificed in favor of osmoregulation. When food is abundant, far more food is consumed, allowing copepods to both osmoregulate and grow rapidly. Our results suggest that invasive clams are likely to decrease the salinity tolerance, and therefore range, of *E. affinis* by limiting their ability to osmoregulate.

Keywords: Eurytemora affinis, salinity, phytoplankton, climate change, invasive clams, tolerance, osmoregulation
Session Title: Food Webs II: Understanding Consumers
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Elemental and Isotopic Composition of Submerged Aquatic Vegetation in Suisun Bay and the Delta: Spatio-Temporal Patterns and Food Web Support

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Recent surveys in Suisun Bay and the west Delta recorded more than 1100 acres of native *Stuckenia* spp. (pondweeds) at locations where submerged aquatic vegetation (SAV) was previously assumed minimal. This prompted efforts to assess the potential of these SAV beds to provide habitat and food web support for native fish. Stable isotope (SI) analysis is a powerful tool in ecological research, now increasingly used to study nutrient fluxes and food webs in aquatic ecosystems. However, identifying the sources of organic matter supporting food webs in ecosystems as dynamic as estuaries requires a sound understanding of the variability of these sources. Here we document spatial and temporal patterns in the carbon, nitrogen and sulfur elemental and stable isotope composition of 9 primary producers including *Stuckenia* spp. and the invasive *Egeria densa*. SAV species were sampled quarterly at 8 sites across the low salinity zone of the San Francisco Estuary from fall 2011 to fall 2012. As expected, some inter-species differences were detected, as well as large seasonal and/or inter-site variations in some species, probably due to a combination of hydrodynamic (freshwater flow directly controlling the position of the salinity gradient relative to SAV beds and indirectly controlling the isotopic signature of the nutrient sources through mixing and residence time) and physiological processes (growth rate and tissue isotopic turnover rate). Moreover, Bayesian stable isotope mixing models further highlighted the need for thorough sampling strategies in SI studies, as the estimated diet of the main invertebrate species varied greatly across sites (e.g., the green macroalga *Cladophora* always significantly contributing when present, but replaced by *Stuckenia* if absent). These results and follow-up studies will help improve our understanding of the trophic relationships in the SAV beds of the upper San Francisco estuary, providing insights into conservation and management strategies for these habitats.

Keywords: food web, stable isotopes, submerged aquatic vegetation, Stuckenia, mixing model
Session Title: Food Webs II: Understanding Consumers
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Effects of Variable Freshwater Flow on Fish and Foodwebs of the San Francisco Estuary

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Freshwater flow is a dominant driver of estuarine change. Conflicts over allocation of freshwater require that we understand mechanisms for flow effects on the estuary to support effective management. We present some recent findings about mechanisms for flow effects on estuarine biota. These results show that interactions between hydrodynamics and organism behavior can have a strong influence on maintenance of biological populations. Foodweb organisms such as copepods and mysids behave in ways that take advantage of flow conditions to minimize losses. Freshwater flow can transport organisms within the estuary, but does not appear to stimulate the foodweb through effects on primary production. Our fall habitat studies show that growth and reproductive rates of the copepod *Pseudodiaptomus forbesi* were unaffected by flow but responded to a brief pulse of phytoplankton biomass transported into the lower Sacramento River. In addition, abundance in this copepod's freshwater population maximum was unaffected by flow, possibly because of vertical migration behavior. Abundance in brackish water increased slightly with increasing flow as a result of transport from the central Delta. However, apparent mortality rate of early life stages was lower in the high-flow 2011 than in two other years, because of a combination of increased subsidy from freshwater and possibly reduced consumption by clams and the predatory copepod *Acartiella sinensis*. Thus, the response of the foodweb to variable freshwater flow was indirect and complex, and would be difficult to interpret without information on transport, predation, and growth rates. Nevertheless, it is feasible to build models that incorporate these effects to allow for predictions of flow effects and possibly refining the efficacy of flow-based management.

Keywords: freshwater flow, copepod, foodweb, population dynamics, modeling
Session Title: Food Webs II: Understanding Consumers
Session Time: Tuesday 3:35PM – 5:15PM Room 307

Spatio-Temporal Patterns of Open Surface Water in the Central Valley of California 2000-2011: Drought, Land Cover, and Waterbirds

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The Central Valley is a nexus for water resources in California containing the Sacramento and San Joaquin watersheds which together provide drinking water to approximately two-thirds of Californians. Improved understanding of the distribution of water is needed to maximize efficiency of water management for urban, agricultural, and ecosystem services and to calibrate water optimization models. We used a supervised classification approach of Landsat satellite imagery to (1) quantify the distribution of open surface water across the Central Valley of California 2000 – 2011, (2) summarize spatial and temporal variation of open surface water July - December during this time series, and (3) assess the factors that might influence the distribution of open surface water, including drought conditions and land cover type. We also applied the classified imagery to identify available habitat for waterbirds. Our analyses indicated that between 2000 and 2011 open surface water has declined across the Central Valley during the months of July – October. Drought had a significant effect on open surface water throughout the Central Valley. The negative impact of a drought was experienced immediately in the southern Central Valley; however, there was a 1 to 3-year time-lag effect in the northern Central Valley. Generally, the highest proportion of open surface water was in lakes, rivers, and streams as well as flooded agriculture, yet the relative proportions varied spatially and across months. Our data supported previous assumptions about the timing and availability of flooded post-harvest rice fields in the northern Central Valley for waterbirds, and highlighted the need to consider flooded agriculture as available habitat for waterbirds in the southern Central Valley. Tracking water distribution using satellite imagery enables an empirically-based assessment of the impacts of changing water policy, land-use, climate, and management on water resources.

Keywords: water; Central Valley; trend; drought; land cover; satellite imagery; waterbirds
Session Title: Managing through Drought
Session Time: Tuesday 1:35PM – 3:15PM Room 308-310

Quasi-Decadal Oscillation in the CMIP5 and CMIP3 Climate Model Simulations: California Case

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The ongoing three drought years in California are reminding us of two other historical long drought periods: 1987-1992 and 1928-1934. This kind of interannual variability is corresponding to the dominating 7-15 yr quasi-decadal oscillation in precipitation and streamflow in California. When using global climate model projections to assess the climate change impact on water resources planning in California, it is natural to ask if global climate models are able to reproduce the observed interannual variability like 7-15 yr quasi-decadal oscillation.

Further spectral analysis to tree ring retrieved precipitation and historical precipitation record proves the existence of 7-15 yr quasi-decadal oscillation in California. But while implementing spectral analysis to all the CMIP5 and CMIP3 global climate model historical simulations using wavelet analysis approach, it was found that only two models in CMIP3 , CGCM 2.3.2a of MRI and NCAP PCM1.0, and only two models in CMIP5, MIROC5 and CESM1-WACCM, have statistically significant 7-15 yr quasi-decadal oscillations in California.

More interesting, the existence of 7-15 yr quasi-decadal oscillation in the global climate model simulation is also sensitive to initial conditions. 12-13 yr quasi-decadal oscillation occurs in one ensemble run of CGCM 2.3.2a of MRI but does not exist in the other four ensemble runs.

Keywords: drought, interannual variability, global climate model simulation
Session Title: Managing through Drought
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2014 Delta Drought Modeling

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In late winter through spring, Delta modeling was performed using historical information and forecasts that represented very dry conditions. These forecasts aided decision-making about if, when, and where emergency barriers might be installed.

In early February, the outlook was grim; 2014 was potentially the driest year in the historical record. Concerns about having enough water for upstream releases, meeting water quality objectives in the Delta, flows for fish, and being able to export enough water for health and safety needs led to a series of modeling studies which also evaluated impacts to farmers/marinas, to salmon migration, and smelt survival. If installed too early, barriers could negatively impact fish migration and spawning. If installed later, there might not be enough water to meet water quality or ecosystem needs later in the summer. As precipitation occurred during the spring, reservoir storages improved, and the urgency of installing the barriers began to diminish.

Consequently, the objective of studies shifted towards evaluating water savings due to installation of the barriers. The water savings could be used as storage and then released later for ecosystem needs, exports, or other diversions. Using a minimum water cost compliance tool in conjunction with DSM2, water savings were determined for meeting D-1641 Water Quality Objectives with and without the barriers and with relaxing or moving the Emmaton Objective. The biggest water savings occurred from relaxing the Emmaton objective (~612 cfs), whereas installation of the three barriers (Sutter Slough, Steamboat Slough, and False River) resulted in a water savings of about 275 cfs if the Emmaton objective was relaxed. So, although significant benefits of the barriers to water quality could be demonstrated given a fixed amount of available water, the water savings from installing the barriers given a fixed water quality objective was not considered large.

Keywords: Drought, Modeling, DSM2, Delta, Barriers, Ecosystem, Water Quality, Water cost
Session Title: Managing through Drought
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Drought Decisions in a Highly Impacted California River; Using Umbrella Species to Inform Water Management

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Virtually all large California rivers are regulated by dams that provide power, water and flood protection to the world's eighth largest economy. This has created conflict between economic needs and protection of key ecological processes. This year, one of the most severe droughts in recorded California history pushed this issue to the forefront of scientific and political discussion. Reservoir storage in the American River, a key California water artery, was at an all-time low, resulting in drastically reduced river discharge, with embryos of native Chinook salmon incubating in gravels of the lower river. Resource agencies, along with local stakeholders, developed a decision–tree management process to identify and implement impact mitigation for key ecological processes using Chinook salmon as an umbrella species. We developed Chinook salmon conceptual life cycle models that included fry emergence and outmigration timing, identifying processes and environmental conditions needed to support key lifestages. We monitored physical and biological parameters and identified several options for flow manipulation to benefit target life stages, which were presented to resource managers.

We estimated that up to 12% of the 2013-14 Chinook salmon brood-year was stranded in dewatered or disconnected incubation or rearing habitat within the lower river. Intergravel temperatures and dissolved oxygen reached stressful levels after several weeks. Emerged fry, stranded in off-channel pools, demonstrated stressed behavior including aggression and very low condition factors. Considering critically low water availability, a 2-day pulse flow was identified as the most feasible management action to mimic a spring freshet. The objective of the flow pulse was to reconnect migration corridors for stranded fry within the gravel and juveniles in off-channel habitats and ameliorate poor water quality parameters. Results from this exercise provide a framework for future water management decisions, as human demands increase and the climate continues to trend toward greater precipitation extremes.

Keywords: flow management, regulated rivers, salmon, life cycle modeling
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Benefits of an Advanced Quantitative Precipitation Information System - San Francisco Bay Area Case Study

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Advancements in monitoring and prediction of precipitation and severe storms can provide significant benefits for water resource managers, allowing them to mitigate flood damage risks, capture additional water supplies and offset drought impacts, and enhance ecosystem services.

A case study for the San Francisco Bay area provides the context for quantification of the benefits of an Advanced Quantitative Precipitation Information (AQPI) system. The AQPI builds off more than a decade of NOAA research and applications of advanced precipitation sensors, data assimilation, numerical models of storms and storm runoff, and systems integration for real-time operations. An AQPI would dovetail with the current National Weather Service forecast operations to provide higher resolution monitoring of rainfall events and longer lead time forecasts.

A regional resource accounting approach has been developed to quantify the incremental benefits assignable to the AQPI system; these benefits total to $35 M/yr. Compared to AQPI system implementation and O&M costs over a 10 year operations period, a benefit – cost (B/C) ratio is computed which ranges between 2.8 to 4. It is important to acknowledge that many of the benefits are dependent on appropriate and adequate response by the hazards and water resources management agencies and citizens.

Keywords: Advanced precipitation forecasts, benefit-cost analysis, San Francisco Bay case study
Session Title: Managing through Drought
Session Time: Tuesday 1:35PM – 3:15PM Room 308-310

Use of the Co-occurrence Pesticide Species Tool (CoPST) to Model Seasonal and Temporal Patterns of Pesticide Presence to Guide Water Quality Monitoring Timing and Location

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Problem statement: A decline in pelagic species has been observed in the San Francisco Bay-Delta, triggering questions as to whether contaminants are contributing to the decline. To help address these questions, Waterborne Environmental, Inc. (Waterborne), in conjunction with UC Davis, USEPA, and DWR, developed the CoPST (Co-occurrence of Pesticide and Species Tool), which is a GIS/modeling framework that incorporates 40 high-risk pesticides and aquatic endangered species presence to identify areas and timing of greatest risk.

Approach: This presentation describes the first management application of the tool. In this application, the co-occurrence of endangered species module was not utilized. The question was "when and where monitoring should be focused for specific pesticides, based on historical use application and available monitoring data." Although many monitoring efforts are ongoing in the California Central Valley and Bay-Delta, research has shown that the current temporal and spatial sampling of pesticides may be insufficient to capture the complete profile of water quality. Coordination was necessary with existing monitoring surveys and regulatory programs such as the Central Valley Regional Water Quality Control Board's Irrigated Lands Regulatory Program (ILRP), Surface Water Ambient Monitoring Program (SWAMP), and Delta Regional Monitoring Program (RMP).

Results: The analyses output was a GIS layer using heat map style representation for predicted pesticide edge of field loading indexes, along with layers of actual monitoring results in a monthly time step. The results layer also incorporates a lookup feature by section (640 acres), allowing users to pass their cursor over the indexed sections, showing the individual pesticides that contributed to the modeled index, as well as the corresponding pesticides if present in the actual monitoring data.

Conclusions/Relevance: Next steps include connecting the model output to current permit requirements for irrigated lands, watershed improvement planning efforts, and determining best management practices placement and monitoring priorities.

Keywords: Modeling, pesticides, toxicity, Irrigated lands, species, best management practices, monitoring
Session Title: Making the Most of Technology: New Tools for Water Quality and Subsidence
Session Time: Tuesday 3:35PM – 5:15PM Room 308-310

A System of Autonomous Fixed Station Measurements Together with Synoptic Spatial Characterization Provide Insights into Dynamics of Organic Matter, Nutrients and Algal Pigments in the San Francisco Bay-Delta

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Continuous water quality measurements (nutrients, organic matter, turbidity, algal pigments, dissolved oxygen, pH, temperature, conductivity) on autonomous and Lagrangian measurement platforms in the San Francisco Bay-Delta (Delta), have improved our knowledge of important biogeochemical and eco-hydrological processes. The Delta is naturally, hydrodynamically complex and affected by human (wastewater and agricultural discharge, water withdrawals, land surface alterations) and natural perturbations (floodplain and riparian interactions, wind, precipitation, snowmelt), which add complexity across eco-hydrological and water management domains. Timescales of important biogeochemical change occur in the Delta in a matter of minutes to hours, with attendant changes in the ecology of aquatic habitats and human use of the resource. Autonomous water quality measurements collected over fine temporal and spatial scales help to effectively identify important drivers of biogeochemical processes in the Delta. An established network of autonomous, continuous water-quality monitoring stations in the Delta operated by the USGS, Sacramento, CA, currently provides temporally-rich data at fixed locations. The fixed station measurements reveal complex, hydrodynamically driven changes in water quality, useful to describe habitat conditions for pelagic organisms and guide future tidal marsh restoration efforts in the Delta. To complement the fixed-station data monitoring, spatially dense data monitoring using a boat equipped with a GPS-time-stamped high-frequency flow-through monitoring system allow for real-time spatial mapping. Here, we present examples from the fixed-station monitoring network, combined with boat based Lagrangian measurements. We find that real-time mapping in concert with fixed station monitoring is useful for identifying sources and sinks of nutrients and organic material, and identify important biogeochemical drivers relating to pelagic habitat quality, algal productivity, and foodweb dynamics.

Keywords: Water quality, Nitrate, Mapping, Real Time
Session Title: Making the Most of Technology: New Tools for Water Quality and Subsidence
Session Time: Tuesday 3:35PM – 5:15PM Room 308-310

The Use of DOC Surrogates to Measure DOC at two Municipal Intakes In the Sacramento – San Joaquin Delta

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The Sacramento – San Joaquin Delta is a major drinking water supply to 2/3 of California. Dissolved Organic Carbon (DOC) is an important constituent in drinking water, as high concentrations of DOC can form Disinfection Byproducts, which are carcinogenic and harmful to human health. Monitoring DOC in the Delta is important, as DOC levels vary both temporally and spatially in the Delta. Unfortunately, DOC is typically collected by discrete grab samples and analyzed in the laboratory. DOC concentrations in the Delta can change hourly, creating the need for in-situ type DOC measurements.

Two studies were conducted by the Department of Water Resources (DWR) and the Solano County Water Agency (SCWA) looking at in-situ type DOC measurements. The first study was a multi-year study by DWR investigating the use of an FDOM sensor at the Banks Pumping Plant, located in the South Delta. The main goal of the study was to investigate and compare the FDOM sensor to DWR's real-time DOC analyzer and discrete grab samples. The second study was conducted by SCWA, at the Barker Slough Pumping Plant, located within the Cache Slough Complex. The main purpose of the SCWA study was to investigate the use of UVA-254 and FDOM as in-situ surrogates for trending of DOC, to support real-time water treatment plant operations.

The results of both studies show that FDOM is a reliable surrogate for DOC in the Delta. Both studies show that FDOM and UVA can track seasonal to tidal changes in DOC concentrations. However, the FDOM sensors are susceptible to fouling, and require weekly cleaning of the optics. Water managers, modelers, and others should consider using FDOM sensors to improve both monitoring and modeling in the Delta. FDOM sensors can also be used to assess large scale wetland restoration impacts in the Delta.

Keywords: Water quality, organic carbon, DOC, FDOM, UVA
Session Title: Making the Most of Technology: New Tools for Water Quality and Subsidence
Session Time: Tuesday 3:35PM – 5:15PM Room 308-310

A Hybrid Coagulation-Wetland System Designed to Decrease DOC, Hg, and Nutrient Loads from Subsided Islands in the Sacramento-San Joaquin Delta

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Water discharged from subsided Delta islands affects water quality in the San Francisco Bay-Delta by contributing dissolved organic carbon (DOC), disinfection byproduct precursors (DBPPs), nutrients, and mercury (Hg). These constituents of concern (COC) have been identified as key components affecting drinking-water safety and environmental health. For example, source water DOC concentrations above 3 mg/L have been identified as a trigger point for upgrading drinking water treatment plants. Additionally, a methylmercury (MeHg) TMDL for the Delta is being implemented to reduce Hg impairment in Delta habitats. In 2014, we completed field tests of a treatment system that uses in-situ coagulation followed by passage through wetlands to remove COCs from the water column and sequester them in wetland sediments via natural settling of particulate material. This type of system is commonly referred to as Low Intensity Chemical Dosing (LICD). The field study, located on Twitchell Island in the central Delta, consisted of nine 4,000 ft^2 replicated macrocosms comparing the effectiveness of wetlands alone to wetlands receiving water treated with iron- or aluminum-based coagulants to remove COCs. The coagulant-dosing system was controlled using on-site instrumentation to maintain DOC removal, monitor flow, and track water quality. We found removal of COCs varied seasonally, but the coagulation treatments generally reduced COCs below levels achievable by wetlands alone. Based on results from this study, we can estimate sequestration rates for the different COCs and the size of LICD treatment wetlands required to effectively treat discharges from Delta islands. This project demonstrates the potential usefulness of hybrid coagulation-wetland systems for managing Delta water quality by (1) reducing island drainage water COC precursor loads to the Sacramento Delta and (2) accelerating accretion of soils through the formation of mineral/organic soil blends formed from the capture of floc and the sequestration of organic matter within associated wetlands.

Keywords: Mercury, methylmercury, DOC, low intensity chemical dosing, wetland, water treatment
Session Title: Making the Most of Technology: New Tools for Water Quality and Subsidence
Session Time: Tuesday 3:35PM – 5:15PM Room 308-310

Radar Remote Sensing of Subsidence in the Sacramento-San Joaquin Delta

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Nearly a quarter of California's fresh water supply flows through the Sacramento-San Joaquin Delta, an area comprised of tidal marshland and reclaimed land in the form of ~60 islands surrounded by 1700 km of levees. Improved knowledge of region-wide subsidence is needed to maintain the integrity of the Delta levee system and protect the integrity and quality of the state's primary water supply and the overall economic and environmental health of the region.

We focus on measuring spatially and temporally varied levee and island scale subsidence across Sherman Island, located in the western Delta. Long-term subsidence on Sherman Island has resulted in surface elevations that now measure as much as 8 meters below sea level. We use data from NASA's L-band (23.79 cm) Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR), collected at 40-day average interval from July 2009 through the current day. Sherman Island is primarily state-owned, and serves as a test site for various state projects. This island has been imaged in detail by 5 of the 9 UAVSAR swaths acquired over the Delta and is thus an ideal location for our analysis. Ground truth for validating our preliminary results is available from USGS and CA-DWR-installed inclinometers and extensometers and corner reflectors installed and maintained by our group. We will present both our techniques and preliminary results for island-scale subsidence and subsidence along levees in Sherman Island, in the form of maps of levees showing areas exhibiting the most change (moisture, movement, instabilities indicated by localized variance from the surrounding area).

The research described here was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Keywords: remote sensing, delta, levees, subsidence
Session Title: Making the Most of Technology: New Tools for Water Quality and Subsidence
Session Time: Tuesday 3:35PM – 5:15PM Room 308-310

How Can Climate Science Best Influence Public Policy in an Era of Drought? Panel Discussion

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California is in a severe drought and though its history is punctuated by long and short droughts, climate change portends a water-short future for the state. This session will bring together a range of experts for thoughtful discussion of California's drought as it relates to climate and water policy. Experts will present condensed information about the current drought vis-à-vis climate issues and water policy and then answer questions from the audience facilitated by a moderator.

Keywords: drought, climate change, public policy, extreme weather
Session Title: How Can Climate Science Best Influence Public Policy in an Era of Drought?
Session Time: Tuesday 1:35PM – 3:15PM Room 311-313

The Delta's Fiscal Orphans: A Score Card

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The decline of the Delta's ecosystem results from multiple sources of stress, caused by decades of harmful water and land uses within the greater Delta watershed. Addressing these stressors will be costly; perhaps several hundred million dollars/year for decades to come. A recent PPIC report, "Paying for Water in California", looked at California's $30 billion a year water sector and identified areas with critical funding gaps. The Delta is home to many of these "fiscal orphans" – with inadequate funds available for ecosystem recovery (both within the Delta and upper watersheds), flood protection, management of stormwater and other polluted runoff, and governance and science programs. While it has been assumed that water users would cover the main cost of the Bay Delta Conservation Plan, the twin tunnels, it is still unclear where funding will come from for the other needed actions. Our study found that while state bonds have helped fill some of these gaps over the past decade, a broader mix of funding solutions is needed. For example, large ecosystem investments may be an appropriate use of state bond funds, but a more reliable funding source, such as a small new special tax, is needed to address ongoing governance and science in the Delta. We also recommended that California address some of the unintended consequences of constitutional reforms, such as Proposition 218, which has limited the ability of local agencies to reduce some ecosystem stressors, like stormwater, directly. Unless we address these funding gaps, California will be unable to tackle the challenges facing the Delta now and in the future.

Keywords: finance, science program, ecosystem management, governance
Session Title: Funding the Delta's Fiscal Orphans: Science, Governance, and Ecosystem Stress Relief
Session Time: Tuesday 3:35PM – 5:15PM Room 311-313

Panel Discussion on Funding Solutions with Delta Science and Management Leaders

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Improving the Delta's ecosystem will be costly. The BDCP calls for more than $8 billion in ecosystem investments, science, and monitoring, and this excludes enhancements in the upper watershed that many scientists consider essential. The Delta science program and fledgling governance institutions – essential for supporting ecosystem recovery – have been funded largely by state bonds, and science funds are due to expire by early 2015. The four leading proposals for a new bond would only make $0.6 to $2 billion available for the Delta ecosystem, with unclear implications for the science program. Although other options exist – including various types of contributions from resource users and taxpayers – science and system integration have been largely left off the table to date. A failure to address this funding challenge will impede significant progress in ecosystem recovery and water supply reliability.

This panel discussion will bring together leaders from Delta science and management organizations to discuss and debate potential solutions to this major challenge. The panel will be moderated by PPIC Senior Fellow, Jeffrey Mount. Panel participants include: Chuck Bonham (director, California Dept. of Fish and Wildlife), Byron Buck (executive director, State and Federal Contractors Water Agency), Randy Fiorini (chair, Delta Stewardship Council), Peter Goodwin (lead scientist, Delta Science Program), Anke Mueller-Solger (lead scientist, Interagency Ecological Program, and Western Science Center, USGS), Karla Nemeth (deputy director, California Natural Resources Agency), and Jay Lund (director, UC Davis Center for Watershed Science and member, Delta Independent Science Board) who will provide a panel wrap-up and a list of the top-ten creative funding solutions.

Keywords: finance, since program, ecosystem management, governance
Session Title: Funding the Delta's Fiscal Orphans: Science, Governance, and Ecosystem Stress Relief
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Natural Delta Hydrodynamic Model Development

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A new three dimensional, stratified flow model is being created to better understand the hydrodynamic and salinity regime of the Sacramento-San Joaquin Delta prior to agricultural development of the 1800's. Geometry of the new model is based on the San Francisco Estuary Institute (SFEI) Sacramento-San Joaquin Delta Historical Ecology Study[i]. The first use of this model will be to establish a draft relationship between isohaline positions and Bay-Delta outflow under "natural" and current conditions. This work is being performed by Resource Management Associates, Inc., (RMA) with support of the Metropolitan Water District of Southern California and in collaboration with the UC Davis Watershed Science Center (UCD) and SFEI. UCD and SFEI are developing detailed plan view channel networks and a digital elevation model to serve as the bathymetric data set for the flow model.

Utilizing a three dimensional, stratified flow model for this study is essential because it is not known at the outset how different the level of salinity stratification might be under the historic condition relative to today, and so there is no way to calibrate empirical mixing coefficients required by lower dimensional models. Representing the complex natural Delta channel network in a 3D model that must also represent the San Francisco Bay is a significant challenge. The UnTRIM3D engine was selected for this application because it is computationally very efficient and because it supports the use of sub-grid scale bathymetry in determining the volumetric and conveyance attributes of computational elements. Using sub-grid bathymetry it is possible to perform reasonably accurate hydrodynamic calculations for detailed tidal marsh channel networks without the extreme grid resolution and very long run times.

http://sfei.org/DeltaHEStudy

Keywords: Natural Delta, Multidimensional Modeling, Hydrodynamics, Salinity
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Reducing Hydrodynamic Complexity in Junctions and the Challenge of Producing Accurate Lagrangian Simulations

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We present simplified metrics to capture the hydrodynamic complexity at junctions based on the bulk discharge measured at flow stations. Making detailed measurements of velocity fields in junctions involves deployment, calibration, and interpolation of data from numerous Side-Looking Acoustic Doppler Current Profilers. These efforts are equipment and man-power intensive and therefore expensive. It is important to make these measurements in the context of process oriented studies where the details help to gain a mechanistic understanding; however, this level of effort is not practical for day-to-day management of the system. The metrics discussed in this talk include tidal averages of: (1) the discharge ratio, (2) critical streakline and, (3) the partitioning of discharge based on canonical flow distributions such as the flow entering the side-channel from upstream, downstream, converging and reversing flow conditions.

We examine time series of these metrics to: (1) document the temporal evolution of a single junction in response to the net flow, (2) compare and contrast the hydrodynamic/entrainment characteristics between junctions, (3) quantify how Delta Cross Channel operations affect velocity distributions in junctions throughout the north delta, and (4) use these metrics to explain tidally-averaged entrainment rates of acoustically-tagged salmon in junctions.

Finally, we discuss the extraordinarily rigorous demands the transport of constituents and particles place on numerical hydrodynamic models. Because transport and particle tracking involves the time integral of the temporal evolution of velocity field throughout the domain, model inaccuracies accumulate. The accuracy/treatment of the velocities fields in junctions is particularly important because the temporal distribution of the entrainment rates of constituents/particles at junctions can lead to vastly different outcomes. Accuracy demands increase the longer and farther constituents are advected, and particles are tracked.

Keywords: Hydrodynamics, Lagrangian
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Reducing Uncertainty in Design of in-Delta Sampling Experiments Using Particle-Tracking Models

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Hydrodynamic modeling and particle tracking animations were used to inform and optimize field experiments designed to evaluate the effects of wastewater derived nutrients on Delta food web dynamics. Using a Lagrangian-based sampling approach, the study involved tracking parcels of water that traveled down the Sacramento River and into the Delta under normal conditions of wastewater effluent release and when effluent flows from the Sacramento Regional Wastewater Treatment Plant were halted for 15 to 20 hours. The two distinct water parcels were monitored for changes in water quality over a 5-day period as they traveled 45 miles down the mainstem of the Sacramento River from the I80 Bridge to Isleton, with tidal forcings increasing with downstream movement. In order to plan for the study, hydrodynamic and particle tracking models were run using different hydrologic scenarios. The modeling objectives were: (1) to test different scenarios relating to the time and duration of the wastewater hold period in order to maximize the length of the wastewater-free stretch of river; (2) to help position the sampling boats over the multi-day sampling campaign to capture wastewater-free and wastewater-containing water samples by using animations to identify areas where the water parcels likely remained intact versus where tidal mixing was most likely to occur, and (3) to generate quantitative results from the predictive models to reduce uncertainty in the experimental design related to Delta operations. We found that the hydrodynamic scenarios and particle tracking simulations provided key information regarding Delta Cross Channel operation, changes in Net Delta Outflow and Sacramento River inflow, and the effect of agricultural diversions. The modeling results were particularly important for the May/June 2014 experiment which occurred during a period of unusually high uncertainty in Delta conditions due to extreme drought conditions.

Keywords: particle tracking lagrangian sampling Delta operations animations forecast modeling wastewater
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Temperature Dynamics in the Sacramento-San Joaquin Delta, CA

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We examine the spatio-temporal dynamics of water temperatures in the Sacramento-San Joaquin River Delta in response to tides, atmospheric forcing, river inflows, diversions, and inflow temperatures. Warm temperatures critically stress the Delta environment and are likely to increase in frequency with global warming, which can lead to degradation of water quality and mortality of endangered species of fish such as the Delta Smelt and Chinook salmon. Thus, we aim to understand what determines water temperatures in the Delta and whether water managers can alleviate elevated water temperatures in the face of climate change. We study the subtidal temperature field, which is determined by surface heat exchanges, solar heating, and entering water temperature. We performed a heat balance at various parts of the Delta by calculating the heat content of the water column and the atmospheric heat fluxes, which are the latent and sensible fluxes and the longwave and shortwave radiation. We find that the most important meteorological factors are air temperature, wind, and relative humidity, which can create large latent heat fluxes that warm the water. While global warming will increase air temperature, we conclude that river inflows can significantly assuage thermal stresses. In particular, barrier and gate operations were found to greatly change water temperatures even during warm atmospheric conditions. Thus, the movement of heat in the water column can have a major effect on temperatures in the Delta. We calculated the amount of heat moved within the water, defined as the downstream heat flux, by finding the difference between the atmospheric and water heat fluxes. By analyzing the spatial and temporal variability of the downstream flux, we see that downstream heat fluxes are greatest in the western Delta close to the Bay, indicating that heat is being advected downstream and enhanced by dispersion at junctions.

Keywords: Temperature, Global Warming, Junctions, Fluxes, Heat Content, Dynamics, Dispersion
Session Title: Connecting Models with Habitat
Session Time: Tuesday 1:35PM – 3:15PM Room 314

Multi-Species Effects Analysis & Ecological Flow Criteria: Lessons from Application of the Ecological Flows Tool (EFT) to Water Planning Efforts in the Delta & Sacramento River

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Since its launch in 2004 the EFT project has had the goal of improving water planning by explicitly linking ecosystem needs with physical models in the Sacramento River and the San Joaquin-Sacramento Delta. Aided by over 70 scientists and managers, we have developed an integrated bio-physical decision support tool that characterizes how a suite of 13 Delta and Sacramento River focal species (and habitats) are expected to respond to alternative flow, river bank, and gravel management scenarios. EFT species submodels are made up of 25 key life-history indicators, each of which is driven by relevant measures of flow, water temperature, channel migration, salinity and/or stage at a daily timescale. Our research has clearly demonstrated that there is a pressing need to develop greater awareness of the value of flexibility to manage ecosystem trade-offs over time within and among objectives. The detailed applications of EFT crystallize the fact that it is impossible to achieve all ecosystem objectives – let alone the co-equal goals of meeting human, agricultural and environmental needs – each and every year. We review these and other findings and describe a paradigm shift involving seeing balance as a condition which does not involve the same species or objectives losing (or winning) unnecessarily often. Other effects analysis findings highlight the need for a stronger focus on climate change mitigation itself (and the general difficulty of comparing future scenarios to a progressively deteriorating baseline). The presentation also summarizes promising results from an initial pilot study using EFT flow criteria to create new rules for CALSIM to improve outcomes for winter-run chinook and Delta smelt. With its emphasis on specific cause-effect linkages based on functional flow needs, EFT provides a solid framework that remains open to testing, enhancement and adaptation over time.

Keywords: Ecological flow, decision support, effects analysis, flow criteria, EFT, modelling
Session Title: Connecting Models with Habitat
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What if We Could Start Over: Large Landscape Scale, 2D Hydrodynamic Modeling of Sacramento Valley "What if" Floodway Scenarios

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Floodplain management planning efforts in the Central Valley of California are moving at an accelerated pace. In the next few years, critical decisions will be made regarding how to modify the current complex flood management system that protects major urban and agricultural areas in the Central Valley, based on holistic and multi-objective criteria aimed not solely for flood management, but also for ecosystem enhancement and agricultural sustainability.

To help inform these critical decisions, an innovative new tool has been developed and tested that will facilitate prediction of floodplain flows over vast areas of the Central Valley under existing conditions and a range of different potential management scenarios. This tool is a new, rapid 2-dimensional hydrodynamic model that is based on novel approaches to approximating the equations of water flow using latest computational hardware. The tool is ideal for testing multiple large-scale planning scenarios in a computationally efficient manner, and is being calibrated and validated for the Sacramento Valley from Ord Ferry to Sacramento, including the major tributaries to the Sacramento River. A range of “What if” scenarios for multi-objective floodplain management were developed and tested using the model. The results are presented in terms of hydrodynamic parameters and ecological indicators. Other current and potential future uses of the tool for planning purposes are discussed.

Keywords: Hydrodynamic, modeling, ecology, Sacramento Valley, Floodplains, multi-objective
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

Numerical Modeling of Sediment Dispersal Following Dredged Material Placements to Examine Possible Augmentation of the Sediment Supply to Marshes and Mudflats in Far South San Francisco Bay

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Recent studies of sea level rise in the San Francisco Estuary have indicated that the majority of tidal marshes surrounding the Bay are likely to lose marsh plant communities by 2100 because natural accretion rates will not keep pace with sea level rise. The Baylands Ecosystem Habitat Goals Update (BEHGU) has identified the need to establish cost-effective strategies to minimize this potential loss of tidal marsh habitat. The beneficial re-use of dredged material may provide a valuable resource to augment sediment supply to mudflats and marshes in the San Francisco Estuary. However, little information currently exists on where waves and currents transport sediment within San Francisco Bay following an in-bay dredged material placement. A three-dimensional hydrodynamic, wave, and sediment transport model was applied to examine sediment dispersal throughout the San Francisco Bay and the Sacramento-San Joaquin Delta. One focus of the sediment transport modeling effort was to examine the sediment dispersal following dredged material placements. The model was applied to evaluate whether smaller shallow-water dredged material placements in Far South San Francisco Bay adjacent to existing marshes or breached salt ponds would result in an increase in deposition rates within these areas through natural dispersal of the placed sediment. In the Far South Bay, dredged material placements were effective at supplying sediment to the surrounding mudflats and breached salt ponds and resulted in increased accretion rates. These model results highlight the usefulness of three-dimensional sediment transport modeling for managing dredged material placements and suggest dredged material placements in strategic locations may be used to augment sediment supply to mudflats, marshes, and breached salt ponds surrounding San Francisco Bay.

Keywords: Baylands Ecosystem Habitat Goals Update, Sediment Modeling, Mudflats, Restoration, UnTRIM
Session Title: Connecting Models with Landscape
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Modeling the Benefits of Yolo Bypass Restoration Actions on Chinook Salmon

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In recent years the Yolo Bypass has been recognized as important rearing, spawning, and migratory habitat for numerous native fish species, including Chinook salmon. The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Draft Implementation Plan (Implementation Plan) was developed to restore Yolo Bypass rearing and migratory habitat through increase of seasonal inundation and modification of water control structures of the Yolo Bypass. Prior to execution of the Implementation Plan, a modeling effort is being undertaken to evaluate potential benefits to all four Central Valley (CV) Chinook salmon runs, particularly Sacramento River spring-run and winter-run, both federally listed under the Endangered Species Act. A model was built that simulates key Chinook salmon life history stages from freshwater emigration (just upstream of the entrance to the Bypass) to adults returning from the Pacific Ocean (escapement) and quantifies the potential impacts of restoration actions on juvenile growth, emigration success, and ultimately survival to adult escapement. This model configuration allows for a direct quantitative comparison of competing management alternatives by comparing the relative abundance of returning adults from juvenile salmon that reared in the Yolo Bypass versus the mainstem Sacramento River. Additionally, the intermediate abundance levels at ocean entry are provided along with fish demographics (% entrainment, survival during rearing, fish size at ocean entry, and ocean survival) for each alternative. Initial modeling results have helped identify management alternatives that provide the greatest growth and survival benefit for CV Chinook salmon runs, allowing managers to focus on a smaller sub-set of alternatives for further evaluation. Future modeling work will help optimize the identified sub-set of management alternatives by evaluating the effects of specific management actions on Chinook salmon, including additional modifications to water control structures, grading of floodplain habitat, and changes to Bypass drainage canals.

Keywords: Chinook salmon, Yolo Bypass, Modeling, Floodplain, Restoration
Session Title: Connecting Models with Landscape
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Use of Daily Historical Data and a Daily Reservoir Model to Evaluate Adaptive Implementation of Alternative Reservoir Operations

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Historical reservoir and river data can be used in a daily model to evaluate multi-purpose reservoir operations that may include adjustments in the flood control rules, alternative water quality objectives to support fish and wildlife (i.e., fish flows based on unimpaired runoff), and conjunctive water supply. A daily model can demonstrate the potential for adaptive implementation of alternative reservoir operations that could improve downstream fish habitat conditions without substantially reducing water available for other beneficial uses (i.e., water supply, flood control, hydropower). Monthly models provide an accurate characterization and allocation of water among beneficial uses for planning purposes; however, historical daily data and a daily model can provide a more resolved evaluation of the effects of alternative reservoir operations and downstream fish habitat conditions (e.g., inundation and water temperature) as needed for implementation. The daily reservoir inflows may be the historical unimpaired runoff or may be modified by upstream storage and diversions. Water supply delivery targets, including increased deliveries in wet years (i.e., conjunctive use) may be determined from the available storage, forecast runoff and specified fish flows. Daily flood control operations may be determined from the daily storage, inflow, and maximum allowable downstream flows. The effects of reservoir release flows on downstream fish habitat conditions can be evaluated and compared with identified or assumed relationships. Using the Merced River as an example, a daily model was developed to adjust flood control operations to provide more sustained reservoir releases for riparian inundation and water temperature control. Reduced flood control releases during moderate storm events could provide more sustained inundation of riparian habitat. The daily model can also be used to evaluate increased spring-time flows (e.g., percent of unimpaired flow). These moderate increases in spring-time flow could improve fish habitat conditions in many years without reducing water supply.

Keywords: Daily data, Flow objectives, Reservoir Operations, flow benefits, riparian inundation
Session Title: Connecting Models with Landscape
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The Delta Salinity Gradient (DSG) Model

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A new empirical sub-tidal model of daily averaged salinity in Suisun Bay and the western Delta was developed. Called the Delta Salinity Gradient (DSG) model, this new tool integrates and expands upon the functionalities of Denton's G-Model and the Kimmerer-Monismith (K-M) X2 equation. The new model predicts specific conductance at user-specified longitudinal distances along the Bay-Delta estuary. The new model also predicts the location of the X2 isohaline, as well as the location of other user-specified isohalines.

The model was calibrated with daily averaged salinity and X2 isohaline observations for calendar years 2000 through 2009. The model was also calibrated with simulated data from the DSM2 model for purposes of demonstration. Model validation was accomplished using the entire period of record that was available at the time of development, i.e. October 1921 through September 2012. Model results were compared with predictions provided by the G-Model as well as the K-M X2 equation.

This new tool will allow scientists and engineers a simple method for evaluating the salinity structure of the Bay-Delta estuary under extremely low outflow conditions such as those experienced prior to Shasta Dam and those that would occur under "without-Project" conditions, i.e. scenarios that assume SWP-CVP project reservoirs are not in place. The ability to model these low outflow conditions is necessary in order to evaluate how and why the salinity structure of the estuary has changed over time. Currently available empirical and mechanistic models are not sufficiently formulated or calibrated to evaluate these extreme conditions.

Keywords: salinity model; X2 position; estuarine salinity gradient; Delta salinity
Session Title: Connecting Models with Landscape
Session Time: Tuesday 3:35PM – 5:15PM Room 314

Spatial Analysis of Juvenile Chinook Salmon Entrainment in Tidally Forced Junctions

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Data from the 2001 and 2003 Delta Cross Channel studies, the 2006 Clarksburg Bend Study, and the 2011 and 2012 Georgiana Slough Non-Physical Barrier (GSBNP) studies show that acoustically tagged juvenile Chinook salmon are not uniformly distributed in these river junctions and river bends. Thus, juvenile salmon are not uniformly distributed throughout a river's cross section approaching a junction, and therefore entrainment probabilities cannot be calculated based on flow data alone. As a result, understanding entrainment rates in these junctions requires an understanding of both the water-velocity patterns and spatial distribution of juvenile salmon within the junction area.

We analyzed large numbers of multidimensional tracks from acoustically tagged juvenile salmon migrating through critical junctions in the Delta using aggregate spatial statistics. In order to understand the processes influencing the spatial distribution of these fish, we aggregated fish tracks into groups that were exposed to a range of similar covariate values. We used the critical streakline and flow ratio metrics discussed in earlier talks to collapse the complexities of the two-dimensional velocity fields in the junctions into time series of critical streakline locations which we used to sort fish into groups that traveled through the junctions under similar velocity conditions. Empirical two-dimensional probability distribution functions (PDFs) were calculated for each of these covariate groups, and statistics calculated from these PDFs were used to gain insights into the mechanisms affecting juvenile salmon entrainment in Delta junctions.

Keywords: fish swimming in moving water
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 8:20AM – 10:00AM Room 306

Using Acoustic Telemetry to Assess the Effect of a Floating Fish Guidance Structure on Entrainment of Juvenile Salmon into Georgiana Slough

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The interior of the Sacramento-San Joaquin River Delta is a location of high mortality for out-migrating ESA listed juvenile salmonids, relative to alternative migration routes. Reducing the probability of entrainment into the Interior Delta from the Sacramento River via Georgiana Slough is therefore one action that can increase juvenile salmonid survival. In 2011 and 2012, a non-physical barrier comprised of intermittent light, a bubble curtain, and modulated sound was placed at the entrance of Georgiana Slough. This non-physical barrier reduced the proportion of juvenile salmon entering Georgiana Slough from 22.3% to 7.7%. However, the largest reduction in entrainment probability (up to 40 percentage points) occurred near the critical streakline which defined the streamwise division of flow vectors entering Georgiana Slough and the Sacramento River. These insights led us to hypothesize that a relatively small shift in the cross-sectional distribution of fish towards the Sacramento River side of the critical streakline could considerably reduce the probability of fish being entrained into Georgiana Slough. To test this hypothesis, a 350 ft long, shallow-draft (5-10 feet deep) floating boom (the "floating fish guidance structure" or FFGS), intended to guide fish away from the Georgiana Slough side of the river channel, was installed upstream of the entrance to Georgiana Slough during the spring of 2014. Nearly 5,000 acoustic tagged late fall Chinook salmon were released into the Sacramento River near Sacramento to evaluate the effect of the FFGS on entrainment of fish into Georgiana Slough. The analysis is currently incomplete, but the presentation will include the effects of the FFGS treatment (FFGS deployed or not deployed) and other factors (e.g., river discharge and location of the critical streakline) on the probability of entrainment into Georgiana Slough.

Keywords: acoustic telemetry, fish protection, behavior, migration routing, juvenile salmon
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 8:20AM – 10:00AM Room 306

Diel Activity Patterns of Juvenile Late-Fall Chinook Salmon with Implications for Operation of the Delta Cross Channel

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Identifying mechanisms affecting fish distribution associated with water withdrawals can provide a basis for management actions to improve juvenile salmon survival. Under the rationale that fish distribute in proportion to the discharge that enters a migration route, the Delta Cross Channel (DCC) has been prescriptively closed for most of the out-migration season to reduce juvenile salmon entrainment and subsequent mortality within the interior Sacramento-San Joaquin River Delta. Recent observations indicate the fraction of fish entering a route can be in disproportion to the amount of flow allocated to the route. To further investigate this, we implanted acoustic transmitters into 2,983 juvenile Chinook salmon and released them upstream of the DCC to evaluate arrival timing and entrainment into the DCC. Nighttime arrival and entrainment into the DCC were modeled using logistic regression with covariates for flow, the change in flow, and water temperature. Although the proportion of the diel period having negative flows was most important to fish arrival, river flow and water temperature were also important drivers of nighttime arrival probabilities at the DCC, whereas river flow and the change in flow were the more important drivers of entrainment probabilities. Application of the model to observed conditions suggests nighttime closure of the DCC may reduce fish entrainment into the DCC (as much as 68%) during the winter migration period. Opening the gates only during the day would allow water to be diverted to the pumping stations and closing the gates at night could minimize entrainment into the interior delta.

Keywords: Day and night salmon movement, water conveyance, and salmon entrainment
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 8:20AM – 10:00AM Room 306

Individual Based Modeling of Juvenile Chinook Salmon

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Movement of juvenile chinook salmon in the north Delta has been investigated by the USGS using acoustic tagged salmon and high resolution hydrodynamic data. Observed salmon movement in the winter of 2008 were strongly influenced by both salmon behavior and hydrodynamics. Due to limited spatial coverage of the hydrodynamic data, the specific behaviors which result in the observed paths through the north Delta cannot be determined from the data alone. In order to better understand and quantify salmon behaviors and thereby improve the ability to predict salmon movement through the Delta, three-dimensional modeling tools have been developed and applied. These tools include a high resolution three-dimensional hydrodynamic model, a three-dimensional particle tracking model and an individual based model that specifies salmon behavior.

The UnTRIM Bay-Delta model was refined in the North Delta to a cross-channel resolution of approximately 5 m and along channel resolution between 5 and 10 m along the Sacramento River between Georgiana Slough and the Clarksburg Bend and downstream of the Sacramento River junctions with Georgiana Slough, the Delta Cross Channel, Steamboat Slough and Sutter Slough. The resulting model was validated using ADCP velocity transects to evaluate prediction of streamwise and cross-stream velocity. The model predicted similar secondary circulation structure to the observations throughout the tidal cycle but typically predicted smaller cross-channel velocity amplitude than calculated from the ADCP observations.

Particle tracking was performed using these hydrodynamics for both passive particles and particles with specified swimming behaviors. We evaluated hypothesized holding behaviors and outmigration behaviors by comparing the distribution of modeled particle transit times for alternative simple behavior scenarios to the observed distribution of travel times for acoustically tagged salmon throughout the North Delta.

Keywords: Individual based model, particle tracking model, hydrodynamic model, chinook salmon
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 8:20AM – 10:00AM Room 306

Evaluation of a Hypothesis for How Water Flow Pattern Shapes Fish Trajectories near Infrastructure

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Decades of empirical studies have identified many factors that affect the relationship between fish movement and water flow, yet applying quantitative knowledge across multiple locations regarding how infrastructure modifies the outcome of naturally evolved behavior, and at a scale that management can use, remains a challenge. Stochastic processes may dominate the moment-to-moment decisions of animals, and individuals may change their behavior response to a fixed stimulus over time. Near infrastructure, studies cannot measure all the external (e.g., hydrodynamic, water quality, social) and internal (e.g., bioenergetic, cognitive) factors across the range of spatiotemporal scales that may influence fish behavior. Recognizing these constraints, we relate fish behavior to factors that management most directly influences, namely the quantity and structure of water flow, and focus at a scale resolution where future environmental pattern might be forecast. Using a hypothesis for how fish might hydraulically navigate flow field obstacles in natural free-flowing rivers, we reproduce the observed 3-D movement trajectories and distribution patterns of juvenile Pacific salmon across 47 flow fields assembled from multiple data sources over 14 years near seven dams. We explain fish movement in terms of a behavioral response to experienced water acceleration and velocity near infrastructure. To describe behavior dynamically, where response can change with context, we use a simple individual-based model coupled to a multi-dimensional hydrodynamic model. With a limited evolutionary history for navigating engineered infrastructure, such as dams, fish behavior should reflect their response evolved in natural rivers. As such, we surmise that our hypothesis is applicable to fish outside the context of dams, in natural settings and near other forms of infrastructure in the Bay-Delta system such as fish diversion devices (booms and non-physical barriers) and passage structures as well as have implications for habitat design.

Keywords: fish movement behavior, hydraulic pattern, individual based model, ecohydraulics
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 8:20AM – 10:00AM Room 306

Juvenile Salmon Response to Levee Repair on the Sacramento River

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California Department of Water Resources (DWR) and the United States Army Corps of Engineers (USACE) are engaged in levee repair focused on preventing levee erosion and flooding. The repairs also include features to improve the fish habitat including shallow water benches and instream woody material. However, there remains uncertainty about how fish respond to these features. In addition, questions regarding which enhancement provides the most benefit to fish also remain. To address these questions, we investigated fish movement using acoustic tags at rivermile 85.6. Approximately 200 detailed 2D fish movement tracks were collected in the vicinity of the repair site in 2010 and in 2011. We also collected detailed bathymetric and hydraulic data and developed a 2D computational fluid dynamics (CFD) model of the levee repair site. We then developed a fish movement model using the Eulerian-Lagrangian-Agent Method (ELAM) and used the fish movement data from the 2D acoustic tag tracks for calibration of modeled fish movement. The fish movement model matched observed travel times and spatial distribution accurately. The fish movement data and subsequent modeling suggest that juvenile salmon respond to local hydraulic features produced by the levee repair by moving away from the habitat enhancement. These results are counter to the goal of the increasing juvenile salmon residence at the repair sites. Before fish arrive in the Bay-Delta they must move through hundreds of miles of river where levees impact the habitat. It is important that habitat be available for all life stages of juvenile salmon as migration to the Bay Delta happens. Our results suggest that the environmental features incorporated into levee design are not working as intended. Given the prevalence of levees on the Sacramento system it is important that we consider how learn how to better improve conditions for migrating and rearing salmonids.

Keywords: levee repair, salmon, hydraulics, fish movement models, telemetry
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 10:20AM – 12:00PM Room 306

Ecohydraulic Design and Post-Project Appraisal of Salmonid Spawning and Rearing Habitat Enhancement Projects on the Lower American River

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The lower American River is a local treasure running through the highly urbanized region of Sacramento and its neighboring communities. Hydrologic regulation of the river by upstream dams, the corresponding blockage of sediment supply to the river downstream and blockage of fish passage to the historically available habitat upstream have resulted in deleterious consequences to populations of Chinook salmon and steelhead trout that depend on the American River Watershed for both spawning and rearing. In the last six years, concerted efforts by agencies including the U.S. Bureau of Reclamation, U.S. Fish & Wildlife Service, California Department of Fish and Wildlife, NOAA Fisheries, Sacramento County Parks and the Sacramento Water Forum have resulted in several habitat enhancement projects in the lower American River. These projects have focused on the creation and enhancement of spawning and juvenile rearing habitat through gravel augmentation and side channel enhancement or creation. The projects are designed using ecohydraulic principles to provide the desired hydraulic conditions at flows that typically occur during the spawning periods for the two species. This approach relies upon two-dimensional hydraulic modeling combined with species specific habitat suitability criteria that were developed using observations made in the lower American River. The potential for mobility of the placed gravel is also considered during the design process. Following implementation, physical monitoring has tracked the evolution of sites through time and documented the hydraulic conditions present following construction. Utilization of the sites for spawning has been rigorously documented. Post-project appraisals indicate that the ecohydraulic design approach is working, with ~80% of the redds that have been documented in the sites occurring in areas predicted to be highly suitable with the hydraulic-habitat suitability modeling approach. Furthermore, river wide redd surveys have shown that a majority of the redds are occurring in the enhanced sites.

Keywords: gravel augmentation, steelhead, Chinook salmon, enhancement, design, spawning, side channel
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 10:20AM – 12:00PM Room 306

Using Agent-Based Models to Gain Insight into the Influence of Behavior, Predation and Water Project Operations on Fates of Migrating Chinook Salmon Smolts

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Problem statement: Migration of anadromous salmonids from freshwater spawning and rearing grounds to the ocean is a key stage in their life cycle. We seek to understand the behavior of migrating Chinook salmon smolts in the Sacramento-San Joaquin Delta in order to predict the effects of changing inflows and outflows on their migration routes, survival, and ultimate fates, both at an individual and population level.

Approach: We began with the California Department of Water Resources' Delta Simulation Model II (DSM2), which includes a spatially-explicit, individual-based particle tracking model with passive, neutrally-buoyant particles. We extended DSM2 to include active swimming and more complex route selection behaviors, and included mortality based on travel distance and time. Model calibration and selection were performed using coded-wire tag and acoustic telemetry data. Smolt fates were simulated for a variety of smolt release locations, historical flow scenarios, and alternative behavioral hypotheses.

Results: Behavior and mortality dramatically affect the fates of particles – in particular, the fraction of smolts entrained in the Central Valley Project and State Water Project export facilities is strongly influenced by migration behavior. The behavioral hypothesis most concordant with the data included active swimming in the downstream direction; selective tidal-stream transport; and a probability of individual smolts incorrectly assessing the downstream direction, with this probability based on the relative strengths of the net flow and the tidal amplitude in a given channel. In accordance with observations, travel times through the Delta were shorter, and mortality much reduced, compared to the null model.

Conclusions/Relevance: Our preliminary results underscore the importance of understanding the behavioral processes underlying observed patterns of smolt migration and fate. A mechanistic understanding of this key life stage will be an essential component in predicting the consequences of water management, conservation actions, and climate change for endangered salmonid populations.

Keywords: Agent-based modeling, Chinook salmon smolts, migration, behavior, mortality
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 10:20AM – 12:00PM Room 306

Visualizing Juvenile Salmonid Behavior, Mortality, and Salvage in the Delta: Practical Application of an Individual-Based Model

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Managers and biologists are expected to manage water project operations and take other actions that can contribute to recovery or, minimally, provide protection for sensitive fish species. In addition, Delta researchers need a means to quantitatively assess the possible fates of tagged fish between points of detection or recovery. We have developed an individual-based model of juvenile salmonid passage through the Delta (the Individual Based Delta Passage Model or IB-DPM) which provides a "sand box'' wherein biologists and managers can explore how different assumptions about juvenile salmonid behavior, predation, and their respective interactions with hydrodynamic conditions may influence the proportion of fish surviving to Chipps Island or arriving at export facilities. The IB-DPM represents a simplified network of Delta channels that include primary migratory routes for juvenile salmonids entering from both the Sacramento and San Joaquin Rivers. The routes represented in the IB-DPM include 196 DSM2 channels, 15 channel junctions, and 2 physical barriers (DCC and HORB). Hydrodynamic inputs to the IB-DPM are based on DSM2 HYDRO simulations of either historic conditions or hypothetical boundary conditions. The historic simulations allow for calibration of the model with data from fish tagging studies and the hypothetical conditions allow for virtual experiments on the effects of proposed water operations on juvenile salmon passage through the Delta. In this talk, we will outline the key biological assumptions of the IB-DPM, demonstrate the user-friendly interface of the model, and illustrate the challenges associated with model calibration based on coded-wire tag and acoustic telemetry studies. The IB-DPM provides an example of a powerful, yet relatively simple individual-based modeling approach that can be broadly applied to enhance understanding and effective management of complex ecological issues.

Keywords: individual-based model, salmonid, migration, salvage, inflow, exports
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 10:20AM – 12:00PM Room 306

A Reevaluation of the Relationships Between X2, the Low Salinity Zone, and Fish Habitat Utilization

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The UnTRIM Bay-Delta model is a three-dimensional hydrodynamic and salinity model of the San Francisco Estuary, which extends from the Pacific Ocean through the entire Sacramento-San Joaquin Delta. The UnTRIM Bay-Delta model has been used in studies of San Francisco Bay and the Sacramento-San Joaquin Delta for California DWR, USBR, USGS, USEPA, and the US Army Corps of Engineers. The UnTRIM Bay-Delta characterizes the areal and volumetric extent of estuarine habitat in the Low Salinity Zone (LSZ) over a range of historic conditions, and has been used to develop maps of Low Salinity Zone extent for a range of X2 values.

This analysis extends the LSZ extent analysis to cover a 34 year period spanning from 1980 through 2013 to evaluate how the size and position of the LSZ has changed over much longer timescales than have previously been explored. In addition, this study re-evaluates the effect of the commonly made assumptions about the low end of the salinity range which have been used in this type of analysis (either 0.5 or 1.0 psu) on the resulting non-monotonic relationship between X2 and the LSZ. A new approach for characterizing the LSZ is proposed which is shown to be more consistent with both the utilization of fish habitat in low salinity ranges based on fish survey data and with the X2-abundance relationships which generally exhibit monotonic trends of increasing abundance with decreasing X2.

Keywords: Low Salinity Zone, X2, Delta smelt, Physical Habitat
Session Title: Ecohydraulic Applications in Fish and Water Management
Session Time: Wednesday 10:20AM – 12:00PM Room 306

Factors Affecting Juvenile Chinook (*Oncorhynchus tshawytscha*) Growth Variability in a Large Freshwater Tidal Estuary

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Estuarine rearing habitat has been shown to enhance within watershed biocomplexity and support growth and survival for juvenile salmon (*Oncorhynchus* sp.). However, less is known about how growth varies across different types of wetland habitats and what explains this variability in growth. This study examined juvenile fish growth over a range of wetland habitats in the freshwater tidal Columbia River estuary. We focused on the estuarine habitat use of Columbia River Chinook salmon (*Oncorhynchus tshawytscha*), which are listed under the Endangered Species Act. We employed a generalized linear model (GLM) to test three hypothesis: (1) juvenile Chinook growth was best explained by temporal factors, (2) juvenile Chinook habitat use was the most important driver of estuarine growth rate, and (3) demographic characteristics, such as stock of origin or the timing of seaward migration best explain juvenile Chinook salmon growth rate. This study examined juvenile Chinook estuarine growth rate, incorporating otolith microstructure, individual assignment to stock of origin, GIS habitat mapping and diet composition in three habitats (mainstem river, tributary confluence and backwater channel) along ~130 km of the upper estuary. These findings present a unique example of the complexity in understanding the influences of the many processes that generate variation in growth rate for juvenile anadromous fish inhabiting estuaries.

Keywords: juvenile Chinook salmon, Columbia River estuary, habitat, growth, diet
Session Title: Salmonid Ecology
Session Time: Wednesday 1:35PM – 3:15PM Room 306

Using Otolith Strontium Isotopes to Reconstruct Life History Portfolios within Salmon Populations: When Do Different Phenotypes Contribute?

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The maintenance of life history diversity within and among populations is thought to be critical for the persistence of salmon stocks. Preserving and restoring diversity in life history traits is thus central to many recovery efforts, but it is necessary to first understand how environmental factors affect their expression and success. Rotary-screw trap sampling in the California Central Valley has indicated that juvenile salmon outmigrate at different sizes, ages and times of the year. We used otolith strontium isotopes in adult Chinook salmon returning to the Stanislaus River, a regulated stream at the southern end of the species range, to determine how river conditions influence juvenile behavior and survival. Paired otolith and scale samples were used to reconstruct juvenile outmigration patterns of successful adults from cohorts emigrating between 1999 and 2011. For each adult, the size it had outmigrated from its natal tributary was reconstructed by coupling otolith strontium isotope and radius measurements. Size distributions and phenotype contributions were compared between the juvenile outmigrants and adult "survivors", and used to identify trends in selective mortality. Our seven focus years exhibited contrasting flow regimes as a result of differences in precipitation patterns and local water operations. In wetter years, the majority of juveniles outmigrated as fry, while in drier years, outmigrants tended to be fewer but larger. Metrics of outmigration behavior (abundance, size and phenology) varied primarily as a function of hydroclimatic regime, while relative survival rates appeared to be driven by conditions within the natal tributary, as well as size- and time-selective mortality. While fry survival is generally assumed to be negligible in this system, our data indicate that they can represent more than 20% of the reproductive population. Patterns in juvenile outmigration behavior and survival are discussed in the context of water and fisheries management, and the portfolio effect.

Keywords: Chinook salmon, life history diversity, juvenile outmigration, otolith strontium isotopes
Session Title: Salmonid Ecology
Session Time: Wednesday 1:35PM – 3:15PM Room 306

Genetic Analysis of Hatchery Steelhead from the Central Valley Reveals Patterns of Reproduction and Migration

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Iteroparous salmonids are more difficult to study than semelparous ones because carcasses are rarely encountered and they are released alive from hatcheries after spawning. Single Nucleotide Polymorphism markers have been shown to be useful in pedigree reconstruction, investigations of stock structure and individual identification and provide biological information that is not available with traditional physical tags. We collected data for 95 SNP markers from more than 10,000 steelhead (the anadromous form of *Oncorhynchus mykiss*) used as broodstock between 2011 and 2014 in the four California Central Valley steelhead hatchery programs: Coleman, Feather River, Mokelumne River and Nimbus hatcheries. Assignment tests allowed us to estimate migration rates between hatcheries and to confirm the clear distinction of the Nimbus Hatchery population, which was founded with coastal steelhead stocks, from the other Central Valley hatcheries. Similarly, we confirmed that Mokelumne River Hatchery steelhead are genetically similar to Feather River Hatchery stock, from which they were derived. The identification of parents-offspring trios allowed us to evaluate age structure and variance in family size in all programs. We found a high proportion of age 2 spawners in three of these programs, but none at Nimbus. Finally, we matching genotypes were used to count how many fish spawned more than once in the same season and identified a significant number of fish that reproduced multiple times in the same season. We also used this approach to investigate iteroparity rates for each hatchery program separately. The comparison of the first spawning date with spawning dates in subsequent spawning events for iteroparous individuals identified a strong correlation, consistent with the heritability of spawning date. This study shows the power of SNP-based genetic tagging analysis to elucidate key life history variables and, as a consequence, it's utility in formulating effective conservation and management strategies.

Keywords: Steelhead, genetics, SNPs, migration, iteroparity, hatcheries, reproduction
Session Title: Salmonid Ecology
Session Time: Wednesday 1:35PM – 3:15PM Room 306

Large-Scale Genetic Tagging Experiment with Chinook Salmon from the Feather River Hatchery Allows for Pedigree-Based Inference

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Studies of aquatic animals often require identifying individuals, groups or populations over a period of time. For Chinook salmon, the coded-wire tag, mechanically inserted in the skulls of juvenile fish, has been the primary tool for tracking cohorts and quantifying stock-specific fishery impacts. However, as the data needs of fishery managers have grown, alternative tagging strategies have gained prominence. One of the most promising technologies is parentage-based tagging (PBT), which uses genotypes collected from a parental breeding generation in a hatchery to tag the offspring cohort. Non-lethal sampling of offspring during their seaward migration, in fisheries, or upon return to spawn (either at hatcheries or instream) is followed by high-confidence parentage assignment, allowing identification of stock and cohort of origin, as well as the reconstruction of multiple pedigrees. Here, we report the results of an 8-year PBT experiment with spring-run Chinook salmon from the Feather River Hatchery. Reconstructed parent-offspring trios were used to assess inter-annual variability in the age structure of offspring cohorts as well as the age structure and relative reproductive success of spawning broodstock. Data on the physical characteristics of parents and offspring were used to estimate the heritability of length and age at maturity and to identify correlations between female body size and the number of her offspring returning to spawn. Inbreeding and relatedness in spawning populations was also assessed and the effect of parental relatedness on reproductive success evaluated. The offspring of hatchery spawners were also identified in a large mixed-stock fishery sample from the coastal ocean of California. This type of information is critical for understanding the population dynamics of hatchery stocks, the effects of hatchery practices and the distribution of specific cohorts in ocean fisheries.

Keywords: Chinook salmon California genetics SNP hatchery parentage-based-tagging heritability
Session Title: Salmonid Ecology
Session Time: Wednesday 1:35PM – 3:15PM Room 306

Application of Genetic Methods To Salvaged ESA-listed Chinook Salmon

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Water exports from the South Delta cause "incidental take" of juvenile salmonids, potentially contributing to jeopardy of ESA-listed species. While the export loss functions essentially estimate the total fish mortality given the number of fish observed at salvaged facilities, a foundational component of these calculations is the determination of which salvaged individuals are "older", as defined by length-at-date criteria (i.e., the "Delta Model"). NOAA's RPA define an "older" juvenile as an individual that resides above the lower boundary of winter run length-at-date criteria. Yet, the Delta Model is known to be ambiguous regarding race determination. The failure of the length-at-date model to accurately categorize race creates considerably uncertainty (variance) in the estimation of loss density. We were charged with using genetic methods to determine the population of origin for juveniles categorized as "older" by the Delta Model, as well as individuals that fell outside the winter run length-at-date criteria. The objectives of this genetic project are intended to directly target (and reduce) one source of uncertainty in the estimation of loss at salvage facilities. Accurate and rapid determination of population was performed using methods based on single nucleotide polymorphism (SNP) markers and fluidic chip technology. We compared our direct observations from genetically-partitioned salvage loss to current regulatory take determinations at both State Water Project and Central Valley Project South Delta export facilities for water years 2010-14. We observed statistically significant differences within-year between facilities, between-year within facility, and between tissue archive sampling strategies. Secondary analyses also found evidence for Sacramento River population survey deficiencies. The presentation will conclude with describing strategies to further integrate genetic information into salvage loss estimation processes.

Keywords: Genetic analysis, population assignment, Chinook salmon, salvage facilities
Session Title: Salmonid Ecology
Session Time: Wednesday 1:35PM – 3:15PM Room 306

What do We Need to Know about Juvenile Salmonids Entering the Delta and How Will We Know it?

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Needs and opportunities for monitoring Central Valley salmonids differ considerably from other fish species inhabiting the Delta. While conservation biology recognizes only a single population of delta smelt, recovered populations of Central Valley Chinook (winter, spring and fall) are expected to consist of several to many sub-populations originating from tributaries up and down the Sacramento-San Joaquin Basin. Application of population genetics to juvenile salmon encountered in current Delta monitoring programs can estimate the proportion of fish matching a particular Chinook race genetic baseline. However, estimating the proportion of spring Chinook present in Delta fish samples, provides less value (for conservation, monitoring and management) than knowing how many juvenile spring Chinook were produced each from Clear Creek, Battle Creek, Butte Creek, the Feather River and the San Joaquin River along with knowing when and where individuals representative of these sub-populations are residing (or perishing) within the Delta. A monitoring program that detects spring run Chinook generally, but can't distinguish subpopulations specifically, would for example, allow the growth of one subpopulation to mask the decline of another. My presentation will describe a vision for Central Valley salmonid monitoring in which innovative sampling and tagging techniques are deployed to guide Delta management and to provide population metrics essential for guiding recovery of Central Valley salmonid populations.

Keywords: salmon, steelhead, monitoring, viability, recovery, spawning, abundance, productivity
Session Title: Looking Ahead: Managing for Salmon
Session Time: Wednesday 3:35PM – 5:15PM Room 306

2012 Georgiana Slough Non-Physical Barrier Performance Evaluation

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The migration of juvenile salmonids into the interior Delta through pathways such as Georgiana Slough has been shown in previous studies to contribute to lower survival. In an effort to identify potential approaches to reduce the percentage of the juvenile salmonids that migrate from the Sacramento River into Georgiana Slough, a team led by DWR implemented a large-scale experimental testing program in 2011 and 2012 to assess the effectiveness of a non-physical barrier using Bio-Acoustic Fish Fence™ (BAFF) technology as a method for guiding outmigrating juvenile salmonids. The experimental design of the 2012 tests included the use of acoustically tagged juvenile late fall-run Chinook salmon and steelhead, released upstream of the non-physical barrier when the barrier was on and when it was off, to determine the effectiveness of the barrier. The BAFF reduced the percentage of Chinook salmon passing into Georgiana Slough from 24.8% when the BAFF was off to 10.3% when the BAFF was on, representing statistically significant overall reduction in entrainment into Georgiana Slough of 14.5 percentage points ($p=<0.0001$). This improvement produced an overall efficiency rate of 89.7%; that is, 89.7% of Chinook salmon that entered the area when the BAFF was on exited by continuing down the Sacramento River. Furthermore, the BAFF reduced the percentage of steelhead passing into Georgiana Slough from 25.6% when the BAFF was off to 12.3% when the BAFF was on, representing an overall reduction in entrainment into Georgiana Slough of 13.3 percentage points. The improvement produced an overall efficiency rate of 87.7%. A generalized linear model analysis of the data showed that the most important predictors of tagged salmonids remaining in the Sacramento River were cross-stream position and BAFF operation. The predation rate of tagged salmonids in the area of the BAFF did not differ between BAFF ON and OFF operations.

Keywords: salmon, barrier, Sacramento River, Delta, telemetry, acoustic, Chinook, steelhead, Georgiana
Session Title: Looking Ahead: Managing for Salmon
Session Time: Wednesday 3:35PM – 5:15PM Room 306

A Method to Estimate the Annual and Daily Abundance of Salmonid Juveniles in the Delta

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Problem Statement: The Sacramento-San Joaquin Delta serves as a migration corridor for salmonid juveniles outmigrating from the Sacramento River, San Joaquin River, and other eastside tributaries. Juvenile abundance in the Delta is a key variable contributing to fish entrainment and is fundamental to managing facility operations in the Delta. Currently, there is no method available for quantifying the annual or daily abundance of salmonid juveniles in the Delta, except for winter-run Chinook salmon that had annual abundance estimates.

Approach: The daily total number of juvenile fish in the Delta (Φ) can be estimated as:

$$\Phi = \Sigma\{\phi_{in} (1 - \gamma)\} - \phi_{out}$$

Where

ϕ_{in} = Number of fish entering the Delta

ϕ_{out} = Number of fish leaving the Delta

γ = Fish daily mortality rate in the Delta

n = Fish residence time in the Delta

The number of fish entering the Delta was estimated from juvenile trawl data in the Sacramento and San Joaquin rivers. The number of fish leaving the Delta was estimated from juvenile trawl data at Chipps Island. Data for juvenile mortality and residence time were obtained from recent acoustic tag studies in the Delta. The overall annual Delta survival rate was estimated from the total annual numbers of fish entering and leaving the Delta.

Results/Conclusions/Relevance: The daily abundance of natural winter-run Chinook salmon juveniles in the Delta was highest (423,000) in 1996 and has been relatively low (below 50,000) since 2008. The daily abundance of natural spring-run Chinook salmon juveniles has been low since 1998 except for 2003, 2005, and 2011. The daily abundance of natural steelhead juveniles has been consistently low since 1998. The median overall Delta survival rates were estimated for juveniles of natural steelhead (0.47), and natural winter-run (0.41) and spring-run (0.26) Chinook salmon.

Keywords: Fish flux, juvenile abundance, Chinook salmon, steelhead, Delta survival
Session Title: Looking Ahead: Managing for Salmon
Session Time: Wednesday 3:35PM – 5:15PM Room 306

Impacts of Interior Delta Flows on Salmonid Species

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Problem Statement: Every year large quantities of salmonid juveniles, including steelhead and winter-run, spring-run, and fall-run Chinook salmon, are entrained to the Federal and state water export facilities in the south Delta; yet it has been in dispute on factors that most likely impact the entrainment.

Approach: We analyzed the available data of 19 years (1993-2011) on juvenile fish salvage/loss, inflows to and outflows from the Delta, water exports, juvenile abundance, Old and Middle rivers (OMR) flow, and tide height, using Pearson's correlation and multiple linear regression methods.

Results/Conclusions/Relevance: The fish salvage of natural juvenile winter-run and spring-run Chinook salmon and natural juvenile steelhead was positively correlated to water exports, juvenile abundance, Sacramento River flow, or tide height; but negatively correlated to the San Joaquin River flow, OMR flow, the inflow-to-export (I:E) ratio, or Delta outflow. The multiple linear regression results indicate that water export and juvenile abundance are the most important variables impacting the number of juveniles salvaged at the fish facilities. To a lesser degree, tide height, inflow, outflow, the I:E ratio, or OMR flow played a role in controlling fish salvage. In addition, juvenile fish survival decreases from the mainstem Sacramento River to interior North Delta to South Delta. Measures to reduce juvenile fish entrainment to interior N. Delta and S. Delta (*e.g.*, DCC gates closure and restriction of OMR flow or water export) will increase their overall Delta survival.

Keywords: salvage, loss, abundance, inflow, water export, OMR flow, tide height
Session Title: Looking Ahead: Managing for Salmon
Session Time: Wednesday 3:35PM – 5:15PM Room 306

Chinook Salmon Rearing in the Lower Sacramento River: Effects of Physical Variables on Near-Shore Habitat Use

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Factors driving habitat use by juvenile Chinook salmon in large, main stem habitats such as the Sacramento River remain poorly understood, yet information pertaining thereto is needed to guide restoration and mitigation approaches intended to enhance rearing opportunities for the species. We used point-based boat electrofishing to sample juvenile Chinook during the spring rearing and outmigration season in the middle section of the Sacramento River, and collected a suite of biologically relevant habitat characteristics at each sampled location, including localized temperature, depth, current velocity, substrate, bank slope and available in-stream cover. Using logistic regression analysis, we evaluated the effects of physical variables on occupancy probability by juvenile Chinook, and found that a number of habitat characteristics - including temperature, cover, depth, velocity, and others - significantly affect near-shore habitat use. In addition, we document drift abundance and diet composition of juvenile Chinook salmon in the middle Sacramento River (vicinity of Knights Landing), which is suggestive of active rearing and foraging as fish emigrate through this reach of the Sacramento River. While some of our findings agree with habitat requirements established on smaller watersheds, others may warrant a reconsideration of restoration and mitigation designs intended to benefit juvenile salmonids in the Sacramento River and the Bay-Delta.

Keywords: Chinook salmon; smolt; fry; habitat; rearing' Sacramento River; restoration; mitigation
Session Title: Looking Ahead: Managing for Salmon
Session Time: Wednesday 3:35PM – 5:15PM Room 306

Science and Media Panel

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Over 25 million California residents are dependent on water deliveries from the Sacramento-San Joaquin Delta yet many do not understand the environmental, physical, or political complexity by which water is provided in their homes. Informing California residents about water supply and aquatic ecosystem issues in the San Francisco Bay Delta Estuary (Bay Delta) is a challenge the science and media communities struggle to meet. However, improving communication to California residents on water supplies and aquatic ecosystems of the Bay-Delta is imperative given the amount of public funds that are dedicated to water delivery infrastructure and natural habitat areas. Equally important, California residents should be aware they are public stewards of the Bay-Delta aquatic ecosystem and the many fisheries (e.g., Chinook salmon) that support California's natural heritage and economy. Despite the importance of the Bay Delta to California, a 2012 public survey of California residents showed that fewer than a quarter of residents are aware of the Bay-Delta as their source of water altogether. In order to make informed decisions (e.g., at the voting booth) about the direction of California's water policy and initiatives, the public deserves to have readily accessible information in a number of media outlets that distills complex science information into easily digestible and impartial reporting.

We are proposing a Science and Media Panel at the Bay-Delta Science Conference to discuss how the science and media communities can work together to improve the quality and quantity of knowledge California residents have about the Bay-Delta. The panel will review the needs and challenges of effectively communicating with a diverse audience and share methods and tools that improve information transfer. Improving Bay-Delta public knowledge is a vital step toward successfully addressing the water supply and aquatic ecosystem challenges of today and tomorrow for all Californians.

Keywords: Science, Communication
Session Title: Science and Media Panel
Session Time: Wednesday 8:20AM – 10:00AM Room 307

Quantifying Nutrient Loads and Transformations in the Delta

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High anthropogenic nutrient loads are hypothesized to be one factor that is contributing to ecosystem decline in Suisun Bay and the Sacramento/San Joaquin Delta. However, to date there has been limited systematic study of nutrient cycling and fate in Suisun Bay and the Delta. Characterizing the role of the Delta in processing nutrients and delivering loads to downstream subembayments will inform near-term management decisions regarding nutrient inputs to these regions. This presentation will describe results of a project that applies multiple approaches at a range of spatial and temporal scales to characterize and quantify the dominant imports/exports to the Delta, as well as transformation/ loss processes and internal nutrient sources or sinks within the Delta. These processes in turn play a major role in shaping ambient concentrations within the Delta and ultimately determine net nutrient loads delivered downstream to Suisun Bay. First, we used a 1-box model to assess transformations/losses on a whole Delta-scale, looking both over multiple decades and during low-flow summer months. We estimated imports, exports, and internal losses or gains (by difference) using DWR-EMP water quality data in combination with DWR-DAYFLOW data. Next, we characterized seasonal, temporal and spatial variability in nutrient concentrations and stable isotope data (NO3, NH4, and POM isotopes) within the Delta with the goal of identifying finer-scale regions and/or time periods exhibiting substantial transformations, losses or internal inputs. Finally, we used the Delta Simulation Model (DSM2-QUAL) to quantify the magnitudes of these processes required to explain observed concentrations within the Delta, and to refine estimates of nutrient loads delivered downstream to Suisun Bay.

Keywords: Nutrients, Suisun Bay, Nutrient loads
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 10:20AM – 12:00PM Room 307

Ocean Nutrients in the Bay-Delta System: When and Where are they Important?

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San Francisco Bay is an estuary, comprised of a mix of salty ocean waters and freshwater from the rivers that flow in through the delta and elsewhere. Wind-driven upwelling along the open coast results in high nitrate levels in ocean waters that are drawn into the Bay by the tides and estuarine circulation. The concentration of nitrate and the timing of intrusion into the Bay are primary factors in assessing the importance of ocean nutrients to Bay nutrient budgets. Preliminary estimates indicate that ocean nutrients are most important during specific events. At other times, the ocean may import organic matter, such as algal blooms, which may also be important to net loading of the Bay. In addition to the nitrate mass imported, a key question is how far into the Bay-Delta system may ocean loading have an impact on the ecosystem.

Keywords: ocean, nitrate, salinity, nutrient balance
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 10:20AM – 12:00PM Room 307

Biogeochemical Fluxes in Bay-Delta Sediments: Seasonal and Spatial Synthesis

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Sediments are key components of shallow water estuarine ecosystems, both responding to changing environmental conditions and at the same time, altering the chemistry of the overlying water column. Over the last 3 years, we have measured rates of sediment-water exchange of oxygen, nitrogen and phosphorus on 6 separate occasions across widely varying sites in the Bay Delta. A high degree of spatial variability of fluxes was found reflecting a broad range of organic matter loading and in the processes that promote retention or release of nutrient elements. Rates of the processes measured here fell largely within the broad range of rates for such processes reported worldwide. Small, but measureable rates of dissimilatory nitrate reduction to ammonium were found. In September 2014 in the San Joaquin River, we observed some of the highest measured rates of denitrification and soluble reactive phosphorus efflux than at any other times or at any other locations, with rates similar to those from more eutrophic estuaries. Extrapolating from both chlorophyll *a* and O_2 fluxes, the sediments may potentially have large impacts on estimates of total system productivity. Bioirrigation by animals was found to have an important effect on oxygen penetration depths; the benthic flux of oxygen and ammonium increased significantly as *Potamocorbula* biomass increased. Nutrient flux measurements in a restored wetland suggest that denitrification represent an important sink for nitrogen. In this presentation, we use this large and diverse data set to identify the key controls on sediment-water exchange in the Bay-Delta Ecosystem, and scale these rates of nutrient exchange to the rates of nutrient input.

Keywords: sediment-water exchange, denitrification, benthic microalgae, DNRA, sediment oxygen demand
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 10:20AM – 12:00PM Room 307

New Insights from Continuous Monitoring of Nutrient Dynamics in the North Delta and Cache Slough Complex

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Characterizing how nutrient dynamics in the north Delta and Cache Slough complex are affected by interaction with adjacent tidal marshes and shallow water habitats is essential for developing accurate nutrient budgets, assessing the impacts of eutrophication, anticipating effects of increased future agricultural intensity and increased population in the Central valley, projecting effects of higher concentrations associated with drought conditions, and planning wetland restoration. The difficulty is that water quality and nutrient supply in estuaries change continuously as river flows, tidal- and wind-driven currents, and other physical processes move new water parcels across comparatively static geomorphic settings. We used high frequency, in situ measurements of nitrate and phosphate in concert with measurement of flow dynamics in tidal wetlands to evaluate the wetlands' effects on nutrient dynamics. We report data from studies in the north Delta and Cache Slough complex that show large variability in dynamics, from tidal to seasonal time scales, and speculate on processes driving the observed differences. We found substantial seasonal and episodic variation in the magnitude and direction of net nutrient fluxes, suggesting that long-term, high-frequency observations are necessary in order to evaluate nutrient retention in wetlands.

Keywords: nutrients, in situ, sensor, wetlands, estuaries
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 10:20AM – 12:00PM Room 307

Estimates of Phytoplankton Nitrogen Uptake and Pelagic Nitrification During Fall in the High Nutrient San Francisco Estuary Delta

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Large rivers carry inorganic nutrients to estuaries and the coastal ocean where they help to shape microbial community production and speciation, and the estuarine food web. Within rivers, microbial processing will influence the magnitudes, forms and the ratios of the inorganic nutrient pools that reach estuaries but at present only limited information exists about the rates of nutrient processes in the San Francisco Estuary Delta. Riverine phytoplankton in the Sacramento and San Joaquin rivers assimilate some fraction of the dissolved inorganic nitrogen (DIN) load, thereby reducing the nitrogen concentration and increasing organic matter that reaches the low salinity zone of the estuary. Additionally, chemosynthetic prokaryotes may transform nitrogen species within the DIN pool, from ammonium (NH_4) into nitrate (NO_3) through pelagic nitrification. This process results in no change in the magnitude of the DIN pool, but does alter the proportion of these two nitrogen species. The goal of this effort was to characterize phytoplankton N uptake and pelagic nitrification processes along the Sacramento and San Joaquin rivers and in Suisun Bay during the fall period, when river flows are relatively low. A series of 12 transect surveys were conducted between September and November from 2010 to 2012. Our results show that anthropogenic inputs of DIN, along with altered patterns in freshwater flow, impart strong consistent spatial patterns in DIN concentration and speciation within the Delta. These patterns in turn influence phytoplankton DIN uptake and nitrification rates in predictable ways and help to explain the resulting concentrations of DIN that reach the low salinity zone in Suisun Bay. Effective nutrient management of the San Francisco Estuary Delta should include estimates of internal nutrient processes in order to constrain the assimilative capacity of the system for anthropogenic nitrogen loads.

Keywords: Phytoplankton, Nitrogen uptake, Ammonium, Nitrification
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 10:20AM – 12:00PM Room 307

Continuous Monitoring of Dissolved Oxygen in San Francisco Bay, California: Using High-Frequency Data to Explore Dynamics and Mechanisms

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Since passage of the 1972 Federal Clean Water Act, reported dissolved oxygen (DO) concentrations in San Francisco Bay (Bay) are routinely above the 5mg/L standard important for supporting biota, with few reported episodes below this concentration. However, long-term monitoring efforts have measured DO only in the main channel of the estuary by research vessel, and only at weekly to monthly sampling intervals. For this study we conducted the first high temporal resolution deployment of dissolved oxygen sensors in both the main channel and the perimeter of the Bay. Four optical DO sensors were deployed near bottom and sampled every 15 minutes for a year: two in the main channel (depth>12m) and two in the estuary perimeter (depth<5m). Main channel sites included one in the upper estuary near the primary freshwater inflow and one in the lower estuary near the ocean boundary; estuary perimeter sites included one at the mouth of a tidal creek in Central Bay and one in a tidal slough in South Bay. The resulting time series for main channel sites showed DO concentrations which always exceeded 5mg/L, whereas during spring, summer, and fall the tidal slough exhibited sustained hypoxic conditions (<3mg/L) and the tidal creek daily minima dropped below 5mg/L. Compared to sites in the main channel, those along the estuary perimeter demonstrated greater variability in DO concentrations at seasonal, tidal, and especially diurnal time scales. At the tidal slough site, DO concentrations varied at the spring/neap time scale, with consistently lower concentrations during neap tides indicating tidally varying transport and system metabolism. These time series are the first to concurrently document the contrasting DO patterns in the main channel versus the shallow periphery of the Bay, with results highlighting the value of high temporal resolution sampling and the importance of measurements in the shallow habitats.

Keywords: dissolved oxygen; continuous monitoring; tidal sloughs; San Francisco Bay
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 1:35PM – 3:15PM Room 307

High-Frequency Measurements Enable a Detailed Assessment of Surface Ammonium Concentration Dynamics in the Bay-Delta

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Problem: Anthropogenic nitrogen loading has been linked to eutrophication in estuarine ecosystems around the world. Yet in the Bay-Delta system, high anthropogenic ammonium inputs have not induced large increases in phytoplankton production, and recent research has advanced the idea that anthropogenic ammonium loading may reduce levels of primary productivity by inhibiting phytoplankton nitrate uptake. While water-column NH_4^+ concentrations have been regularly measured over the last decade throughout the Bay-Delta system, assessments of the ecological influence of anthropogenic ammonium loading on the Bay-Delta ecosystem have necessarily relied on water samples at discrete stations, often spaced kilometers apart.

Approach: In order to provide a more detailed spatial picture of ammonium concentrations throughout the Bay–Delta system, we have measured near-surface NH_4^+ concentrations using an under-way, real-time flow-through ammonium analyzer deployed on monthly cruises to the Bay-Delta beginning in early 2014. Our achieved sampling frequency -- approximately one measurement every 110 seconds while under-way – has effectively increased the spatial sampling resolution of this critical nutrient by an order of magnitude.

Results: We present a characterization of the dynamics of ammonium concentrations from anthropogenic sources in the Sacramento River, pinpointing where concentrations first rise, their variability moving downstream, and where, precisely, concentrations cease to decrease moving downstream. We also provide descriptions of the variability of ammonium concentrations, including localized “hotspots”, in Suisun Bay. Finally, we present correlations of high-frequency ammonium measurements with turbidity, salinity, temperature and chlorophyll fluorescence throughout the Bay-Delta.

Implications: The largest single source of anthropogenic NH_4^+ loading to the Bay-Delta is the effluent plume from the Sacramento Regional Wastewater Treatment Plant located in Elk Grove, CA. The detailed mapping of the dynamics of this plume and its relationship with chlorophyll fluorescence, salinity and turbidity helps inform on-going decision-making processes about the management of multiple anthropogenic stressors in the Bay-Delta system.

Keywords: ammonium, nutrients, phytoplankton, wastewater, biogeochemistry
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 1:35PM – 3:15PM Room 307

Egg Production and Egg Viability of the Copepods Acartia and Eurytemora Differ When Grown on Food of Varying N:P Ratios

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Ecological stoichiometric theory suggests that the chemical composition of food (phytoplankton) plays a key role in the success of grazers at all stages in their life cycles. Here, results of a controlled laboratory study are reported in which cultures of phytoplankton (the diatom *Thalassiosira*) were grown under different dissolved N:P conditions but maintained at the same growth rate and then fed to two copepod species, *Acartia tonsa* and *Eurytemora* sp., for periods of several days. Food was provided at the same carbon content level and was not limiting. When the algal food was grown at an N:P ratio of 32 vs 16, the number of eggs produced per female of *Acartia* declined 6-fold. In the case of *Eurytemora*, a similar decline in egg production was noted when food was grown in media for which N:P was 24 vs 4. Both of these copepod species have declined over time in the Bay Delta, trends that have been attributed to increased grazing from invasive clams as well as changes in the total amount of phytoplankton (food quantity). However, long-term trends in these copepod species have also been found to be related to long-term increases in N:P of the dissolved nutrients. The implications of these experimental results are that the chemical composition of dissolved nutrients can affect food quality even without a change in food quantity, and such changes may ultimately affect zooplankton reproductive success even when food is not limiting.

Keywords: Nitrogen, Phosphorus, Ecological stoichiometry, Food quality, *Eurytemora*, *Acartia*, egg production
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 1:35PM – 3:15PM Room 307

The Form of Nitrogen Alters Total Chlorophyll, the Composition of Phytoplankton, and Total Productivity: Experimental Results and Implications for the 2014 Spring Bloom

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It is well documented in N-limited systems that increased availability of nitrate (NO_3^-) typically leads to new production that supports a food web leading to secondary production, while increased ammonium (NH_4^+) commonly leads to greater production within a microbial loop. What has been unclear is whether changes in N form under conditions of N sufficiency alters the composition or production of the primary producers that, in turn, may affect the food web. We tested the effects of changes in N form on phytoplankton composition and rates of productivity on samples collected over a 3-year period from both the Sacramento River and Suisun Bay. Overall, proportionately more chlorophyll *a* and fucoxanthin (generally indicative of diatoms) was produced per unit N taken up in samples enriched with NO_3^- and incubated at reduced (~15% of ambient) light intensity than in treatments with NO_3^- with high (~60% of ambient) light exposure or with NH_4^+ under either light condition. Proportionately more chlorophyll *b* (generally indicative of chlorophytes) and zeaxanthin (generally indicative of cyanobacteria) was produced in samples enriched with NH_4^+ and incubated under high light intensity than in treatments with low light or with added NO_3^- at either light level. Rates of productivity enriched with NO_3^- were higher than those enriched with NH_4^+. The 2014 spring bloom in Suisun Bay was consistent with these relationships, with higher NO_3^- availability (apparently from substantial riverine nitrification) sustaining high production of diatoms. These findings confirm that N form is related to the amount and "quality" of phytoplankton, all other factors being equal. These results bear substantially on the management debate concerning the importance of reducing total N loads from sewage effluent and/or adding nitrification with or without N reductions. These results also have implications for development of numeric nutrient criteria and the importance of accounting for N form.

Keywords: nitrate, ammonium, productivity, diatoms, spring bloom
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 1:35PM – 3:15PM Room 307

Physiological Assessment of the "Bad Suisun" Phenomenon: Nutrient-Phytoplankton Interactions

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A dramatic decline in native and introduced pelagic fish species in the northern part of San Francisco Bay (SFB) has been linked with, among a number of factors, a decline in prey abundance precipitated by a decrease in phytoplankton production and biomass. This decline at the base of the food web has in turn been attributed to a number of ecological and environmental factors, one being the build-up of ammonium (NH_4^+) in the water column resulting from increased discharge of wastewater effluent over the last three decades. While nutrient input from effluent has traditionally been thought to promote phytoplankton growth, and in severe cases lead to eutrophication, it has also been documented that too high concentrations can lead to toxicity. Few investigations have characterized the tipping point between the concentration of NH_4^+ that supports optimal growth, and that which inhibits growth, of estuarine phytoplankton. This investigation is the first to do so with a number of phytoplankton species, including diatoms and chlorophytes, isolated from Suisun Bay in the northern part of SFB. The primary goal of this investigation is to investigate phytoplankton productivity and growth over a range of NH_4^+ concentrations, to identify optimal concentration of NH_4^+ for growth, and to characterize the tolerance threshold to NH_4^+. A secondary goal is to compare the growth of phytoplankton on NH_4^+ with that on nitrate to determine whether certain species grow better with one source versus the other. Comparisons of several species of native phytoplankton will provide a mechanistic understanding of the interactions between NH_4^+ concentration and phytoplankton growth, information that is necessary to make sound management decisions regarding the degree to which nutrients forms and concentrations exert negative control over the food web in Suisun Bay.

Keywords: Phytoplankton Suisun Bay Diatoms Chlorophytes Ammonium Nitrate Tolerance Growth
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 1:35PM – 3:15PM Room 307

Heavy Hitters in the San Francisco Bay Phytoplankton Community - Diatoms, Dinoflagellates, and Cryptophytes

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Phytoplankton are the largest living component of San Francisco Bay (in mass/tons of carbon). These microscopic, single-celled plants are the primary food source on which the Bay's consumers, such as zooplankton, bivalves, crabs, fish, birds, and seals, ultimately depend. Over 600 phytoplankton species have been detected in the Bay, they come in a variety of shapes, sizes, nutritional value, functionality, and potential toxicity, and the combination of those variables determines their value as a food resource to consumers.

Since 1992, our long-term USGS research program has been measuring phytoplankton taxonomic composition, abundance, and biomass throughout San Francisco Bay. Cloern and Dufford (2005) analyzed the first decade of this record and discovered that three functional groups dominate phytoplankton biomass (as cell biovolume): diatoms, dinoflagellates, and cryptophytes. In recent years, it has been hypothesized that elevated concentrations of certain nutrient forms and changes in nutrient ratios have created shifts in the relative percentages of these groups. Here we analyze data from the salty, ocean-influenced parts of the Bay to answer the following questions: (1) What are the relative contributions of the three dominant groups to total phytoplankton biomass? (2) Do these contributions differ between San Pablo, Central Bay, and South Bay? (3) Are there seasonal fluctuations of these contributions, and have they changed over time?

Keywords: phytoplankton, microalgae, primary production, taxonomy, diatoms, dinoflagellates, cryptophytes
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 3:35PM – 5:15PM Room 307

Does San Francisco Bay have a Harmful Algal Bloom problem?

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San Francisco Bay is well-known for multiple impairments directly and indirectly linked to human activity, including excessive mercury, PCBs, invasive species, and increasing concentrations of ammonium. These impairments are associated with increased urbanization, diverted water flow, point and non-point introduction of pollutants and contaminants. Despite these many impacts and alterations, San Francisco Bay is generally considered to be resilient to eutrophication, and harmful algal blooms (HABs) caused by nuisance and toxic phytoplankton are considered to be episodic and unusual events. However HABs and related toxins have received insufficient study and monitoring to date, and, in fact, both HAB-forming cells and toxins are routinely found in the Bay/Delta. Here we present 3+ years of toxin monitoring, 20+ years of phytoplankton composition, and toxin levels in a newly acquired set of bivalve tissue samples to explore the potential HAB issue in San Francisco Bay and to establish a baseline for identifying trends in HAB dynamics, together with recommendations for monitoring potential events and impacts. Both microcystins (freshwater toxin) and domoic acid (marine toxin; Amnesic Shellfish Poisoning) are nearly ubiquitous in the Bay, and it is likely that other toxins including saxitoxin (Paralytic Shellfish Poisoning), okadaic acid (Diarrhetic Shellfish Poisoning) and yessotoxin (responsible for the mass abalone mortality in Sonoma during 2012) are at least occasionally present. Using data on both toxin and cell abundance, we will explore several questions, including: Do toxin concentrations in the Bay reach levels that could cause adverse impacts? What is the source of marine toxins – transport of coastally-produced toxins into the Bay or production by marine HAB-species within the Bay? Has "intrusion" of estuarine HAB organisms occurred following the opening of the South Bay salt ponds?

Keywords: harmful algal blooms, phytoplankton, nutrients
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 3:35PM – 5:15PM Room 307

Examining Long-Term Phytoplankton Monitoring Data in the San Francisco Estuary: What Changes Have Occurred?

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The northern San Francisco Estuary (SFE) has experienced major ecological disturbances due to anthropogenic activities over the past century, and the pronounced declines post-2000 of several important pelagic fish species serve as recent evidence that these disturbances affect all levels of the SFE food web. Conceptual models, developed with broad input from regional and national experts, recognize that multiple factors have acted in concert to degrade the northern SFE habitat, including: water withdrawals, land use changes, invasive species, and contaminants including nutrients. A few recent studies have argued, based on analysis of multi-decade monitoring data (Department of Water Resources Environmental Monitoring Program (DWR-EMP)), that food web restructuring in the northern SFE is due in large part to shifts in phytoplankton community composition that have resulted from high anthropogenic nutrient loads. With the goal of developing an improved understanding of how and when changes in phytoplankton community composition occurred and of the hypothesized bottom-up nutrient-phytoplankton driver of food web restructuring, we examined the DWR-EMP phytoplankton monitoring data from 1975-2007. This presentation will present our observations related to the following fundamental questions: 1. Is there evidence to indicate that phytoplankton community composition has changed in the northern SFE? In particular, have diatoms decreased and been replaced by other (undesirable) classes of phytoplankton? 2. When did changes occur, and were they abrupt or gradual changes? 3. Using simulations designed to assess the robustness of the DWR-EMP data, what types of changes in community composition could have been confidently identified?

Keywords: phytoplankton ecology, long-term monitoring, microscopy, data analysis
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
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What Caused the Diatom Decline in Suisun Bay after 1986?

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Measurements from the IEP Environmental Monitoring Program have shown that phytoplankton biomass (as chlorophyll *a* concentration) decreased five-fold in Suisun Bay after introduction of the clam *Potamocorbula amurensis* in 1986. The diatom component (as cell abundances) decreased ten-fold after 1986, and one proposed explanation for the selective loss of diatoms is suppression of diatom growth by sewage-derived ammonium. We explore a more direct explanation: diatoms are removed by clam grazing faster than other algae because they sink. Diatoms, especially in the presence of high sediment concentrations, sink rapidly. Fast vertical transport to the sediment-water interface makes phytoplankton cells accessible to clams that can permanently remove them, thus preventing their resuspension back into the water column. Relative to diatoms, motile and non-sinking algae may be transported more slowly down into the bottom zone of clam filtration. We used a numerical model of a coupled shoal-channel system representative of Suisun Bay to: (1) explore the linkages between algal sinking, clam grazing, turbulent mixing, light availability, and horizontal transport; (2) assess whether those linkages can result in differential removal of diatoms and non-diatoms by benthic filter feeders; and (3) evaluate the plausibility of a sinking-grazing based mechanism to explain why the diatoms declined faster than flagellates, green algae and cyanobacteria in Suisun Bay after 1986.

Keywords: phytoplankton, diatom, clam, Suisun Bay, sinking, model, Potamocorbula, sedimentation, algae
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
Session Time: Wednesday 3:35PM – 5:15PM Room 307

The Suisun Bay Problem: Food Quality or Food Quantity?

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Suisun Bay provides habitat for endemic fish species occupying low salinity habitats of the San Francisco Bay-Delta estuary. It is a highly disturbed biological system, manifested as decreased primary production, proliferation of non-native species, restructured communities across multiple trophic levels, and population collapses of pelagic fishes. The consensus of the broad scientific community is that these symptoms of environmental degradation are the result of multiple human disturbances including landscape transformations, altered freshwater inflows, nutrient and contaminant inputs, and disruption by introduced species. In recent years an alternative explanation has emerged that these changes were driven by a single factor – growing wastewater inputs of ammonium and associated increases in the N:P ratio. The proposed underlying mechanism is an altered chemical environment that slows growth of diatoms and/or promotes growth of other algal forms, leading to degraded quality of the phytoplankton food resource for consumers. If this explanation is correct we would expect patterns of change in the Suisun Bay phytoplankton community that are synchronous with patterns of change in ammonium loading. We analyzed phytoplankton data collected by IEP and USGS to look for four patterns that would be expected if the alternative explanation is correct: (1) significant decline of diatom abundance; (2) synchrony of the diatom decline with increasing ammonium loading; (3) increased abundance of non-diatom algal groups; and (4) indicators showing that that the phytoplankton food quality is low.

Keywords: Suisun Bay, ammonium, phytoplankton
Session Title: Nutrients in the Bay-Delta: Ambient Conditions, Ecosystem Response and Management Implications
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The Delta Science Plan

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There are many science efforts in the Sacramento-San Joaquin Delta (Delta) that are well-designed and well-implemented to address a narrow set of issues. However, they lack the organization, support, and many of the approaches and tools needed to support the full range of policy and management challenges associated with achieving the coequal goals. A plan is needed to produce and communicate highly credible, relevant, and legitimate science to guide durable and comprehensive policy solutions and support effective and robust management actions for achieving the coequal goals. In addition, processes for developing and communicating high-caliber system-wide scientific synthesis are needed to inform Delta policy and management decision-making.

The Delta Science Plan, completed in December 2013, addresses these problems. It provides a strategy for achieving the vision of '*One Delta, One Science*' – an open Delta science community that works together to build a shared state of knowledge with the capacity to adapt and inform future water and environmental decisions in the Delta. The Delta Science Plan establishes and strengthens science synthesis and communication among policy, science, and management communities. It also builds the infrastructure for growing the knowledge base through identifying actions for prioritizing research, shared modeling, integrated monitoring, improved data management and accessibility, synthesis to accelerate knowledge discovery, independent scientific peer review and advice, and communication.

Since the completion of the Delta Science Plan, several of its actions have been initiated and accomplished by the Delta science community. New mechanisms for organizing science to inform policy and management have been established, an environmental data summit has resulted in guidelines for data sharing, and mechanisms for science synthesis are being employed. Shared implementation of the Delta Science Plan is creating a collaborative culture for science and accelerating the discovery of new understanding to inform decision-making to achieve the coequal goals.

Keywords: collaborative science, coordination, integration, policy-science, coequal goals, synthesis
Session Title: Implementing the Delta Science Plan: Improving Science Capacity to Meet Current and Future Challenges
Session Time: Wednesday 8:20AM – 10:00AM Room 308-310

Interim Science Action Agenda

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While every agency has mission-specific science needs, many commonalities exist. However, there is no shared science agenda that lays out common priority science questions and actions for the whole Delta. This makes comprehensive and efficient science planning, funding, coordination and integration difficult, while critical science gaps persist.

The Interim Science Action Agenda takes an initial step in implementing the Delta Science Plan (completed December 2013) and creates a shared science agenda in pursuit of *One Delta, One Science* – which means an open Delta science community that works together to build a shared state of knowledge with the capacity to adapt and inform current and future water and environmental decisions in the Delta. The Delta Science Plan calls for a Science Action Agenda to prioritize and align specific science actions to inform management decisions and inform updates to our scientific understanding of the Delta as reflected in updates to the *State of Bay-Delta Science*. To make immediate progress on a full Science Action Agenda, the Delta Science Program, working with others, is developing an Interim Science Action Agenda.

The Interim Science Action Agenda is an initial list of shared priority science actions from existing documents and expert input to be addressed within a two-year time frame. Building on existing efforts, it will serve as a shared agenda for science collaboration among agencies and programs. It will be a collaborative road map for addressing science questions to inform decision-making about improving water supply reliability and the resilience of Delta ecosystems. The Interim Science Action Agenda will enable leveraging resources to accelerate learning and achieve shared science and information needs. It will also be the basis for the full Science Action Agenda that will cover a four-year time frame and include prioritization of science actions to inform water and environmental decision-making.

Keywords: science actions, coordination, integration, priority, decision-making, science and information needs
Session Title: Implementing the Delta Science Plan: Improving Science Capacity to Meet Current and Future Challenges
Session Time: Wednesday 8:20AM – 10:00AM Room 308-310

Delta Science Vision- Sustaining Data Integration Efforts while Taking Advantage of Constantly Evolving Technology

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Pressing matters such as climate change, an aging water infrastructure, and a deep drought affecting California force all citizens to recognize and respond to the fragile balance between our natural resources and competing water uses across the state - but nowhere more important than in the California Delta.

California's natural resource decisions must accommodate the rate of environmental change. To be effective leaders under these circumstances, state and local agencies, private organizations, academia, and the public must make use of today's innovations with an equally fast rate of adoption. The need for transparency and sharing of data demands an open community of science with interoperability data standards and state-of-the-art data exchange and access tools.

Decision-makers, analysts, and the public recognize the need for a common data sharing initiative. With the world's most advanced technology resources located in California and the Environmental Data Summit held in June of 2014, these resources provide recommendations to ensure that sharing information and building on our technology investments becomes the norm for improving natural resources management, rather than the exception. The resulting environmental data road map works towards achieving our common vision to identify solutions associated with:

- Improving data coordination, sharing, and interoperability
- Adopting new technologies for use across data generators and users
- Making environmental data meaningful for decision-makers and the public
- Providing alternatives in their pursuit of making defensible choices.

Keywords: Data Availability, Open-Data
Session Title: Implementing the Delta Science Plan: Improving Science Capacity to Meet Current and Future Challenges
Session Time: Wednesday 8:20AM – 10:00AM Room 308-310

Successful Business Models to Support Sustainable Technology Initiatives

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California enjoys its surfeit of technology innovation, and yet the state's resources agencies labor to keep pace with technological change, despite their best efforts, considerable expertise, and ingenuity. Initiatives to distribute environmental data more broadly and transparently have resulted in qualified success. The “My Water Quality” portals, for instance, are a good measure of environmental data-sharing efforts, but even each portal’s creators would readily admit that they are merely hinting at the possible rather than offering comprehensive solutions. The portals were developed under the stewardship of the Water Quality Monitoring Council’s workgroups, which are composed of multiple state agencies, as well as private, non-profit, and tribal representatives. While this model of engagement continues to yield results for broad-based collaboration, decision-making, and the advancement of scientific standards, each workgroup nevertheless finds itself at a loss for a business model to sustain its ongoing technology needs. This shortcoming represents, in microcosm, a shared experience for state agencies and partners alike.

This presentation highlights the challenges and the opportunities for producing successful business models to support and sustain technology initiatives. During the recent Environmental Data Summit, a cross-section of professionals -- scientists, technologists, business representatives -- sought to address the lack of a viable business model. The team coalesced around certain observations and proposals which have in turn been incorporated into a white paper produced under the auspices of the Delta Stewardship Council.

The emerging “vision document” explores the connections between the state’s open-data mandates and its technology development projects, while making recommendations for advancement. If technology remains expensive, then what are the costs associated with not sharing data more robustly? A viable business model forms the connective tissue among many information gaps that would facilitate information infrastructure development to keep pace with public demand, agency needs, knowledge development, and government mandates.

Keywords: Sustainable Technology Initiatives
Session Title: Implementing the Delta Science Plan: Improving Science Capacity to Meet Current and Future Challenges
Session Time: Wednesday 8:20AM – 10:00AM Room 308-310

A Restoration Hub for the Delta – Better Tools and Process for Science Based Restoration

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Recently the Delta Restoration Network (DRN) has developed a proposal for a Restoration Hub that would be developed as a 3 year pilot effort. The Hub proposal was developed by the DRN to address the following concerns about current restoration planning: 1. We lack a broadly accepted landscape-scale restoration vision for restoration opportunity areas supported by conceptual and mechanistic models, 2. We lack a standing expert restoration design team to support timely property-scale restoration project planning, implement long-term restoration visions for restoration opportunity areas, and consider the Delta-wide effects of restoration projects, 3. We lack sufficient early engagement of the Delta community, and 4. We don't have sufficient modeling, data inventory, and synthesis tools to support information sharing, analysis, and adaptive management. The Hub is intended to be a place where the best available tools can be used to integrate data and models and work with subject experts and community members to inform restoration planning and result in projects with high ecological value, with the least possible impact to current land uses and within the confines of the flood protection system.

The approach has been to work collaboratively on the development of the Hub concept and to develop a broad coalition of supportive agencies and organizations to demonstrate the necessity of the Hub to potential service providers and funders. The Restoration Hub is the place where we will bring together the best available tools, 21st century technology, and a workflow process that ensures best available science and adaptive management are the cornerstones of an effective restoration program for the Delta.

Keywords: Restoration, Big Data, Workflow, Coalition, Science Based Adaptive Management
Session Title: Implementing the Delta Science Plan: Improving Science Capacity to Meet Current and Future Challenges
Session Time: Wednesday 8:20AM – 10:00AM Room 308-310

Rice in the Delta – The Potential to Mitigate Subsidence and Enhance Sustainability

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Subsidence threatens Sacramento – San Joaquin Delta sustainability, with implications on the Delta agricultural culture and viability, on the economies of the Delta and other California regions, and on security of California's water conveyance infrastructure. Rice potentially offers a viable agricultural alternative that is a regional solution for subsidence through its effect on peat biogeochemistry and on resulting oxidation rates. Reviewing agronomic, GHG emission and direct measurement data shows subsidence rates under rice essentially stop as compared to other cropping types. Strategic placement of rice throughout the Delta could stabilize levees and the risks to California's water supply. Current hypotheses that strategic rice placement on islands can decrease levee failure risks are being tested using standard tools for assessing Delta levee stability. For a significant impact, large-scale implementation of rice in the Delta would be needed. Transitioning to a Delta crop mosaic with a critical mass of rice needed to meaningfully address subsidence risks will result in a broad range of effects including agricultural, water quality, water hydrology, greenhouse gas emissions, and carbon cycling. The AFRI (Agriculture Food and Research Initiative) Rice project is a $5M National Institute of Food and Agriculture (NIFA) Climate Change and Water Resources grant funded project. Under the AFRI Rice project, peer reviewed findings to lab-scale studies to regional-scale assessments are being integrated to understand and prioritize the key drivers behind the different effects. These findings are being integrated into a regional Delta assessment and into the Delta Agricultural Production (DAP) and other economic tools to quantify local, regional and statewide economic costs and benefits. The project will provide an economic and mechanistic based framework for future land use decisions in the Delta with the goal of creating a more sustainable and beneficial future for the Delta and to improve water security for California.

Keywords: GHG, Subsidence, Levees, Hydrology, Water quality, economics, water security
Session Title: The AFRI Rice Project: Developing a Strategy for Rice in the Sacramento-San Joaquin Delta
Session Time: Wednesday 10:20AM – 12:00PM Room 308-310

The Influence of Soil Total Carbon on Yield and Nitrogen Uptake in Continuously Flooded Rice Paddy Soils Dominated by Peat

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Agriculture on peat soils has a well-documented negative impact on peat subsidence, leading to undesired environmental consequences. Rice cultivation shows potential to enable peat soils to remain agriculturally productive while reducing these environmental impacts. However, peat soils have unique fertility requirements that must be better understood for rice cultivation to be successful. Specifically, this study sought to quantify the amount of nitrogen supplied to a rice crop from peat mineralization across a wide range of soil organic carbon (SOC). A total of ten nitrogen rate trials over three seasons were established over a range of SOC from 2.5% to 23% in the Sacramento-San Joaquin Delta. Nitrogen fertilizer rates of 0, 40, 80, 120, and 160 kg N/ha were applied in each trial in a RCBD with four replicates. Additionally, 30 nitrogen-omission plots were established in 2013 to observe yield response outside of the rate trials across the range of SOC. Yield response to nitrogen application was greatest in the 2.5% and 23% SOC trials, with little to no yield response in the intermediate range of 10-15%. The nitrogen-omission plots mirrored this trend, with the greatest yields observed in the 10-15% SOC range and with lower nitrogen-omitted yields occurring in the 2.5% and the >23% SOC range. Aboveground nitrogen uptake was modeled as a function of SOC, showing the SOC range with maximum nitrogen uptake coincided with the SOC range with lowest observed yield response to added nitrogen. The estimated model coefficients agreed generally with previous work although greater background nitrogen variability was observed. These results suggest nitrogen fertilization of flooded peat soils may be unnecessary in certain ranges of SOC. Further study is needed to understand the mechanisms that result in the quantity of plant available nitrogen release from these soils during flooded conditions.

Keywords: rice, agriculture, peat soils, mineralization
Session Title: The AFRI Rice Project: Developing a Strategy for Rice in the Sacramento-San Joaquin Delta
Session Time: Wednesday 10:20AM – 12:00PM Room 308-310

Interannual Variation in CO_2 and CH_4 Fluxes from a Rice Paddy in the Sacramento-San Joaquin Delta, California

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The Sacramento-San Joaquin Delta was drained over a century ago for agriculture and human settlement and has since experienced subsidence rates that are among the highest in the world. To help capture carbon and reverse subsidence and there is growing interest in converting drained agricultural land-use types to flooded ecosystems such as rice paddies. Rice has been shown to be a viable crop for slowing subsidence in the Delta as the flooded status of these ecosystems inhibits peat oxidation. However, while rice can help reverse net carbon loss and subsidence, flooding also increases the emission of methane (CH_4). We measured continuous fluxes of carbon dioxide (CO_2) and CH_4 over a rice paddy in the Delta from April 2009 through April 2014 using the eddy covariance method to document how CO_2 and CH_4 fluxes vary interannually and to examine how environmental and management factors influence annual CO_2 and CH_4 budgets.

While the rice paddy was consistently an atmospheric sink for CO_2, annual CO_2 budgets were highly variable between years; net CO_2 sequestration ranged from 537 g C m^{-2} yr^{-1} in 2010 to 70 g C m^{-2} yr^{-1} in 2013. There were also considerable differences in CH_4 budgets between years, with the rice paddy releasing between 2.5 to 6.6 g C m^{-2} yr^{-1} as CH_4 throughout the study. Year to year differences in CO_2 and CH_4 budgets were due in part to variations in weather, but were also strongly influenced by differences in management practices between years (e.g. the timing of flooding/draining and planting/harvesting, discing versus plowing, and herbicide and fertilizer treatments). The results of this study can be used improve management of rice agriculture to maximize carbon uptake and minimize CH_4 emissions, which is critical to halting subsidence in the Delta and reducing greenhouse gas emissions from the region.

Keywords: Rice, Carbon fluxes, Methane, Greenhouse gas, Management, Eddy covariance
Session Title: The AFRI Rice Project: Developing a Strategy for Rice in the Sacramento-San Joaquin Delta
Session Time: Wednesday 10:20AM – 12:00PM Room 308-310

Hydrologic and Water Quality Effects of Varying Land- and Water-Management Strategies, Sacramento-San Joaquin Delta

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On Delta islands where organic soils predominate, ongoing subsidence results in increasing seepage, drainage volumes and drain-water constituent loads. To assess alternate land- and water-management strategies on Delta islands, we used hydrologic data and groundwater-flow and solute-transport modeling to answer questions about drainage-groundwater interactions, effects of drain-water DOC and salinity loads for business as usual and with alternate land- and water-management strategies. We considered various assemblages of cropping and land-use patterns that included rice and wetlands for carbon sequestration.

We determined hydraulic conductivity of island sediments, monitored groundwater levels, collected and analyzed ground- and drain-water samples, and measured drain flow. We used these data to construct a groundwater flow model for Twitchell Island. For the solute transport model, we developed dispersivity and diffusion coefficient values from laboratory experiments and the literature. We used the models to simulate different cropping and water-management practices. We simulated land-surface elevation changes using previously published subsidence and accretion models. Island groundwater levels and drainage volumes are influenced by varying recharge, channel water levels, and seepage through levees. Drainage loads are determined primarily drain flow and secondarily by mobilization of solutes from soil to groundwater and drain water.

Model results agreed well with measured water levels, drain flows, and DOC loads and concentrations. Under the business as usual scenario, continuing subsidence and sea level rise lead to increases in drainage DOC loads by about 20% by 2050. Model results also indicate that subsidence mitigation measures such as rice and wetlands can reduce organic-soil oxidation will reduce seepage, drain flow, and drain DOC loads, relative to business as usual.

Keywords: subsidence, water quality, sustainability, levees
Session Title: The AFRI Rice Project: Developing a Strategy for Rice in the Sacramento-San Joaquin Delta
Session Time: Wednesday 10:20AM – 12:00PM Room 308-310

Expanding Rice Farming in the Delta: Significance for GHG, Water Supply Reliability and Water Quality

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Conversion of selected areas in the Delta to rice farming has the potential to reduce net greenhouse gases (GHGs), improve Delta water quality, support through-Delta water conveyance, and support flood-protection of subsided lands. These outcomes achieve major policy goals of the State of California as set by AB32, the Porter-Cologne Water Quality and Clean Water acts, and the Delta Reform Act. Through the AFRI Delta Rice Project, our team is identifying feasible agronomic approaches to rice production in the subsided Delta that reduce net GHG production, halt ongoing land subsidence, improve levee stability, and reduce DOC and nutrient loading to Delta waters. We present a framework that uses the team's findings on the effects of rice production in order to articulate when and where rice could be deployed, and to what net gain. Now ending its third year, the AFRI team has identified the primary factors controlling GHG production, DOC and nutrient loading, subsidence rates, and levee stability associated with rice farming in the Delta. We combine these factors with spatial data on soils, topography, land management, and through-Delta conveyance to construct hypothetical models that use rice farming to optimize for each effect. With this framework, we will assess where conversion to rice production can enhance water conveyance security and protect Delta lands through reduced levee failure risk, and estimate the cumulative benefits to GHG emissions and Delta water quality. Results to-date indicate that conversion to rice production can offer demonstrable benefits across this range of societally valued outcomes. These findings feed directly into the economic assessment for the AFRI Delta Rice Project by helping to identify potential types and sources of subsidies suited to support rice where production alone does not cover all of the costs.

Keywords: Greenhouse gases, subsidence, conveyance, flood protection, water quality, regional scaling
Session Title: The AFRI Rice Project: Developing a Strategy for Rice in the Sacramento-San Joaquin Delta
Session Time: Wednesday 10:20AM – 12:00PM Room 308-310

Insights from the Inland Sea: The Hydrology and Management of the Yolo Bypass Floodplain

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This presentation is designed as an introduction to the Yolo Bypass, a leveed, 59,000-acre floodplain of the lower Sacramento River. It is a highly successful component of a flood control system that conveys floodwaters from several waterways to the Sacramento–San Joaquin Delta. Complete inundation of the floodplain results in a doubling of the wetted area of the Delta, creating an "inland sea" approximately 1/3 the size of San Francisco Bay. Lateral variability is also important as the unique flow and topography of the Bypass often result in incomplete mixing and the formation of spatially persistent tributary bands during high flow events. The historical record suggests that at least some of floodplain is seasonally inundated from Sacramento River and west-side tributaries in most years. Modeling results also demonstrate that relatively low flow events can result in substantial inundation as a result of the low elevation gradient of the floodplain. These patterns generate complex relationships between flow, surface area, and depth. The hydrology of the system is also influenced by land use in the basin including local water diversions, canals, weirs, road crossings, berms, and multiple habitat types such as agriculture, grasslands, managed wetlands, perennial channels, and ponds.

Keywords: Floodplain, hydrology, Delta, modeling, inundation
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 1:35PM – 3:15PM Room 308-310

Yolo Bypass as a Source of Delta Phytoplankton: Not Just a Legend of the Fall?

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The Yolo Bypass is the primary floodplain of the San Francisco Estuary, designed primarily as a flood-control system for the greater Sacramento Valley. Studies have historically focused on the benefits of the inundated floodplain habitat during the winter and spring months for fish and lower trophic levels. However, in the fall of 2011, and again in 2012, significant phytoplankton blooms occurred upstream of the confluence of the Sacramento and San Joaquin rivers. Substantial evidence from water isotopic studies and ongoing water quality monitoring within the region suggested that these phytoplankton blooms were supported in part by elevated fall agricultural drainage flows in the Yolo Bypass. Phytoplankton blooms that provide an essential base to the San Francisco Estuary food web have become increasingly rare in recent decades. This decline has been linked to decreases in both zooplankton and pelagic fish abundance. In fall of 2013, a multi-agency collaborative study with the Department of Water Resources, Central Valley Water Resources Control Board, Bureau of Reclamation, and University of California Davis investigated the spatial and temporal trends of phytoplankton, nutrients, flow and water quality conditions before, during, and after increased fall agricultural flows in the Yolo Bypass. The initial results from this study provide insight into the complexity of nutrient dynamics in the Yolo Bypass and the importance of possible flow thresholds in the transport and development of downstream phytoplankton blooms. Our hope is that continued investigation into the processes that facilitate increased fall phytoplankton biomass could yield management tools to benefit the Delta pelagic food web.

Keywords: Yolo Bypass, phytoplankton, flow, fall, agriculture, blooms, food web, pelagic
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 1:35PM – 3:15PM Room 308-310

Nutrient and Chlorophyll Concentrations in the Lower Yolo Bypass

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Nutrient and chlorophyll concentrations were monitored monthly in the lower Yolo Bypass for a year. Purpose of the monitoring was to describe chlorophyll concentrations prior to restoration and determine whether nutrients controlled primary production. The conceptual model was that algal production would primarily occur on the two shallow, flooded islands and be transported off-site in the surrounding deeper channels. A comparison of nutrient concentrations and the Redfield ratio suggested that nitrogen will limit primary production. Chlorophyll concentrations increased northward in both channels and flooded islands. Concentrations at the northern end of the Bypass were about 3 and 5 times greater in winter and summer than in the Sacramento River at Rio Vista. In summer, nitrogen concentrations were highest in Cache Slough and decreased northward on the flooded islands and adjoining channels. Very low nitrogen concentrations were measured in the northern portion of Liberty Island and surrounding channels. Amendment experiments confirmed that nitrogen limited accumulation of algal biomass. In contrast, in winter no consistent nitrogen gradient was observed and nitrogen limitation of algal biomass accumulation is not predicted to occur. The primary source of nitrogen in summer is from the Sacramento Regional Wastewater Treatment Plant (SRWTP) and is tidally dispersed north into the Bypass from Cache Slough. In contrast, in winter the nitrogen sources are from the SRWTP in the south and from the Cities of Davis and Woodland Wastewater Treatment Plants discharging down the Toe Drain from the north. Nitrogen from the two northern sources does not typically enter the Bypass in summer as flow in the Toe Drain is negative. Nitrogen limitation in the Bypass may be important as wetlands, such as are being proposed for the lower Yolo Bypass, are known to be strong denitrifiers and restoration may further decrease nitrogen concentrations and reduce primary production.

Keywords: Nitrogen, nitrogen limitation, chlorophyll, Liberty Island, Toe Drain
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 1:35PM – 3:15PM Room 308-310

Evaluation of Flow Thresholds and Their Effects on the Composition and Relative Abundance of Lower Trophic Biota in the Yolo Bypass, California, USA

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Previous work in the Yolo Bypass has demonstrated that providing river-floodplain habitat connectivity can quickly enhance production of lower trophic levels, and thus potentially benefit secondary consumers such as Chinook Salmon, *Oncorhynchus tshawytscha*. Despite the considerable amount of research in this area, there is still a lack of knowledge regarding the extent to which productivity in the Bypass influences downstream areas, although some research suggests that floodplain inundation represents one of the most effective approaches to improving primary productivity in the Bay-Delta Estuary. Studies in the Yolo Bypass suggest that the food web of the floodplain is much more productive than the adjacent Sacramento River, linking increases in productivity to the quantity of flow and hydrologic residence times in the Yolo Bypass. However, specific flow thresholds for enhanced lower trophic productivity have not yet been identified. We use data from a long-term study of the Yolo Bypass to explore the community composition of zooplankton and drift invertebrates in Yolo Bypass between 1999-2012. Those data will also be used to examine changes in the relative abundance of those taxa in relation to environmental conditions, as well as to test whether any specific flow thresholds exist (magnitude and duration of inundation), which result in enhanced productivity of lower trophic levels. The results from this study will provide further insight regarding Yolo Bypass food web ecology, as well as baseline monitoring information and guidance for future Yolo Bypass restoration projects.

Keywords: food web, primary productivity, floodplain, flow thresholds, Yolo Bypass
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 1:35PM – 3:15PM Room 308-310

You are What You Eat: Isotope Forensic Science to Track Floodplain Rearing on the Yolo Bypass

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Benefits of floodplain rearing for salmonids have been well documented, yet the population-level benefit in terms of increased survival during downstream migration and ocean residence remain unquantified. This is largely due to methodological challenges linking habitat-use in one life stage to long-term survival benefits. Here we explore whether differences in the floodplain food web relative to the riverine food web provide a unique "fingerprint" that could be used to identify individuals that spent a portion of their early life rearing on the Yolo Bypass. The phytoplankton in the water in the Yolo Bypass has been shown to have a uniquely lower sulfur isotope composition ($\delta^{34}S$) than phytoplankton in other water sources in rivers and the Delta, presumably because of rice farming providing a useful fingerprint for the base of the food web (Kendall, Bay-Delta Science Conference, 2010). Like carbon isotopes and unlike nitrogen isotopes, sulfur isotopes of organisms show minimal change with increasing food web position. Thus, isotopic differences at the base of the food web propagate up the trophic hierarchy from the water, to invertebrate prey, and into the muscle, and ear bone (otolith) protein of fishes feeding on that food web. We will present results on sulfur isotopes in prey items in the stomach, muscle, and fin tissue of archived juvenile salmon collected on the floodplain in 1998, relative to juveniles foraging in the mainstem Sacramento River. Results from this study will be discussed in the context of whether sulfur isotopes are a unique, temporally, and spatially robust marker functioning at the appropriate scales to characterize floodplain habitat use by juvenile fish. Sulfur isotopes are permanently recorded in otoliths and future work will investigate their use to reconstruct floodplain habitat use and residence time for different native fish species such as salmon, steelhead, sturgeon, and splittail.

Keywords: Sulfur isotopes, diet, floodplain, habitat use, tracer
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 1:35PM – 3:15PM Room 308-310

Telemetry Studies of Adult Chinook Salmon and White Sturgeon in the Yolo Bypass

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Given substantial evidence over nearly fifteen years for its benefits to native fishes during flooded periods, the Yolo Bypass has become the focus of interest in managing seasonally flooded habitat in the Delta. Adult fishes such as Chinook salmon (*Oncorhynchus tshawytscha*), sturgeon (*Ascipenser* spp.), and Sacramento splittail (*Pogonichthys macrolepidotus*) seasonally enter Yolo Bypass at its base, located north of Rio Vista. While splittail will spawn on the floodplain, the prevailing view is that the area acts like a giant "fish trap" for salmon and sturgeon en route to spawning areas on the upper Sacramento River; they are drawn into the floodplain's perennial channels following late fall or early winter flows with no exit from the Bypass at its upstream end. The Fremont Weir is located at the northern tip of the Bypass, and is only connected to the Sacramento River during brief periods of high flows. Hence, the Yolo Bypass represents one of the most serious passage barriers to migratory fishes in the Central Valley. However, beyond a general description of the timing and occurrence of large numbers of migrating Chinook salmon, sturgeon, splittail, and striped bass, remarkably little is known about what happens to these fish once they enter Yolo Bypass. How is the Bypass affecting fish positively, negatively, and/or neutrally? Which stimuli influence whether the fish choose to enter the Bypass or not, and whether they can get out if they choose? In an effort to address these questions, UC Davis and the California Department of Water Resources are currently conducting research on the way that native fishes use the Yolo Bypass for transport and habitat. We present here the results of telemetry studies on migrating adult Chinook salmon and white sturgeon between 2012 and 2014.

Keywords: floodplain, migration, telemetry, conservation, movement, behavior, sturgeon, chinook, salmon
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 3:35PM – 5:15PM Room 308-310

Who's There? Genetic Tools Reveal Habitat-use by Juvenile Chinook Salmon in the Yolo Bypass

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The Yolo Bypass provides critical floodplain habitat for a number of special status fishes, including the threatened and endangered populations of Central Valley Chinook salmon (*Oncorhynchus tshawytscha).* Therefore, the Yolo Bypass has been identified as a high restoration priority; however, we have a limited understanding of how the different populations of Chinook salmon use the habitat in the Yolo Bypass and how this compares to their habitat use in the mainstem of the Sacramento River. The major obstacle to an understanding of habitat-use has been an inability to accurately identify individual salmon to their run of origin. To address this shortcoming, we developed a new genetic panel of single nucleotide polymorphisms (SNPs) to identify Chinook to their run of origin. We then sampled juvenile Chinook found in the Yolo Bypass and the mainstem Sacramento River, applied our new SNP panel to identify them to their run of origin, and evaluated habitat use. We found differences in use of floodplain habitat among the different runs, which has implications for the management of the floodplain habitat in the Yolo bypass. Restoration plans should be developed in light of these results, considering which populations of Chinook juveniles are most likely to be affected by proposed actions. As our data collection occurred during drought years, this work should be continued in a long-term monitoring plan to compare habitat use of wet and dry years. Additionally, our newly developed panel of SNPs offers an exciting new tool for identifying both adult and juvenile Chinook salmon and will greatly improve our ability to conduct informative field studies throughout the Bay-Delta system and Central Valley.

Keywords: Chinook, salmon, genetics, SNPs, assignment, run-type, habitat use, floodplain, tools
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 3:35PM – 5:15PM Room 308-310

Managing Floodplain Productivity: Slow it Down, Spread it Out, Grow 'Em Up

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Each winter and spring broad, shallow wetlands were inundated as the rivers covered the floodplains, of the pre-development Central Valley. The Valley has been engineered to drain efficiently and rapidly, shedding high volumes of storm water quickly through incised, armored flood channels. This rapid high-volume drainage system is the antithesis of the historic prolonged, broad and shallow seasonal inundation of the predevelopment flood pattern. Levees and drainage of marshes and floodplains diminished seasonal primary productivity and may literally "starve" rivers, by interrupting the flood processes that create seasonal engines of trophic productivity.

The Agricultural Floodplain Habitat Investigation at Knaggs Ranch on Yolo Bypass, is demonstrating that ***mimicking*** historical floodplain processes – spreading water out over the winter rice fields which replaced many marshes and floodplains – can still produce phenomenally productive aquatic food webs. Which in turn can support rapid growth and improved body condition of juvenile salmon.

The first two years of the project demonstrated that winter-flooded rice fields can provide high quality floodplain rearing habitat, as evidenced by the fastest growth rates of juvenile Chinook salmon ever recorded in the Central Valley. Two elements were added in 2014; varying field depth and volition passage (fish were allowed to leave the fields on their own at any time). Results were once again encouraging: growth was similarly rapid but survival was substantially increased.

The project provides evidence when native fish and bird populations are exposed to a system they " recognize" – habitats similar to those under which they evolved and to which they are adapted – they respond quickly and favorably. A better understanding of how to manage floodplain dynamics may allow integration of "engines" of natural productivity into the design and operations of a central valley water infrastructure built in era before ecological function was a system objective.

Keywords: Knaggs, floodplains, reconciliation, salmon, rice
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 3:35PM – 5:15PM Room 308-310

Depth and Flow: Do Juvenile Salmon Demonstrate Preference on a Managed Agricultural Floodplain?

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The 59,000 acre Yolo Bypass is an engineered floodplain managed for agriculture, wildlife and flood control. Several studies have documented benefits of the Yolo Bypass floodplain to juvenile salmonids, making it a target area for restoration. However, design parameters that may maximize benefits to native fishes in floodplain and wetland restoration projects (e.g., how deep? how much water?), are often unknown, particularly in an agricultural context. Since 2012, the Knaggs Ranch Experimental Agricultural Floodplain Investigation has examined salmon growth, survival, and behavior on an agricultural parcel that is farmed for rice during the spring and summer. In 2014, we investigated behavioral associations of juvenile salmon in relation to various water depths and proximity to inflow, as part of the larger Knaggs Ranch investigation.

A 0.35-acre experimental field was constructed with three enclosed sections, each with three depth treatments (18”, 30”, 42”) arranged in varying sequences relative to inflow (upstream, midstream, downstream). Passive integrated transponder (PIT) tag detection antennae were placed in every depth panel (9 total). 149 juvenile hatchery salmon between 58 mm and 75 mm were implanted with 12 mm PIT tags and released in the experimental field. During the 2-week experimental period, there were approximately 3.8 million PIT tag detections. Survival and growth rate across all enclosures was very high (95% and 1.15 mm/d, respectively). Results indicate that both depth and position relative to inflow influenced where individuals spent the most time, with fish preferring deeper areas closer to inflow. These results can inform the design of floodplain restoration projects and management strategies so they may maximize benefits to juvenile salmon based on behavioral preferences in the floodplain landscape.

Keywords: floodplain, wetlands, Yolo Bypass, salmonids, habitat, rearing, behavior, restoration, management
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 3:35PM – 5:15PM Room 308-310

Invertebrate Abundance and Colonization Pathways on a Managed Floodplain in the Yolo Bypass

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Evidence from the Yolo Bypass suggests that agricultural floodplains provide a valuable seasonal winter habitat for juvenile Chinook salmon. As part of a managed inundation study ("Knaggs project") in the northern Yolo Bypass rice fields, we investigated the trophic resources available to juvenile Chinook salmon. Specifically, we examined the relative contribution of soil and drift invertebrates to the invertebrate community across three agricultural habitat types: stubble, fallow, and disked. Although soil emergence was an important colonization pathway in our study, drift was the main contributor to the invertebrate community in the experimental floodplain. Additionally, soil emergent invertebrate abundance was positively influenced by agricultural land use with densities greater than 2,400 individuals/m^2 in rice stubble and fallow fields. However, disking decreased abundances to less than 1,500 individuals/m^2. The abundance and diversity of invertebrates that colonized via drift did not significantly differ between habitat types, but produced abundant trophic resources for rearing Chinook salmon during experimental flooding with invertebrate densities greater than 150,000 individuals /m^3. In particular, the main food resource for juvenile Chinook salmon, *Daphnia pulex,* had abundances ranging from 2,300 individuals/m^3 in the beginning of the study period to greater than 51,900 individuals/m^3 at the end of six weeks. As drift was the most significant colonization pathway in our study, it is important to assess the invertebrate community and abundance within water used to artificially inundate managed floodplains.

Keywords: Floodplains, Zooplankton, Chinook salmon, Yolo Bypass, Agriculture
Session Title: Progress in Floodplain Ecology: Lessons from Yolo Bypass
Session Time: Wednesday 3:35PM – 5:15PM Room 308-310

Thirty-Five Years of Fish Studies in Suisun Marsh: Perspectives and Animations

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Suisun Marsh is a key part of the San Francisco Estuary. Thirty-five years of monthly trawling and seining for fish at numerous locations in the Marsh has established its importance as a highly productive area for fish and invertebrates. We examine some of our complex findings with both conventional graphics and data animations. Over 60 species of fishes and macroinvertebrates have been collected, and data show that native and non-native species populations mostly follow similar trends. Abundance of most species is driven by young-of-year which show large variability from year to year in quantity, timing, and location, as illustrated by data from the most abundant native species in the Marsh, Sacramento splittail. Trends in two of the Pelagic Organism Decline species show different patterns from those in the rest of the estuary. The Suisun Marsh study is a long-term monitoring and research program that is unusual because of its focus on fish assemblages from its inception. It has been a major source of new information on estuarine fishes and their relationship to a changing environment.

Keywords: Suisun, fish, splittail, pelagic organism, decline, animation, long-term monitoring
Session Title: Suisun Marsh and the Arc: New Findings on Tidal Marsh Fishes
Session Time: Wednesday 8:20AM – 10:00AM Room 311-313

Fishes of Suisun Marsh: Trends and Connectivity

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Problem: The 50+ species of fish in Suisun Marsh show considerable variability in populations among years and places, a phenomenon poorly understood prior to this study. Migratory fishes, such as splittail, seemed to show the strong influence of outside factors, such as river flow.

Approach: We documented the abundance of fishes in trawls and seines monthly for 35 years. Otoliths were removed from splittail for microchemistry analysis to determine the success of spawning inside and outside the marsh.

Results: Populations of native and alien species show some concordance; both declined during severe drought. Species that spawned outside the marsh, such as splittail and striped bass, showed response to both outside and inside factors. Otolith analysis revealed splittail spawned both on floodplains, as expected, and in brackish water. The ability to spawn in brackish water bolsters the population during extended droughts.

Conclusions: Suisun Marsh has a novel fish assemblage with fish abundance influenced by conditions both inside and outside the marsh. Abundant native fishes, such as splittail, have adaptations that allow them to persist despite alien species and severe habitat alteration.

Keywords: Suisun Marsh, fish assemblage, splittail, otolith
Session Title: Suisun Marsh and the Arc: New Findings on Tidal Marsh Fishes
Session Time: Wednesday 8:20AM – 10:00AM Room 311-313

Fishes of the North Delta: Trophic Pathways & Habitat Use

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***Problem*:** The Cache Slough Complex in the Sacramento-San Joaquin Delta is characterized by high fish species diversity and a diversity of habitat. Each slough within the Cache Slough Complex has unique habitat characteristics, and a unique community of native and nonnative fishes. However, little is understood about interactions between these fish species, the role that these fish play in local food webs, and their use of differing habitats.

***Approach*:** In order to address this deficiency we used a combination of stable isotope analysis and targeted fine-scale habitat sampling to evaluate local food webs and fish communities.

***Results*:** Our analysis of food web structure has demonstrated the existence of multiple trophic pathways in various sites within the Cache Slough Complex. Notably, there are strong differences in trophic structure between Cache and Lindsey sloughs and their tributaries. Differences in carbon sources and nitrogen enrichment suggest the importance of differing pathways to native and nonnative fishes. Sampling of fine-scale habitats has provided insight into habitat preferences of fish and invertebrates. Native and nonnative benthic fish and large invertebrates show significant differences in substrate and vegetation preference, consistent across regions, including both the North Delta and Suisun Marsh.

***Conclusions*:** Together, these conclusions provide insight into the importance of physical and chemical habitat in supporting various trophic pathways and differing fish communities.

Keywords: Food web, habitat preference, fish communities
Session Title: Suisun Marsh and the Arc: New Findings on Tidal Marsh Fishes
Session Time: Wednesday 8:20AM – 10:00AM Room 311-313

Hydrodynamics and Pelagic Productivity: Suisun Marsh and Cache Slough

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Problem: The interaction between pelagic productivity and hydrodynamic transport are poorly understood in the Sacramento-San Joaquin Delta.

Approach: Empirical data on chlorophyll-a concentration and zooplankton abundance are compared to modeled residence time distributions in Suisun Marsh and the Cache Slough Complex.

Results: Low residence time habitat is characterized by more stable temperatures and DO values, low levels of chlorophyll-a (mg/L), and low zooplankton density. High residence time habitat is characterized by variable temperatures and DO values, high levels of chlorophyll-a, and high zooplankton density. Unique pointsources in certain areas also affect *in situ* chlorophyll-a and zooplankton production. Hydrodynamic interactions along the slough gradient result in the dispersal and concentration of production.

Conclusions: Combining empirical data with modeling provides an elegant method for describing lower trophic food-web dynamics in channelized, tidal environments. Comparing sites from different regions contrasts the effects of adjacent land management practices, channel morphology and hydrodynamics, and nutrient supply on *in situ* channel food web production. This approach has the potential to guide the understanding of effects of proposed restoration sites on pelagic productivity and the conditions under which hot spots of production may occur.

Keywords: Hydrodynamic modeling, Residence-time, Productivity, Food-web, Chlorophyll-a, Phytoplankton, Zooplankton, Suisun, North-Delta
Session Title: Suisun Marsh and the Arc: New Findings on Tidal Marsh Fishes
Session Time: Wednesday 8:20AM – 10:00AM Room 311-313

Passive and Active Restoration of Tidal Habitat in Suisun Marsh

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Problem: The Suisun Marsh plan mandates that 5,000-7,000 acres of Suisun marsh will be restored to tidal marsh in the next 30 years, but little is known of the effectiveness of restoration design for native fishes in the region.

Approach: We compared fish and macro-invertebrates in Blacklock tidal marsh restoration site with surrounding tidal sloughs and a managed pond that is operated to enhance waterfowl hunting conditions.

Results: We found that Blacklock has lower productivity, fish abundance, and fish diversity than an adjacent tidal slough and a more intensively managed pond. This is most likely due to the high tidal exchange and low residence time within the restoration site.

Conclusions/Relevance: Comparing open restoring sites to managed wetlands provides an opportunity to understand potential endpoints of future restoration projects. It is imperative to evaluate both benefits and losses of returning managed wetlands to tidal marsh, and choose sites and strategies which will promote desirable outcomes. In the future, managed wetlands should be constructed with features that support adaptive management through effective experimental design.

Keywords: restoration, wetlands, managed wetlands, fish, pelagic production, adaptive management
Session Title: Suisun Marsh and the Arc: New Findings on Tidal Marsh Fishes
Session Time: Wednesday 8:20AM – 10:00AM Room 311-313

The Baylands and Climate Change: What We Can Do

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The Baylands Ecosystem Habitat Goals, produced in 1999 by a team of more than 100 scientists, managers, and regulators, was a science synthesis that created a vision of what would be needed to restore functioning estuarine ecosystems in San Francisco Bay. Guidance from the Goals report contributed to the restoration of 7,000 acres of tidal marsh by 2009, with 30,000 more acres acquired and permitted for restoration in the coming decades. An Update to the science and recommendations of the Baylands Goals is underway that addresses climate-change projections and other drivers of long-term change to the end of this century. Using future scenarios based on climate-change analyses and marsh-accretion models, the Update considers future trajectories of habitat evolution and shoreline migration, the transition zone between Baylands and terrestrial areas, the connection between the Bay and the Baylands, risk to wildlife populations, and carbon accounting over time. Landscape visions for how to conserve and restore Baylands habitats, the processes that maintain their resilience, and the ecological functions they provide are given for the Bay region and its subregions. Recommended actions to achieve these visions are detailed at the regional, subregional, and local scales.

Keywords: Baylands, landscape-scale planning, ecosystem restoration, climate change, applied science
Session Title: Design and Management of Resilient Landscapes: The Baylands Goals Update
Session Time: Wednesday 10:20AM – 12:00PM Room 311-313

Baylands Habitat Evolution: How Sea Level Rise and Other Drivers of Change May Change the Bay

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Our understanding of tidal marsh processes in the Bay continues to advance as does our awareness of the interconnectedness of habitats. Over the next century climate change and other drivers, such as sediment and salinity, will create a more dynamic landscape with shifts in location and nature of these habitats. This raises two questions: how are Baylands habitats likely to evolve and what management actions can we take to guide their evolution in the near- and long-term. This paper summarizes how, through a collaborative process involving many Bay scientists, the 2014 Baylands Goals Update (BEHGU) starts to address these two key questions.

Presently, tidal Baylands habitats appear to be accumulating enough sediment to keep pace with near-term projections of sea-level rise. The future of these habitats depends significantly on the actual rate of sea level rise and the availability of suspended sediments in the Bay. However, greater uncertainty on their fate occurs towards the end of the next century. Similarly, the functioning of diked Baylands will be most impacted as sea level rise accelerates later in the century. Continued monitoring remains key to understanding the Baylands response to climate change, evaluating ongoing changes, and determining the accuracy of marsh modeling efforts

We find despite the numerous challenges, there are still options available for planners and land managers to adapt to these changes. Specifically we recommend a strong sense of the management action timeline, linking planning and implementation to physical thresholds; multi-objective and multi-habitat projects that can maximize cumulative benefits; immediate implementation of pilot studies to explore and validate recommendations; and flexibility from the regulatory community to allow for new and creative solutions which increase the resilience of Baylands habitat and function while protecting the ecological values of the Bay.

Keywords: BEHGU, Baylands Goals Update, climate change, wetlands
Session Title: Design and Management of Resilient Landscapes: The Baylands Goals Update
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Managing for Uncertainty--Maximizing Resilience of Plant and Animal Populations in the Face of Climate Change and Other Stressors

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Bayland plants and animals have evolved in California's variable climate, in a landscape marked by dramatic changes of salinity and sea level. Human activities have severely reduced natural habitats and remnant habitat is fragmented and degraded. Simultaneously, wildlife populations have been subject to multiple stressors such as contaminants, invasive species, and human-associated predators. Thus, the capacity of wildlife to adaptively respond to stressors is already limited, and will be reduced more in the future because: (i) climate change, and human response to climate change will alter habitat at an accelerated pace, and (ii) extreme events that affect wildlife, such as droughts, flooding, and storms, are expected to become more frequent and severe. We summarize insights gained and recommendations compiled from the efforts of the Wildlife Workgroup of the Bayland Ecosystem Goals Habitat Update Project, which address two principal questions, (1) How will populations of plants and animals in bayland habitats be affected by climate change? And (2) Which management actions will be most effective in restoring or protecting population health given multiple impacts?

The foundation of this synthesis is 32 case studies written by bayland scientists and that span a wide variety of taxa, including plants, invertebrates, and vertebrates, found in aquatic, wetland, and terrestrial habitats of the San Francisco Estuary baylands. To effectively address the challenges posed by new sediment, inundation, storm, and salinity regimes, we suggest how to promote robust, interconnected, and resilient populations. Maximizing resilience entails long-term planning of habitat protection and short-term responses to catastrophic events. Connecting habitats and reducing barriers for mobile species and facilitating recolonization by translocating less mobile populations are examples of such responses. Active and anticipatory management actions are needed to allow wildlife to weather the landscape-level changes and intensified stresses that climate change will bring to the estuary.

Keywords: Climate change, population resilience, wildlife, management recommendations, extreme events
Session Title: Design and Management of Resilient Landscapes: The Baylands Goals Update
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The Role of Carbon in the Development and Management of the Baylands

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Carbon accumulation from local plant production is an important process contributing to the maintenance of elevation and sustainability of tidal wetlands. In addition, carbon accumulation and greenhouse gas (GHG) emissions (carbon dioxide, methane, and nitrous oxide) affect overall climate regulation. However, little consideration has been given to these processes, and much remains to be learned concerning the past, present and historic role of carbon dynamics and GHG emissions for tidal wetland development and management. We reviewed available data to address these issues as part of the 2014 Baylands Goals Update (BEHGU). Based on our analysis of the area and elevation of diked and drained wetlands, approximately 1.2 million metric tons of carbon has been lost from former Bayland wetlands since diking and drainage occurred. Currently tidal wetlands sequester greater carbon per unit area than most ecosystems, with 14,560 metric tons of carbon sequestered annually across all tidal wetlands in the Estuary. Organic-rich soils in diked brackish marshes are likely to continue releasing carbon dioxide, while more mineral-rich soils in diked salt marshes are probably depleted of oxidizable carbon. Data are lacking to estimate emissions of carbon dioxide and other GHGs from diked areas or current tidal wetlands; however, sulfate likely limits methane emissions in high salinity wetlands. No data are available to evaluate nitrous emissions across the Baylands. Potentially, GHG reductions could be attained by reducing the extent of impounded freshwater behind barriers in Baylands, as well as recognizing the benefits of reducing nitrogen loading to coastal waters. The restoration of tidal wetlands within the region will result in increased soil carbon sequestration, and considering the salinity gradient across the estuary will likely result in the net removal of greenhouse gases. Improved quantification of on-going GHG fluxes across the landscape would be helpful to inform management decisions.

Keywords: BEHGU, Baylands Goals Update, climate change, wetlands, carbon sequestration
Session Title: Design and Management of Resilient Landscapes: The Baylands Goals Update
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Connection and Transgression: Designing a Dynamic Upland-Estuarine Transition Zone at Rush Ranch

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Accelerating rates of sea level rise in the San Francisco Estuary are challenging wetland restoration scientists and engineers to anticipate and plan for the gradual transgression of tidal habitats over adjacent upland areas. Without transgression, tidal wetlands in many locations throughout the San Francisco Estuary are anticipated to drown over the next 100 years, severely impacting ecological function and further restricting the distribution of habitats for special-status plants, fish, and wildlife. In many locations, the potential for estuarine transgression is constrained by incompatible land use practices, transportation and utility infrastructure, the predominance of non-native upland plant communities, and disconnection between fluvial and tidal processes. We developed and applied innovative science-based approaches to these constraints in order to design three wetland restoration projects at Rush Ranch in Suisun Marsh, which contains the largest remaining extents of tidal brackish marsh within the Estuary. These restoration approaches focus on the physical and ecological mechanics of habitat transgression, with a particular emphasis on fostering (1) native transitional plant communities that often include regionally rare and special-status species, and (2) sediment transport within and between fluvial and tidal environments. The implementation of these designs will serve as an emerging pilot test of the anticipated recommendations of the Baylands Ecosystem Habitat Goals Update (BEHGU) Project, and are expected to further inform wetland restoration efforts upstream in the Sacramento-San Joaquin Delta. These and related strategies are necessary to encourage the long-term sustainability of tidal habitats throughout the entire Estuary, especially in the face of climate change and reduced Estuary-wide sediment supply.

Keywords: BEHGU, transition zone, tidal wetlands, uplands, habitats, restoration, transgression, estuarine
Session Title: Design and Management of Resilient Landscapes: The Baylands Goals Update
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Experimental Adaptation Pilot Projects: Results to Date from Living Shoreline Reefs, Active Tidal Marsh Revegetation, and High Tide Refuge Island Construction

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The Coastal Conservancy and our partners are implementing several experimental pilot climate change adaptation projects to test specific approaches and methods in San Francisco Bay. There is a critical need to get started early on pilot projects which test new integrative design concepts and adaptive approaches, in order to gain knowledge and scale efforts into larger projects to achieve habitat results that may better facilitate resilience to future climate changes. These pilot projects have been thoughtfully designed in a collaborative approach within a strong scientific framework, and include frequent monitoring to assess outcomes and to compare replicated designs across a variety of sites and conditions. In 2011, the Conservancy and USFWS established a five-year program to rapidly improve habitat for California clapper rail (*Rallus longirostris obsoletus*) in tidal marshes of the San Francisco Estuary. Program components include constructing high tide refuge islands and rapid intensive revegetation with the goal of rapidly enhancing cover, nesting, and high tide refuge habitat for rails. In 2012, the Conservancy constructed the SF Bay Living Shorelines Project, a multi-objective habitat restoration pilot project with the overarching goal to create biologically rich and diverse subtidal and low intertidal habitats, including eelgrass and oyster reefs, that is resilient to changing environmental conditions. Habitat features such as these all have the potential to achieve dual biological and physical goals: enhancing critical habitat features and function, while also positively influencing physical processes (such as waves and sediment transport) that determine shoreline morphology and baylands health. This presentation will focus on sharing key components of adaptation designs, preliminary results to date, permitting considerations, and lessons learned that can be applied to additional adaptation planning efforts.

Keywords: Coastal Conservancy, experimentation, adaptation, revegetation, high tide, refugia, living shorelines
Session Title: Design and Management of Resilient Landscapes: Implementation and Monitoring
Session Time: Wednesday 1:35PM – 3:15PM Room 311-313

Addressing Climate Change in the South Bay Salt Pond Restoration Project

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The South Bay Salt Pond Restoration Project (www.southbayrestoration.org) is the largest tidal wetland restoration project on the West Coast. When complete, the project will restore 15,100 acres of former industrial salt ponds to a rich mosaic of tidal wetlands and other habitats. San Francisco Bay has lost an estimated 85 percent of its historic wetlands due to fill or other alterations. This dramatic decline in tidal marsh habitats has caused populations of marsh-dependent fish and wildlife to dwindle. It has also decreased water quality and increased local flood risks.

The highly urbanized setting of San Francisco Bay provides unique challenges for large-scale estuarine restoration, especially in the face of new threats such as accelerated sea level rise. Restoration of the South Bay salt ponds provides an opportunity to begin to reverse past trends of habitat degredation by improving the health of San Francisco Bay, as well as becoming part of a resilient shoreline protection portfolio for Bay-side communities. This presentation will examine the use of an adaptive management framework to achieve significant short-term success, while remaining viable in the long-term. This presentation will explore some of the innovative approaches to address climate change in tidal marsh restoration that are sometimes in conflict with current regulatory policies.

Keywords: salt pond restoration, BEHGU, Baylands Goals Update, wetlands
Session Title: Design and Management of Resilient Landscapes: Implementation and Monitoring
Session Time: Wednesday 1:35PM – 3:15PM Room 311-313

San Francisco Bayshores: Patterns of Transformation, Migration, and Resilience

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The Baylands Habitat Goals Project provided a science-based vision for the distribution and abundance of baylands needed to achieve critically important ecosystem services for San Francisco Bay. Achieving this vision will require revising conservation strategies based on new understanding of the likely responses of the baylands to climate change, especially sea level rise. While there has been substantial research focused on the natural processes that create and maintain the baylands themselves, there has been less research about the various bayland interfaces most sensitive to changing sea levels, namely the foremarsh (Bay-marsh transition zone), the upland transition along the backmarsh (estuarine-terrestrial transition zone or "T-zone"), and the head of tide in creeks and rivers that flow through baylands (estuary-riverine transition zone). The 2014 update of the Baylands Goals Project recommends strategies to restore and manage these interfaces in the context of sea level rise. Here, we present findings from regional studies and local pilot projects that inform and test some of these strategies.

We find that the form and function of these interfaces between baylands and adjacent areas are strongly controlled by local hydrogeomorphic setting. Local foremarsh evolution is strongly influenced by suspended sediment supply and the presence of sediment trapping features (e.g., jetties and headlands). The T-zone varies in width depending on the amounts of terrestrial runoff, the width of the adjoining marsh, and the steepness of adjacent uplands. The head of tide position around the Bay is driven by local channel gradient and engineered channel crossings (e.g., roadways, and sewerage) that constrain upstream tidal inundation extent. Early implementation projects show how this information about physical drivers should translate into restoration design. Taken together, these findings provide a foundation for developing restoration priorities and site-appropriate, resilient bayland conservation strategies.

Keywords: baylands, transition zones, resilience
Session Title: Design and Management of Resilient Landscapes: Implementation and Monitoring
Session Time: Wednesday 1:35PM – 3:15PM Room 311-313

Delta Landscape Metrics: Creating a Spatial Framework to Inform Restoration Planning

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The Delta was a 365,000 acre freshwater inland delta located in the middle of the state until the early 1800s. Since then over 97% of that marsh has been converted to other land use, and the remaining marsh fragments are small and isolated. With the native biological communities of the Delta now in crisis, plans for extensive ecosystem restoration are underway. While policy-makers and managers recognize the need to accomplish ecosystem restoration at a landscape scale in the Delta, we have relatively little information about how "the pieces should fit together" to create a resilient future landscape. Understanding the inherent physical and biological processes that maintain the landforms and their habitats and enable resilience will be critical to success.

We will present mid-project findings from the first detailed landscape analysis of Delta habitat change. We have synthesized historical and contemporary data sets to quantify and understand the Delta's transformation from the perspective of life-history support for native wildlife and other key ecological functions. These landscape metrics provide a new level of understanding for quantification of change, spatial and temporal variation in processes and functions, and regional vision for future restoration opportunities.

Keywords: Landscape Ecology, Restoration Planning, Resilience, Spatial Metrics, Ecosystem Management
Session Title: Design and Management of Resilient Landscapes: Implementation and Monitoring
Session Time: Wednesday 1:35PM – 3:15PM Room 311-313

Framework to Integrate Compliance and Effectiveness Monitoring for Water Quality and Habitat Conservation Plans

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Plans for water quality protection and habitat conservation need to be coordinated for their consistency and to share costs for monitoring and reporting. The CA Water Quality Monitoring Council has endorsed the Wetland and Riparian Area Monitoring Plan (WRAMP) as a framework to define data needed for regulatory and management decisions affecting water quality. WRAMP guides development of tools to meet these needs:

- “CARI” (CA Aquatic Resource Inventory) for comprehensive mapping of surface waters;
- "S&T" (Status and Trends) program plan for assessing net change in wetland acres;
- “Project Tracker” for mapping and sharing information about restoration and mitigation projects;
- “Online 401” for web-based application and tracking of CWA Section 401 certifications;
- “RipZET” for estimating the extent of riparian areas based on their needed functions;
- “CRAM” (CA Rapid Assessment Method for wetlands and streams),
- “Landscape Profile Tool” to summarize environmental information for user-defined landscapes;
- “EcoAtlas” for visualizing and sharing environmental data.

The WRAMP toolset can inform project proponents and regulators alike about avoiding, minimizing, and mitigating impacts to aquatic resources as directed by the US Clean Water Act and the CA Water Quality Control Act. The tools have been piloted in multiple eco-regions and reviewed by technical staff of targeted agencies, notably the State Water Resources Control Board, US Army Corps of Engineers, and US EPA. The tools meet the essential requirement to account for cumulative effects of implementation actions at the landscape scale.

The suitability of these tools for tracking and evaluating efforts to implement federal and state habitat conservation plans is being explored through the Placer County Conservation Plan. The expectation is that, with integration of wildlife habitat types and wildlife data into the toolset, WRAMP can help increase consistency in compliance and effectiveness monitoring and reporting across water quality and habitat conservation plans.

Keywords: monitoring, water quality, habitat conservation
Session Title: Design and Management of Resilient Landscapes: Implementation and Monitoring
Session Time: Wednesday 1:35PM – 3:15PM Room 311-313

Aligning Policy, Regulation and Management with Habitat and Community Resilience Goals in the Bay and Delta (Moderator: Matt Gerhart)

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This facilitated panel session will explore the ideas from the earlier special oral sessions through the lens of policy, regulation and management, with an eye towards upcoming challenges and changes that will be needed to develop new solutions to climate change. The Bay Delta estuary will be dramatically affected by climates change as seas rise, sediment declines, runoff to the Delta from the Sierra changes, water temperatures rise, and water demands change. Strategies in the form of Recovery Plans, goals projects, laws and policies, or historical ecologies serve as entry points for initiating large scale conservation efforts. Identification of conservation objectives and what is possible to achieve in the context of past landscape alteration and future change are critical in developing effective resilience goals. The resolution of these issues at the landscape, community and project scales create the need for innovative robust planning, policy and implementation approaches.

Each panelist will begin with a ten minute statement providing their viewpoint on the challenges presented for long term management of the estuary in a climate change context. Panelists will then respond to “popcorn” style questioning via the moderator and audience regarding key issues. Topics and questions to be addressed will include the changes needed in adaptive management of resource projects; funding structures supporting future investments in restoration and infrastructure; integration of planning between and across the bay and delta; how to integrate habitat restoration with community protection or redevelopment in multi-benefit adaptation strategies; evolving water management and necessary infrastructure investments in a rapidly changing Delta; challenges facing us in watershed and sediment management, and strategies for allowing the transmigration of habitats and species. Panelists are experts on a range of planning, policy, funding and regulatory concerns across both the Bay and the Delta.

Keywords: Resilience, Climate Change, Sea Level Rise, Landscape Scale Policy
Session Title: Design and Management of Resilient Landscapes: Policy Panel Discussion
Session Time: Wednesday 3:35PM – 5:15PM Room 311-313

North Delta Hydrodynamics from a Fish Perspective

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Juvenile salmon, and in fact all organisms that reside in the water column (i.e., pelagic), swim within a reference frame that moves with the water—the Lagrangian reference frame. Yet we typically characterize hydrodynamics from an Eulerian, fixed site perspective. In river deltas and estuaries, transport within the spatial domain can be quite complex, creating a divergence between the Eulerian and Lagrangian representations. The network of canals that comprise the Sacramento -- San Joaquin Delta offer an array of possible migration routes, and thus a great deal of travel time and distance variation within the system. These concepts are not limited to fish but apply equally well to anything that is moving with the water, such as abiotic constituents like suspended sediment, nutrients, and pollutants.

We will discuss results obtained from numerical hydrodynamic model simulations in RMASim, and particle tracking methods, where we have characterized transport in the north Delta from a pelagic fish (Lagrangian) perspective, focusing on the out-migration of juvenile salmon from the Sacramento River watershed. Comparisons of the metrics developed from the particle tracking study will allow us to directly assess the impacts of changes in the Lagrangian environment. Additionally, this study provides the hydrodynamic baseline prior to implementation of any significant changes proposed by Bay Delta Conservation Plan (BDCP). Accordingly, the metrics developed as a result of this study could be used to quantify the effect of changes from BDCP actions on the hydrodynamics that out-migrants experience as they traverse the north Delta.

Keywords: particle tracking, hydrodynamics, modeling, outmigration, survival
Session Title: Connecting Models with Behavior
Session Time: Wednesday 8:20AM – 10:00AM Room 314

Estimating Habitat Based Movement and Mortality of Winter-Run Chinook in the Central Valley

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Management of the Sacramento River and San Francisco Estuary requires models that can reflect population responses to alternative actions, such as timing of water releases, exports, and habitat restoration. We developed a population life cycle model that is sensitive to management variables in both the aquatic and marine stages of the life cycle. Freshwater hydrologic variables, such as Sacramento River flow and exports, and habitat characteristics such as channel morphology and tidal marsh inundation affect the survival and movement rates of juveniles rearing in river, floodplain (Yolo bypass), delta, and bay habitats. Similarly, marine variables such as ocean productivity and harvest affect the survival of ocean life history stages. The general model structure runs on a monthly time step and provides a rich set of rearing options as a function of hydrologic decisions that affect flow and habitat availability, while also accounting for the effect of ocean variability. To apply the model to winter-run Chinook we estimated the coefficients in a Bayesian statistical framework. The model predictions of abundance were compared to observed abundances (adult escapement and juvenile abundance at Red Bluff Diversion Dam, Knights Landing, and Chipps Island). Furthermore, CWT study results (Newman 2003) were used as informative priors on survival rates of juveniles in the river, floodplain, and delta habitats. Modeling results from the first version indicated that winter-run habitat use is primarily in the river and to a lesser degree delta and floodplain habitats with some variability in timing among years. Future work on the second version will incorporate additional survival information (e.g., derived Particle Tracking Model outputs) and temperature relationships to reflect proposed actions and reasonable alternatives in the BDCP and OCAP decision-making processes.

Keywords: Life Cycle Model, Bayesian Estimation, Winter-Run Chinook, Movement
Session Title: Connecting Models with Behavior
Session Time: Wednesday 8:20AM – 10:00AM Room 314

How Do Habitat Restoration, Flow, and Temperature Affect Salmon and Steelhead Populations? Conclusions from a Based Model

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Predicting the benefits to salmon and steelhead of channel restoration or changes in flow and temperature regime is a critical problem for project planning and evaluation. This problem is practically impossible to address using only field studies or simple population models, so our approach was to develop inSALMO, an individual-based simulation model. InSALMO represents stream habitat as a series of reaches, each made up of cells varying in depth, velocity, and several cover types. Salmon are represented from the arrival of adults at spawning streams through spawning, egg incubation, juvenile rearing, and outmigration. We applied inSALMO to 17 reaches of Clear Creek below Whiskeytown Dam, representing 17% of the actual stream length. Results for fall Chinook salmon include that an existing restoration project did not increase total numbers of outmigrating juveniles but did increase production of larger juveniles that appear more likely to survive to adulthood. A potential future restoration project was predicted to further support large juveniles, in part because its downstream location makes it useful to most juveniles as they migrate out. Concerning how management affects the production of anadromous steelhead vs. resident trout, inSALMO predicted that steelhead smolt production was highest under conditions of relatively high survival and high growth, conditions that also produce large numbers of resident trout. We conclude that models like inSALMO are valuable for organizing information and field studies in a way that clearly leads to well-documented and reproducible decision support. InSALMO led to clear results about the relative (and sometimes conflicting) effects of alternative management actions such as spawning gravel injection, re-shaping channels, providing cover, reducing temperatures, and altering flow regimes. The model is useful both for planning new actions and evaluating finished actions.

Keywords: habitat restoration, salmon, steelhead, population effects, modeling
Session Title: Connecting Models with Behavior
Session Time: Wednesday 8:20AM – 10:00AM Room 314

Where and Why are the Fish? Investigating the Relationship between Hydrodynamic Complexity and Delta Smelt Abundance in Suisun Bay

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We determined the extent to which delta smelt catch in the Fall Midwater Trawl (FMWT) survey can be correlated to specific hydrodynamic conditions. The three-dimensional UnTRIM Bay-Delta model was used to determine habitat complexity metrics, such as the current speed gradient, around each of 49 stations in Suisun Bay. These physical metrics were related to delta smelt catch at the time and location of each trawl. A station index, normalized with regard to historic delta smelt catch, was developed using the entire FMWT dataset to determine the relative consistency of smelt catch at each of the FMWT stations in Suisun Bay. Hydrodynamic, topographic, and salinity variables from the model were used to determine the general characteristics of each of the FMWT stations. The stations with consistent catch were located in regions with relatively slower current speeds and reduced seabed variability, relative to the lower quality stations. However, at the medium quality stations, on a tow-by-tow basis delta smelt catch was more likely when the hydrodynamic conditions at the time of the trawl were more energetic, relative to the conditions over the preceding 25 hours. In this way the FMWT data combined with the model results suggest that delta smelt broadly prefer relatively less energetic and less variable areas of Suisun Bay, but were more likely to be caught when the tidal currents were flowing. Numerical models can be combined with long-term data sets to improve the understanding of the observed biological data, but results differ on different spatial and temporal scales.

Keywords: Delta Smelt, Habitat Complexity, Numerical Modeling
Session Title: Connecting Models with Behavior
Session Time: Wednesday 8:20AM – 10:00AM Room 314

DSM2 PTM, an Open Source Platform for Delta Fish Migration Behavior Research and Model Development

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Can hydrodynamics, water project operations, and water quality (e.g., turbidity) explain and predict route choice, travel time and survival of juvenile Chinook Salmon migrating through the Sacramento – San Joaquin Delta? To answer this question, numerous field studies have been conducted and large amount of acoustic telemetry fish tag data have been collected, on the basis of which various agencies and organizations have begun to make efforts in fish behavior modeling. Facing the need for a collaborative effort among agencies and organizations to tackle the question and to conduct efficient and effective fish migration behavior research and model development, DWR is teaming up with USGS to build an open source platform so that these efforts can be shared and future work can be better coordinated.

The effort for building such a platform is started from DSM2 PTM, a model that has been used to simulate the transport and fate of individual neutrally buoyant particles through the delta. Because the original model only simulates neutrally buoyant particles, the model has limitations when used to simulate fish migration through the delta. To overcome these limitations, DWR is working with USGS to develop swimming, route selection and survival modules, which are statistically inferred/developed from wide ranges of multi-year, multi-station acoustic telemetry fish tag data. DWR has also started the structural changes of the original DSM2 PTM to make it more suitable for an open source platform. The modified model will allow behavior modules developed outside of DWR to be easily integrated into the model without cracking open the existing code. In this presentation, we highlight how telemetry data is being used to improve DSM2 PTM as a model for predicting fish behavior and survival.

Keywords: Modeling, Fish Behavior, Salmon, PTM, Open Source, Telemetry Data, Ecohydraulics
Session Title: Connecting Models with Behavior
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An Historical Perspective of Nutrients and Dissolved Oxygen: Changes in Wastewater Loads and Water Quality in Lower South San Francisco Bay, 1957-2013

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The San José-Santa Clara Regional Wastewater Facility (Facility), located in the Lower South Bay (LSB), is the largest advanced wastewater treatment plant in San Francisco Bay. From 1957 to 2013, the Facility added a series of expansions and upgrades that increased treatment capacity and improved the quality of treated effluent.

Using long term data sets of BOD, DO, TSS, NH_4^+, NO_3^-, and PO_4 in wastewater effluent and LSB surface water, this study addressed two primary questions: (1) To what extent have treatment plant expansions and upgrades during the past six decades resulted in improvements to Facility effluent quality? (2) How and to what extent have the changes in the Facility effluent translated into changes in the water quality of the LSB? Five hypotheses were formulated to evaluate long-term trends and correlations regarding wastewater loads and concentrations of BOD, TSS, NH_4^+, NO_3^-, and PO_4 in the LSB on spatial, seasonal, and annual scales. R software was used to analyze the data.

All five hypotheses were confirmed by the data, with a few qualifications that can be readily explained. The first major finding is that, in spite of substantial increases in population, both influent and effluent flow to the Bay decreased in the past decade. A second major finding is that the data show major load reductions in BOD, TSS, and nutrients corresponding to Facility improvements. Third, anoxia and hypoxia were virtually eliminated following the Facility's upgrade to nitrification, significantly improving DO concentrations in the LSB. Fourth, LSB nutrient concentrations showed significant decreases corresponding to capital improvements of the Facility.

Keywords: Wastewater, BOD, TSS, Nutrients, Lower South Bay, Dissolved Oxygen
Session Title: Trends in Water Quality
Session Time: Wednesday 10:20AM – 12:00PM Room 314

Trends and Environmental Implications of X_2 in Northern San Francisco Bay, 1988-2012

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The need for a sensitive habitat indicator to manage the threatened biological resources in northern San Francisco Bay first motivated the interest in X_2, the 2 psu bottom salinity position, two decades ago. While early studies quantified the relationship between X_2, freshwater flow rate (Q), and estuarine resources, there has not been an updated and comprehensive review of X_2 using real-time data since 1993. It is important from a water users' perspective that the connection between salinity and freshwater flow rate be as accurately known as possible. Using water quality data made available by the U.S. Geological Survey, U.S. Bureau of Reclamation, and California Department of Water Resources, we were able to: 1) identify and address irregularities from previous analyses; 2) determine the temporal and spatial evolution of X_2 in the upper estuary from 1988 to 2012; 3) update the power-law relationship between X_2 and Q by including more extreme flow events; and 4) explore the implications of X_2 on turbidity levels, stratification, and phytoplankton growth due to light limitations. Comparison with historical data shows that the mean decadal X_2 position has undergone significant changes. Maximum turbidity levels also appear to be positively linked to the nose of the salinity intrusion, but the relationship between X_2 and chlorophyll a is less distinct due to strong biological controls. As the low-salinity zone in San Francisco Bay continues to respond and adjust to changes in physical and biological drivers, the expected challenges to proper management of salinity-sensitive habitats and organisms will require even more diligent monitoring and synthesis of the collected data.

Keywords: X2, salinity, freshwater flow, sediment, chlorophyll *a*
Session Title: Trends in Water Quality
Session Time: Wednesday 10:20AM – 12:00PM Room 314

The Effect, or Lack Thereof, of Sediment Supply and Deposition on Subsequent Fall Turbidity in Suisun Bay

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During fall, delta smelt occupy the low salinity zone (salinity 1-6) of the San Francisco Estuary which is located (X2) in eastern Suisun Bay or landward at the river confluence. Delta smelt favor more turbid water and turbidity is primarily a function of suspended-sediment concentration (SSC) in the estuary. Mean September and October (fall) SSC at the landward boundary of Suisun Bay (Mallard Island) decreased by about one-half from 1994 to 2011 due to a limited erodible sediment supply. In this work, the hypothesis that wet years deliver and deposit sediment, increasing the erodible sediment pool and subsequent fall SSC, is explored. Suspended-sediment flux at the landward and seaward (Benicia) boundaries of Suisun Bay for water years 1997, 1998, and 2002-2012 were estimated using surrogate relations dependent on Delta outflow, SSC, and the longitudinal salinity difference across Suisun Bay (□S). There were three groups of water years: 1) large inflow, large sediment supply, net erosion, seaward X2 in fall, small fall □S, and large fall SSC compared to the trend line (1998 and 2011); 2) large inflow, large sediment supply, net erosion, landward X2 in fall, large fall □S, and small fall SSC compared to the trend line (1997 and 2006); and 3) small freshwater flow, small sediment supply, net deposition, landward fall X2, large fall □S, and fall SSC near the trend line (2002-2005 and 2007-2010). Neither sediment supply nor deposition affected fall SSC. The salinity difference was relatively low in turbid falls, indicating that gravitational circulation in Suisun Bay and associated sediment trapping was not likely any stronger than less turbid falls. From 1994-2011, only 1998 and 2011 had seaward fall X2 and those were the only two water years with an anomalously large fall SSC. Thus, when fall X2 was in Suisun Bay, fall SSC was elevated.

Keywords: turbidity, Suisun Bay, sediment, habitat, delta smelt, suspended-sediment
Session Title: Trends in Water Quality
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Status and Implications of Stormwater Quality Monitoring in the Cache Slough Watershed (2010-2014)

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Solano County Water Agency as part of the Cache Slough Watershed Group (CSWG) has implemented a watershed-wide wet-weather stormwater sampling program since 2010 to characterize water quality contaminants detected within the Cache Slough watershed by sampling tributary creeks during substantial storm events. The program builds on prior monitoring to inform watershed management while evaluating implications for proposed pelagic fish habitat restoration in Cache Slough, part of the Sacramento-San Joaquin Delta. Along with physical stressors, observed water quality toxicity in Cache Slough is a potential factor in declining native fish species including delta smelt (Werner et al. 2010). Sampling results indicate that TSS, bacteria, metals, nutrients, and pesticides continue to be primary constituent groups detected and that locations downstream of urbanized and agricultural areas typically exhibit lower water quality conditions than those in the upper watershed. The Upper Putah Creek location in relatively undeveloped conditions consistently exhibited the most favorable water quality conditions, whereas observed conditions at the Upper Ulatis Creek location in a suburban area were moderately impacted. Excluding the Upper Putah Creek location, bacteria detections also influenced by natural phenomena were consistently elevated. Pyrethroids and other pesticide detections observed throughout the watershed were generally poorly correlated with TSS data, and yielded lower, potentially diluted concentrations after intense rainfall. However, higher-intensity rainfall events yielded higher TSS and closely correlated metals concentrations. Observed TSS levels are associated with pollutants of concern but also provide turbid conditions favorable to delta smelt. Legacy pesticide detections decreased in favor of pyrethroids, the local dynamics of which require more research. Urbanized and agricultural areas in the contributing watershed greatly influence the variety and concentration of metals, pesticides, and nutrient detections. Findings indicate that careful management of urbanized and agricultural areas is imperative to overall Delta water quality and to sensitive biological receptors in Cache Slough.

Keywords: water quality, stormwater, pyrethroids, sediment, Cache Slough, sampling, toxicity, watershed
Session Title: Trends in Water Quality
Session Time: Wednesday 10:20AM – 12:00PM Room 314

South San Francisco Bay: Status, Trends, and a 21st Century Baseline

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Our USGS research project has regularly measured water quality in South San Francisco Bay since 1978. We will describe a synthesis of this long-term data set to identify patterns of variability in water temperature, salinity, nutrients, suspended sediments and turbidity, dissolved oxygen, and phytoplankton biomass as chlorophyll *a*. The synthesis includes measures of water-quality changes over time, and uses simple models to identify potential drivers of those changes. The synthesis answers a set of fundamental questions, such as: (1) has South San Francisco Bay warmed in response to recent decades of global warming; (2) do signals of oceanic variability, such as the past decade of low dissolved oxygen in coastal waters, propagate into the Bay; (3) has the South Bay become more efficient at converting nutrients into phytoplankton biomass; (4) are stratification events more frequent and water transparency higher; how do these patterns influence changes in chlorophyll *a* trends? Our purpose is to assess status and trends of water quality across the South Bay system, and to establish a 21st century baseline from which we can measure future responses to climate change and human actions.

Keywords: water-quality, phytoplankton, long-term trends, global changes
Session Title: Trends in Water Quality
Session Time: Wednesday 10:20AM – 12:00PM Room 314

Tracing Nitrate and Ammonium Dynamics within the San Joaquin-Sacramento River Confluence Region Using Stable Isotopes

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The stable isotopic composition of dissolved nitrate (δ^{15}N- and δ^{18}O-NO_3) and ammonium (δ^{15}N-NH_4) was measured in the lower San Joaquin River, the Sacramento River, and north San Francisco Bay during three separate trips in April 2010, October 2010, and April 2011 in order to trace differences in nitrogen sources and dominant biological processes throughout the region and between different seasons. In the San Francisco Bay and Delta, high concentrations of nitrate are transported from the San Joaquin River, while the Sacramento River contains elevated ammonium concentrations from wastewater treatment plant discharge. Concentrations and distributions of different nitrogen forms can influence algal growth rates and community compositions. δ^{15}N-NH_4 increased downstream in the Sacramento River, indicating nitrification, and creating a distinct difference between the δ^{15}N-NO_3 and δ^{15}N-NH_4 within the confluence region and north San Francisco Bay. A much more pronounced increase in δ^{15}N-NH_4 was observed in October in comparison to April, suggesting seasonal controls on the extent of nitrification. δ^{15}N-NO_3 of nitrate was consistently higher in the San Joaquin River in comparison to the Sacramento River and north San Francisco Bay, making it a strong tracer for San Joaquin-derived nitrate within the Delta. During all trips, δ^{15}N-NO_3 in the San Joaquin River channel decreased towards the confluence with the Sacramento River. Volumetric flow calculations from the DSM2 model, along with geochemical and water stable isotope data indicated that this shift was driven primarily by a change in water sources. The shift in δ^{15}N-NO_3 reflects higher contributions of Sacramento River water and nitrate, rather than spatial differences in biological nitrate cycling. The Delta is a highly complex region, and combining concentration and stable isotope measurements with hydrodynamic modeling provides insights into how nutrients from the two major rivers move and cycle through the Delta.

Keywords: nutrients, stable isotopes, nitrate, ammonium, Sacramento River, San Joaquin River
Session Title: Water Quality in Space and Time
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Salinity and Flow Variability in Suisun Bay during FLaSH

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Problem: The goal of this work is to how Suisun Bay "works" in the fall, particularly focusing how the salinity and velocity fields respond to variations in flow.

Approach
We deployed a set of 26 salinity loggers (CTDs), and 12 Acoustic Doppler Current Profilers (ADCPs) throughout Suisun Bay during the 2011-12 Fall Low Salinity Habitat Study (FlaSH) that logged data continuously from 11/17/11 to 1/9/12.

Results:
Our FLaSH hydrodynamic data provide a uniquely detailed view of the spatial and temporal variability of the salinity field in Suisun Bay, including stratification, as well as of tidal and sub tidal flows, including gravitational circulation. Firstly, our observations showed a significant difference in the X2 calculated using Dayflow and what was directly recorded by bottom CTDs. The overall time variability appears to be better predicted using USGS UVM data, although even then the transient associated with increasing X2 was much more abrupt and of longer duration in the observations than in predictions. Depth-averaged subtidal flows recorded by the ADCP at Chipps Island agree better with the UVM flows. Estimates of subtidal drag there are in balance with subtidal free surface pressure gradients associated, suggesting that ADCP-derived mean flows were likely closer to the real outflow rates than were Dayflow derived values. Additionally, there are pronounced north-south differences in salinity, with salinities being somewhat lower in the northern channels and perimeter habitats than in the main channel, behavior that may be due to freshwater coming from Montezuma Slough.
Conclusions/Relevance:
(1) During low flow periods Dayflow may not accurately represent Delta outflows to Suisun Bay affecting its utility as a metric of flow; (2) Salinities in shallow water habitats of Suisun Bay differ from salinities in the main channel such that calculations of LSZ habitat may differ from what is calculated assuming no North-South variation.

Keywords: hydrodynamics, salinity, tides, X2, Dayflow, habitat
Session Title: Water Quality in Space and Time
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Real-Time Water Quality Mapping in the Cache Slough Complex: High Resolution Data across Space and Time

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Water-quality measurements collected over both fine temporal and spatial scales are needed to understand biogeochemical processes in hydrologically complex environments, such as the Sacramento-San Joaquin Delta, in order to adequately resolve sources and processes. Recently established real-time water-quality stations operated by the U.S. Geological Survey are providing temporally-rich data for fixed points in the Cache Slough complex. To complement these data, we collected spatially-intense data by using a boat configured with flow-through monitoring tools, enabling real-time mapping of water quality. Real-time mapping can spatially resolve, for example, different sources and sinks for nutrients and phytoplankton, such as agricultural drains, wastewater, and wetlands. We will present data collected over two sampling events in October 2013 and May 2014 across Liberty Island and its surrounding wetlands and sloughs using the boat-mounted in-situ sensor package. Nitrate, dissolved organic matter and chlorophyll were measured along with standard water-quality measurements (temperature, dissolved oxygen, pH, specific conductance, turbidity). Real-time mapping of water quality has the potential to provide valuable information about key processes occurring in dynamic systems, such as the Cache Slough complex, to better inform those making water-management decisions.

Keywords: real-time water quality mapping, nitrate, chlorophyll, dissolved organic matter
Session Title: Water Quality in Space and Time
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Application of an Estuary Model to Quantify Factors Contributing to Low Dissolved Oxygen Conditions in the San Joaquin River Deep Water Ship Channel

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The Stockton Deep Water Ship Channel (DWSC), located in the San Joaquin River estuary, has had seasonal and episodic low dissolved oxygen (DO) concentrations for decades. The occurrence of low DO causes the assimilative capacity of the river to be exceeded, impacting ecosystem health and the quality of water supplies that are designated for various uses. To address this impairment, a DO total maximum daily load project was initiated to quantitatively identify the causes of low DO and develop restoration strategies. Here, a one-dimensional link-node model was used to simulate water quality conditions in the DWSC. The model was calibrated and validated using six years of data that reflects both wet and dry conditions in the San Joaquin River Basin. Model simulations were run to determine the effect of four factors influencing low DO conditions in the DWSC: elimination of the deepened ship channel, elimination of import of oxygen-consuming substances (ODS) from the San Joaquin River watershed, elimination of import of ODS from the urban tributaries, and elimination of discharge of ODS from the regional wastewater treatment plant. The model results suggest that the deepening of the ship channel has had the largest impact on low DO conditions, followed by ODS from the agricultural watershed. Since the Stockton wastewater treatment plant was upgraded in the 2007, the impact of ODS from this facility has been significantly reduced. The estimated impact of stormwater from the City of Stockton appears much smaller than the other factors. The study results are useful for assigning responsibility for low DO conditions in the DWSC and for formulating effective restoration strategies. The study results also suggest that removal or elimination of any single variable would not result in a complete resolution of low DO events.

Keywords: Dissolved oxygen, TMDL, San Joaquin River
Session Title: Water Quality in Space and Time
Session Time: Wednesday 1:35PM – 3:15PM Room 314

Spatial and Temporal Patterns in Bay-Delta Sediment Quality: Relationship to CA Sediment Quality Objectives

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California became one of the first states in the U.S. to establish regulatory objectives for sediment quality when the State Water Resources Control Board adopted sediment quality objectives (SQOs) in 2008. These objectives included a new sediment quality assessment framework for benthic community protection based on the evaluation of sediment chemistry, sediment toxicity, and benthic community condition, as well as a narrative objective for protecting human health related to seafood consumption. Monitoring data from 2005-12 was evaluated using the SQO assessment framework to evaluate Bay-Delta sediment quality in comparison to other CA bays and estuaries. San Francisco Bay contained the greatest extent of contaminant-impacted sediments in California (52% of area); approximately twice the extent of impacts present in southern California bays and estuaries. Better sediment quality was present in the Delta, with lower levels of chemical contamination and sediment toxicity. Temporal analyses indicate some improvement in San Francisco Bay sediment quality that appears to be related to changes in sediment toxicity. Widespread sediment toxicity in San Francisco Bay has been observed since the 1980s and studies have associated sediment contamination with benthic community degradation in portions of San Francisco Bay. The specific cause of adverse impacts on San Francisco Bay sediment quality remains elusive, and may be due to multiple factors. Additional studies to identify the stressors responsible for these biological responses are needed to help inform environmental management agencies regarding strategies to improve sediment quality in the Bay-Delta system.

Keywords: sediment quality, San Francisco Bay, toxicity, contamination
Session Title: Water Quality in Space and Time
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The Contribution of Sacramento Valley Rice Systems to Methylmercury in the Sacramento River

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In anoxic, mercury contaminated sediments, sulfate reducing bacteria and iron reducing bacteria convert inorganic mercury to toxic methylmercury (MeHg). MeHg is readily absorbed by living organisms, particularly at higher trophic levels, and is a concern for wildlife in the Delta. In the Sacramento watershed, the conjunction of significant acreage of paddy rice and wetlands with mercury contaminated soils from historical gold and mercury mining enhances production of MeHg. This study sought to quantify the contribution of rice systems to MeHg entering the Delta through a meta-analysis of published data from 1996-2007. The analysis focused on sample sites located on tributaries carrying agricultural drainage waters, and sites on the Sacramento and Feather Rivers immediately upstream and downstream of agricultural drainages. Tributaries carrying agricultural drainage waters had higher MeHg concentrations than sites on the Sacramento River, and concentrations were lower at mainstream sites upstream of agricultural drainages, compared to downstream sites. All locations showed low concentrations of MeHg from June through October, and higher, more variable MeHg concentrations November through May. These patterns are consistent with studies of MeHg exports from rice systems in the Yolo Bypass and the Delta. However, MeHg loads from agricultural drainages were significantly lower than what would be predicted from field scale load measurements from rice systems in the Yolo Bypass and the Delta. Future studies will be needed to determine the reason for the discrepancy between this and other studies. Results from this study suggest that the contribution of rice systems to MeHg loads occurs primarily in November through May. Management practices designed to reduce loads are likely to be more effective during this season.

Keywords: methylmercury, rice, Sacramento Valley
Session Title: Water Quality: When It's Bad
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Using Biosentinels to Assess Mercury Risk in Wetland Restoration Projects

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Methylmercury contamination in food webs is one of the primary water quality issues in the San Francisco Bay. Wetlands have been shown to be important sites of methylmercury production and there is concern that wetland projects may result in increased mercury bioaccumulation. Biosentinel monitoring can be used to provide a direct link between marsh projects and the protection of marsh wildlife at risk of mercury contamination. Here we present data from a two-year project that used a region-wide approach to monitoring wetland restoration in San Pablo Bay. Our data showed concentrations above levels of concern in most species. The design for this project was developed with input from a Science Advisory Group consisting of experts in biosentinel monitoring for mercury and the ecology of potential biosentinel species. The approach and sampling plan were also vetted with local stakeholders, who expressed interest in the following four management questions: 1) *What is the current potential for impairment of beneficial uses due to methylmercury in each major habitat of interest in the North Bay intertidal habitat restoration projects? 2) How will the status of impairment due to methylmercury in each major habitat of interest change over a timescale of years in response to the project? 3) How do the status and trends in impairment due to methylmercury at this project compare to status and trends in impairment in other project and non-project wetlands in the region? and 4) Will tidal marsh restoration introduce a problematic amount of methylmercury into the Bay?* We evaluated the ability of this biosentinel approach to answer each of these management questions in a cost-effective way.

Keywords: Methylmercury, monitoring, wetland restoration, biosentinel, small fish
Session Title: Water Quality: When It's Bad
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The Potential Influence of Pyrethroids, Metals, and Sediment Characteristics on Benthic Communities in Cache Slough

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Benthic communities in the Cache Slough area of California's Bay Delta are critical for the diet of various key fish populations. Research was conducted at 12 sites in the Cache Slough area during the spring and fall of 2012 and 2013 to determine the influence of 8 pyrethroids, 8 metals, and 4 sediment characteristics on native benthic communities. Forty-three to 56 different benthic taxa were collected during the spring and fall of both years and the most dominant taxa collected was the amphipod *Americorophium*. The sum of pyrethroid Toxics Units (TUs) in the sediment based on *Hyalella azteca* (a pyrethroid sensitive species) exceeded a value of 1 (suggesting toxicity) at 4 of the 12 sites during the spring of 2012 but did not exceed 1 at any site for the three other sampling periods. The highest number of metals Threshold Effects Level (TEL) exceedances in sediment were reported for nickel, chromium, copper and arsenic. The predominant type of sediment collected at all sites during random sampling was fine grain material (depositional areas) where hydrophobic chemical concentrations could be greatest. A series of statistical analyses were employed to examine relationships between benthic metrics and environmental variables (pyrethroids, metals and sediment characteristics). Relatively few statistically significant and ecologically meaningful relationships were observed. The benthic metric *% Collectors/Filterers & Collectors/Gatherers* was directly related to concentrations of arsenic. The benthic metric *Abundance* was inversely related to % silt and total organic carbon, suggesting that numbers of benthic organisms tended to be greater in the coarser, less organic-rich sediments. The results from this research are relevant for Bay Delta science because important variables influencing benthic communities, arsenic and sediment characteristics, were identified within a multiple stressor context.

Keywords: Cache Slough, metals, pyrethroids, sediment characteristics, benthic communities
Session Title: Water Quality: When It's Bad
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Concentrations and Loads of Current-Use Pesticides Entering the Sacramento/San Joaquin Delta May 2012-April 2013

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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. A recent USGS study measured concentrations of 99 pesticides and degradates in filtered water samples collected bimonthly (May 2012 – April 2013) from the Sacramento and San Joaquin rivers where they enter the Delta. Thirty-four pesticides and pesticide degradates were detected during the study, with samples containing mixtures of 3 to 14 pesticides. Herbicides, herbicide degradates, and fungicides were detected most frequently, while insecticides were rarely detected.

Herbicide concentrations in the Sacramento River were greatest in samples from the late spring through early summer, while fungicide concentrations were greatest in late summer. Pesticides applied to rice were the main compounds detected during these periods and included the herbicides clomazone, thiobencarb, and propanil (along with its degradate 3,4-DCA), and the fungicide azoxystrobin. Herbicide and fungicide loads were elevated during these periods, and again in the early winter.

Pesticide concentrations in the San Joaquin River were greatest in samples from the winter and early spring. Increases in both concentrations and loads correlated with spikes in discharge following rainfall events. Pesticides detected frequently included the herbicides hexazinone (100%), metolachlor (100%), simazine (83%), diuron (96%) and its degradates 3,4-DCA (96%) and DCPMU (83%), and the fungicides azoxystrobin (75%) and boscalid (96%). These compounds are applied to a variety of crops including alfalfa, stone fruits, and vegetables, while diuron is also used for roadside weed control.

With the exception of pesticides used on rice, concentrations were generally higher in the San Joaquin River samples. Pesticide loads to the Delta however, were greater from the Sacramento River. These data provide valuable information to scientists and resource managers working to understand the role of contaminants in the region.

Keywords: Pesticides, Water-quality, herbicide, fungicide, insecticide
Session Title: Water Quality: When It's Bad
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A Multi-Year Temporal and Spatial Evaluation of Pyrethroid Concentrations and Biological Effects in the Lower American River

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Previous studies of the lower American River reported that grab water samples collected over a 30-km reach contained pyrethroid insecticides at concentrations reported to be toxic to the amphipod *Hyalella azteca*. Beginning in 2011, we initiated a multi-year monitoring study with the goal of providing a robust understanding of how pyrethroid concentrations vary spatially and temporally in the lower American River. Water samples have been collected during 11 rain events and 3 dry events along multiple cross-river transects and analyzed for pyrethroids. The sampling design initially included the collection of water samples from multiple depths, and later transitioned to depth-integrated sampling. Samples were also collected during special studies, including a boat-drift study between two key stations, a "loitering" study performed at one transect, and a multi-day sampling study. In addition, water samples were collected from multiple events for toxicity testing with laboratory-reared and field-collected *H. azteca*. In contrast to the conclusions of the previous studies of pyrethroids in the lower American River, we concluded that pyrethroid detections were rare and episodic, and concentrations were generally low and highly spatially variable. Toxicity was only reported for one sample collected during the day of predicted peak runoff, but was not observed in the exposure using sequential days of sample collection or in the exposures with resident organisms. Based on a comparison of grab samples collected both near the bank (i.e., immediately downstream of a discharge) and across the river transect, we concluded that caution should be used when drawing general ecological conclusions based on grab sampling from the bank. In addition, our results suggest that stormwater monitoring programs that include toxicity testing using a single sample collected during the day of projected peak runoff may be overestimating the toxicity for the acute 96-hour toxicity tests.

Keywords: American River, Pyrethoids, Water Quality, Toxicity, Riverine, Sampling, Design
Session Title: Water Quality: When It's Bad
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South Delta Salmon Smolt Survival Studies

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The escapement of adult salmon to the San Joaquin basin appears to be related to flow during their spring smolt migration period. Studies estimating salmon survival in the south Delta have been ongoing since about the mid - 1980's. The results of early studies indicated that coded wire tagged (CWT) juvenile salmon released in the San Joaquin River just downstream of the junction at the head of Old River (near Lathrop), usually survived at a higher rate to Chipps Island than those released in Old River. Additional studies also indicated that survival to Chipps Island increased as flows increased for CWT fish released near Lathrop, and for CWT fish released at Mossdale or Durham Ferry with a physical rock barrier at the head of Old River. Modeling using the CWT data suggested that survival would be higher through the Delta when a rock barrier was installed as it reduced the proportion of water and fish entering Old River where survival appeared to be lower. In 2008, 2010, 2011 and 2012 juvenile Chinook salmon survival between Mossdale and Chipps Island was estimated using acoustic tags, with survival being low for all years. In addition, the proportion of tagged salmon entering Old River, or route entrainment, was also estimated in these years. Comparisons of both route entrainment and route and reach specific survival between Mossdale to Chipps Island allows us to identify why survival is so low through the Delta and find the mortality hot spots in each route as the fish migrate downstream. These studies can also be used to assess various management actions, such as the physical head of Old River barrier or increases in flow as was done in 2012.

Keywords: Salmon, survival, Delta, Smolt
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
Session Time: Thursday 8:20AM – 10:00AM Room 306

Juvenile San Joaquin Steelhead Migration and Survival through the South Delta, 2011 and 2012

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The Six-Year Steelhead Study originated in 2011 to address questions about migration and survival of juvenile San Joaquin steelhead through the Delta. Each year, approximately 1500 – 2200 juvenile hatchery steelhead have been tagged using microacoustic tags and monitored as they move through the Delta. Results from the first two years of the study will be presented. In 2011, river flows were high and no barrier was installed at the head of Old River; average survival through the Delta ranged from 0.38 to 0.69 (SE≤0.05). Approximately half the steelhead that arrived at the head of Old River entered Old River, and 38% of the tagged steelhead that reached Chipps Island came via the CVP and SWP water export facilities. In 2012, river flows were considerably lower and a physical barrier was installed at the head of Old River. The large majority of tagged steelhead remained in the San Joaquin River at the head of Old River. Delta survival estimates ranged from 0.24 to 0.32 (SE≤0.03) in 2012, and only 5% of those that reached Chipps Island came via the water export facilities. Delta survival was higher in the San Joaquin route than in the Old River route for 2012 (low flows, barrier) but not in 2011 (high flows, no barrier) (α=0.05). The median travel time to Chipps Island was 5 – 6 days in both years, and ranged up to 35 days in 2011. The lowest survival was observed for fish that entered the interior Delta via Turner Cut. Within the San Joaquin route, the reach between MacDonald and Medford islands had the lowest survival rate per km in both years. Significant improvements to steelhead survival through the Delta may require increasing survival in tidal areas, in addition to keeping steelhead out of the interior Delta.

Keywords: Acoustic telemetry, migration route, Steelhead, survival, travel time
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Sharing Risks: Applicability of the Surrogate Species Approach for San Joaquin River Salmonid Species

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Fall run Chinook and steelhead are members of the same family, Salmonidae, and thus the population response to various drivers may be representative of each other. However, the 2009 VAMP review panel suggested that Chinook salmon are a poor surrogate for steelhead. Thus, the potential to run simultaneous survival studies of juvenile Chinook salmon and steelhead smolts was considered an important objective during the 2011 and 2012 Lower San Joaquin River and South Delta telemetry investigations. During these two years, extensive efforts that would later allow for examining questions concerning surrogacy between fall run Chinook salmon and Central Valley steelhead were made. These included intensive pre-study planning to ensure standardized procedures for surgeries, data processing and coordinated field implementation. Results regarding salmonid route selection and survival from four simultaneous releases in the lower San Joaquin River and South Delta telemetry investigations are considered with environmental and flow data to assess the response of fall run Chinook and steelhead to equivalent environmental drivers. The responses of both species to environmental conditions are compared to evaluate how using one species may or may not reflect a reasonable substitute for the other regarding hypothesized benefits and risks of managing environmental conditions. Finally, this presentation will discuss how surrogacy assumptions influencing the certainty in interpretation were addressed in planning and implementation to increase certainty in results.

Keywords: salmonidae, surrogacy, San Joaquin, biological response
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Sacramento River Reach-Specific Movement and Survival Rates of Outmigrating Winter-Run Chinook Salmon Smolts

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Winter-run Chinook salmon (winter-run) are state and federally listed as endangered. In recent years, spawning escapement has declined, with 3-year cohort replacement rates consistently less than 1.0. Causes of this decline are poorly understood. Juvenile winter-run are thought to delay outmigration and rear at unknown locations in the river for a longer duration than other Central Valley salmon runs. In-river juvenile mortality rates are known to be high in other runs. We hypothesized that in-river movement rates would be lower, leading to reduced survival for winter-run than for stocks like the fall-run that migrate out of the river more rapidly. In February to April of 2013, we used Juvenile Salmon Acoustic Telemetry System (JSATS) technology to estimate reach-specific survival rates for hatchery-raised winter-run juveniles during their outmigration to sea. Cumulative survival estimates for 148 fish showed only 20% of juveniles survived beyond a region in the upper Sacramento River between Salt Creek (Rkm 475) and Tisdale Weir (Rkm 287). In stark contrast to all other Central Valley Chinook salmon stocks evaluated so far that exhibit rapid and persistent migratory behavior, surviving winter-run remained within this stretch of river for as long as 30 - 50 days**.** Preliminary migration and survival results of 359 acoustic tagged winter-run released in February 2014 suggest that holding time in the upper river was less than in 2013 and survival was correspondingly higher. More acoustic tracking data are needed to determine whether the delayed outmigration observed during the drought conditions experienced in 2013 are generally characteristic of winter-run. Our findings reveal that juvenile winter-run in-river survival is among the lowest of Central Valley Chinook salmon runs. If rearing occurs in the same area from year to year, we suggest that these data can be used to prioritize targeted restoration efforts for improving juvenile salmon habitat.

Keywords: Sacramento River, winter-run, Chinook salmon, JSATS, outmigration
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Salmon Migration Behavior and Survival in Sacramento River - Knights Landing to the Delta

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New levee designs are being implemented by the US Army Corps of Engineers along the middle reaches of the Sacramento River to increase available habitat features for outmigrating salmonids. We are seeking to understand how these new levee designs are affecting Chinook survival and migration behavior. We have designed telemetric studies to gather information on juvenile salmon movement behavior, survival and migration rates through the targeted reaches to complement electrofishing surveys conducted at specific levee repair sites. In 2013 we used ultrasonic VEMCO transmitters to tag approximately 600 late-fall Chinook salmon juveniles from Coleman National Fish Hatchery, and detected these fish at a series of receiver gates as they migrated from the release site near Knights Landing, CA toward Clarksburg, CA. In this first year of the study we found that survival rates were higher in the upper reaches, but decreased as fish slowed and approached areas with tidal influence around Sacramento. We also saw indications of temporal variation in survival, possibly corresponding with the striped bass migration period. Using an existing database of bank habitat features as well as a high-resolution hydrodynamic model, we examined how levee features might affect migration speeds. We are also using the mean free-path length model (Anderson et al 2005) to explore predation patterns within the reach-specific survival estimates. The results of this analysis will be incorporated into upcoming phases of levee repair in the Sacramento River basin, to improve current practices and increase the survival of our declining salmonid species.

Keywords: acoustic, telemetry, Chinook, salmon, behavior, habitat, migration, survival, river, levee
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Survival and Movement Rates of Wild Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) Smolts from Mill and Battle Creeks through San Francisco Bay - 2013-2014

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Spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are state and federally listed as a threatened species in California. Historically spring-run represented the largest component of Chinook salmon in California's central valley, but today wild spring-run Chinook are only established in Mill, Deer, Butte, Clear and Battle Creeks. The number of returning adult fish to these tributaries varies between 500 – 1500 fish, with the exception of Butte Creek which receives 6,000-15,000 adults. Previous studies of hatchery produced Chinook indicate that emigrating smolts experience high levels of mortality in the Sacramento River, Sacramento-San Joaquin River Delta and San Francisco Bay, but no studies of survival of wild spring-run smolts during their migration to sea have yet been conducted. In 2013-2014 we used Juvenile Salmon Acoustic Telemetry System (JSATS) technology to track reach-specific movement and survival rates of wild Chinook smolts from natal streams to the Pacific Ocean. Emigrating smolts were captured in rotary screw traps. In 2013 we captured and tagged 59 smolts from Mill Creek, and in 2014 tagged 36 smolts in Mill Creek and 80 smolts in Battle Creek. In 2013 the highest levels of mortality during downstream migration occurred between Woodson Bridge and Colusa, and cumulative survival to the Golden Gate was ~2%. These smolts also emigrated later in the spring compared to hatchery released smolts which potentially exposed them to warmer water temperatures and increased rates of predation. Our findings provide new information on the behavior and survival of wild spring-run smolts. Understanding how survival of these smolts relates to flows could help water management adjust flows to benefit these fish. More acoustic tracking data are needed during periods of high, turbid flow to determine if movement and survival rates are higher compared to the low flow conditions that were present during this study.

Keywords: Chinook salmon, spring-run, Sacramento River, San Francisco Bay, Predation
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Reach-Specific Movement and Survival Rates of Emigrating Feather River Spring-Run Chinook Salmon Smolts

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Hatchery-origin Feather River spring-run Chinook salmon smolts are released off-site, with half the production released in the Feather River and the other half west of the Delta. Differences in escapement rate between the two release sites suggest that mortality for the smolts released in the Feather River must be significant. We determined reach-specific movement and survival rates for smolts released in the Feather River for 2012-2014 using the Juvenile Salmon Acoustic Telemetry System (JSATS). We also examined the effect of direct versus net pen held release method (2013) and day versus night release timing (2014). The number of tagged fish released was 139, 302 and 300 for years 2012, 2013 and 2014 respectively. Survival was lowest for reaches in the Feather River compared to reaches through the Sacramento River, Delta, and SF Bay. Compared to survival rates of other Chinook runs, the reaches in the Feather River are particularly bad. There was no clear effect of direct versus net pen release method on initial survival. Causes of the low survival in the Feather River are not clearly understood. It is likely due to predation by other fish species. Acoustic telemetry provides valuable information on emigrating Feather River spring-run smolts that can be used by hatchery managers to adjust release timing, location, and methods to maximize survival. Determining what survival rates are and how they relate to river flow, water temperature and distribution and abundance of predators is critical to the long term management of the Bay-Delta ecosystem.

Keywords: Chinook salmon, smolts, survival, telemetry, Feather River, spring-run migration, movement
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Eliminating Bias in Survival Estimates Due to the Effect of Tag Failure on Right-Skewed Travel Time Distributions: A Bayesian Approach

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Tag loss or failure is a primary consideration when estimating survival from marked or telemetered animals. Traditional mark-recapture methods used to estimate animal survival cannot distinguish between tag loss and mortality, and so tag loss may lead to negatively biased survival estimates. In particular, fish telemetry studies inherently involve limitations due to battery power such that tags will fail at some point. When tags fail, estimating survival requires accounting for the probability of tag failure in the model.

Current methods try to account for tag failure by modeling tag failure as a function of observed travel times through the study area. However, travel times are only observed for fish whose tags do not fail. Consequently, missing information from fish with longer travel times may still lead to negatively biased estimates of tag failure and survival even when tag failure is included in the model. In this presentation we use Bayesian methods within a complete data likelihood structure to simulate missing values from a travel time distribution. This approach allowed us to recover the shape of a complete travel time distribution, given observed travel time data and observed tag failure times from an auxiliary tag life study, and thus the method may be used to obtain unbiased estimates of tag failure and survival.

Keywords: mark-recapture, tag failure, MCMC, telemetry
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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The Importance of Identifying and Quantifying Fish Behaviors to Predict the Migration Rate of Juvenile Salmonids

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Predicting the movement of a species is important for conservation and management, but remains a challenge. As part of the California Department of Water Resources Stipulation Study, we examined how well a physical model can predict the movement of acoustically-tagged steelhead (*Oncorhynchus mykiss*) and investigated underlying biological mechanisms limiting model accuracy. During the spring of 2012, we conducted a mark-recapture experiment to examine the movement patterns of steelhead emigrating through the south Sacramento-San Joaquin Delta. We released approximately 500 juvenile steelhead near Buckley Cove in the lower San Joaquin River. The quantitative statistical analyses determined that a purely physical model in the form of the Delta Simulation Model II Hydro Particle Tracking Model was not able to predict the movement of steelhead tags. The model greatly underestimated the steelhead tag movement rate through the study area as steelhead tags were traveling significantly greater distances than passive particles. We also documented some behaviors of steelhead that could explain the discrepancies between the passive particles and steelhead tag data. Our findings suggest that migrating steelhead exhibit a complex set of behaviors that are not captured by simple physical models. Additional studies are needed to better understand these behaviors and ultimately improve forecasting of salmonid migrations. By understanding and predicting how salmonids migrate through the Delta, this can inform how to minimize the time that salmonids are in the Delta- where they have low survival probabilities- determine which routes have the fastest migration rates, and when export operations should be conducted to minimize loss. Overall, this research has both ecological, economic, and management implications.

Keywords: Steelhead, DSM2, migration, selective tidal-stream transport, diurnal/ nocturnal movement
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Out to Sea and Home Free? Shifting the Salmon Freshwater-Ocean Survival Paradigm: Is Selection Now Favoring Shorter Fresh Water Life Histories?

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Variable ocean conditions contribute to large fluctuations in salmon survival and escapement. For California salmon populations this idea is coupled with an assumption of stable, abundant input of juveniles into the marine environment annually from continuous, large-scale hatchery production. Because of this, there is a tendency to attribute large fluctuations in escapement solely to variable ocean conditions. However recent studies on hatchery and wild smolts from multiple stocks in California's Sacramento River have assessed survival and interannual production of juvenile life stages using acoustic telemetry. These studies suggest instream mortality may be much greater and more variable than previously suspected. For example, out-migration mortality rates from basins several hundred kilometers upstream to the Golden Gate Bridge for hatchery fish range from 85-98%, typically within their first two weeks post hatchery release, yielding fewer and more variable contributions to the ocean. Given known escapement trends, this implies that marine survival rates are much higher, with only 80-90% mortality over the next two years for all fish that make it past the Golden Gate. Further, recent otolith microchemistry analysis suggests naturally produced fry may contribute as much as 20% to the returning adult population, and monitoring surveys revealed that annual catch-per-unit-efforts of fry may vary by 2 orders of magnitude. It is possible that sub-yearling and fry life histories that minimize time in river and race to sea are now favored by 'natural' selection forces over the yearling life histories that were more prevalent historically. Given continuing anthropogenic impacts to freshwater habitats, there is potentially a need to shift the paradigm that the ocean component of the salmon freshwater-ocean survival trade-off is the primary source of mortality, and rather may be a place of refuge at times. This hypothesis can be tested by salmon life cycle models under development.

Keywords: marine survival, freshwater, survival, salmon, life history strategy
Session Title: What's New Using Acoustic Technology to Identify Behavior and Survival of Fishes
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Shorebird Response to Varying Salinity and Water Depth in an Experimental Design in Salt Pond Management

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San Francisco Bay Estuary supports thousands of shorebirds during fall and spring migration and over winter. These shorebirds rely on foraging opportunities in the bay mud flats and former salt production ponds. The South Bay Salt Pond Restoration Project plans to restore 50-90% of salt ponds to tidal marsh and sediment demand for restoration may reduce the extent of remaining mud flat. Ponds E12 and E13 in the Eden Landing Ecological Reserve were enhanced to provide varying levels of salinity and water depth for increased foraging opportunities. Each pond was divided into three cells and foraging mounds were constructed to provide variation in topography. Our objectives were to understand shorebird use and invertebrate colonization immediately post-construction. We surveyed shorebirds across the cells and within survey plots on foraging mounds during the first winter (Jan-April) post-construction. We measured water quality and collected benthic macro-invertebrate cores and sweep samples on the mounds. Preliminary results show small shorebirds, predominantly Western Sandpiper and Dunlin, were the most abundant shorebirds, with over 5,000 observed across all ponds each month. Small shorebird abundance was greater in high salinity (49.2 psu) cells compared to the lowest salinity (40.8 psu) cells. Small shorebird abundance on foraging mounds ranged from zero to several hundred; however only 10% were observed foraging. We found aquatic invertebrates in our sweep samples and very few benthic invertebrates in our sediment cores; however, we expect additional colonization to occur over time. Our research highlights immediate shorebird use of managed ponds manipulated to provide suitable water depths for roosting and foraging opportunities. Our on-going studies at these experimental ponds will increase our understanding of shorebird spatial distribution in relation to water salinity, depth, and invertebrate composition and will provide managers with key information to optimize ponds for wintering and migrating shorebirds.

Keywords: shorebirds, foraging, experimental design, salt ponds, salinity, water depth, invertebrates
Session Title: Species and Communities I: Community Response to Management **Session Time:** Thursday 1:00PM – 2:40PM Room 306

Emerging Perspectives on Salt Marsh Harvest Mouse Conservation and Management - Ducks, Dikes, and Demographics

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Conservation and management of the salt marsh harvest mouse (*Reithrodontomys raviventris*) has long focused narrowly on presence/absence data. This project is delving deeper into the population dynamics, habitat use and behaviors of the salt marsh harvest mouse than has ever been attempted. Through monthly trapping in paired tidal and managed wetlands, and quarterly diet and habitat use assessments we are working to build a more complete picture of this endangered species. We are specifically looking to improve multispecies management by identifying waterfowl management practices that favor salt marsh harvest mouse conservation. One year into this three year study has yielded exciting preliminary results. During monthly trapping we have seen marked differences in capture rates across seasons with the highest occurring, surprisingly, during the winter. We have also seen interesting trends in population structure, with sex ratios varying across months. Finally, by trapping during the winter we were able to confirm that mice do not vacate managed marshes during the fall flood up, but remain in flooded wetlands even in the absence of emergent land close by. The diet assessment has shown that often salt marsh harvest mice choose foods that are highly preferred by ducks over those we presume they prefer based on trapping data. Through the use of radio telemetry we have observed interesting trends in habitat use, such as mice using vegetation types traditionally thought to be poor quality (such as *Phragmites australis*) when pickleweed (*Salicornia virginica*) is widely available. We have also documented salt marsh harvest mice using a variety of nest types as well as underground refuges, both self made and appropriated from other species.
The emerging perspective on the salt marsh harvest mouse is that it is a much more dynamic species than historical research has revealed, and our management must be equally dynamic.

Keywords: Salt marsh harvest mouse, *Reithrodontomys raviventris*, wetland management, populations, diet
Session Title: Species and Communities I: Community Response to Management **Session Time:** Thursday 1:00PM – 2:40PM Room 306

Diving Duck Response to Multi-Species Pond Management at Eden Landing Ecological Reserve

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San Francisco Bay is a critical wintering site for waterfowl and shorebirds using the Pacific Flyway. While in the estuary these species rely both on mudflat and salt pond habitats for foraging. The South Bay Salt Pond Restoration Project (SBSPRP) is the largest tidal marsh restoration project on the Pacific coast, with an objective of maintaining current bird numbers on salt ponds while converting 50 to 90% of them to tidal marshes to benefit endemic species. At the Eden Landing Ecological Reserve (ELER), managers are working to achieve this goal through multi-species management on a subset of ponds. These ponds are drained to create shorebird nesting habitat in the summer and filled for diving duck foraging habitat in the winter. Our objective was to evaluate response of diving ducks and their invertebrate prey to management actions. During the winters (Oct – April) of 2013-2014, we measured diving duck abundance and behavior, benthic invertebrate density and community composition, and water quality in E6A, E6B, E8 and 3 reference ponds. We coordinated with hunters to obtain digestive tracts and examine diets of birds foraging in the ponds. The most abundant divers were scaup (*Aythya affinis and A. marila*) and ruddy ducks (*Oxyura jamaicensis*), and ponds were used mainly for roosting with more foraging in reference ponds. Invertebrate diversity and richness was lowest in treatment ponds prior to flooding in the fall and increased over the winter. The main items in diet samples (n=30) were ostracods and seeds. Results from our study should provide valuable information for managing ponds to benefit multiple species which will be critical to meet restoration goals as the SBSPRP project progresses.

Keywords: diving ducks, benthic invertebrate, diet, salt ponds, restoration
Session Title: Species and Communities I: Community Response to Management **Session Time:** Thursday 1:00PM – 2:40PM Room 306

Rapid Fouling Community Shifts in San Francisco Bay Linked to Climatic Extremes and Water Management

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Problem: Human alteration of the hydrological cycle in the western US is resulting in greater variability and extreme interannual fluctuations in freshwater flow. The ecological impacts of extreme climatic fluctuations and human alterations to the hydrological cycle are less well known in downstream, estuarine systems.

Approach: We present results from a thirteen-year study of sessile marine invertebrate communities in San Francisco Bay demonstrating clear links between salinity levels, which are controlled by high and low estuarine outflow extremes, and mechanisms driving community composition and abundance. Using observational and experimental approaches, we assessed the effect of changes in water column conditions on fouling community diversity over thirteen years, including some of the wettest and dryest years in the past half century. We examined correlations between sessile invertebrate recruitment and survival patterns and seasonal variation in salinity and temperature in the Bay. We experimentally manipulated: (1) temperature and salinity levels to assess their effects on survival and community assembly processes, and (2) community composition to examine community assembly processes in the presence and absence of dominant species from wet and dry extremes.

Results: We show that even modest, decadal extremes in wet and dry climatic conditions drive dramatic, yet predictable shifts in sessile marine invertebrate community composition and abundance. During high flow (wet) years, low salinity levels cause mass mortality in fouling communities, significantly altering community composition and function throughout the estuary. In contrast, during dry years, fouling communities are dominated by non-native species, and sessile species move upstream into areas of the estuary traditionally inhabited by freshwater or brackish communities. Adult organisms' high salinity tolerances allow persistence and continued impacts following recruitment to areas more typically inhabited by freshwater organisms.

Conclusions: Our study shows consistent, predictable community changes driven by environmental changes tightly linked to both climatic change and management regimes.

Keywords: community, diversity, invasions, climate, flood, drought, salinity, outflow, extreme
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Ballast Water Management Compliance of Commercial Vessels Operating in the San Francisco Estuary: A Ten-Year Perspective

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The discharge of ballast water from commercial ships is a well-known and highly documented vector for the introduction of nonindigenous species (NIS) to coastal waters and estuaries. Within California, it is estimated that up to 81% of the state's 257 established aquatic NIS were introduced via commercial shipping. The California State Lands Commission's Marine Invasive Species Program (MISP) has overseen the prevention of NIS release from commercial vessels into California waters since its inception in 2000. A vital information-gathering component of the MISP is the requirement that all vessels greater than 300 gross registered tons and capable of carrying ballast water submit ballast water reporting forms upon departure from each port or place of call in California. These forms detail ballast water management activities for the approximately 10,000 annual vessel arrivals to CA ports, forming a robust data set through which compliance and management patterns can be examined. The use of GIS allows the MISP to assess ballast water management compliance on several levels, including the source and management (i.e. exchange) locations of all reported ballast water discharges into California waters. GIS analyses can also illustrate broad patterns and processes, such as noncompliant ballast water exchange discharge densities by location, which offer greater insight into potential NIS hotspots and areas of increased risk.

Ballast water management compliance data for the approximately five million metric tons of ballast discharged annually into the San Francisco Estuary from 2004-2013 will be presented. Trends involving the quantities and geographies of managed ballast water, where such ballast water has been exchanged, and where it has been discharged will be discussed. Such analyses provide valuable information that can inform the development of more effective ballast water management regulations, as well as inform both retrospective and predictive studies of NIS invasion patterns.

Keywords: invasive species, ballast water
Session Title: Species and Communities I: Community Response to Management **Session Time:** Thursday 1:00PM – 2:40PM Room 306

Trophic Integration of an Invasive Plant: Lepidium latifolium's Impact on the Suisun Song Sparrow Food Webs

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Over the last two decades, human-induced habitat changes, such as urbanization and introduced species, have degraded California's tidal wetlands. *Lepidium latifolium* (perennial pepperweed) is a pervasive invader of California wetlands, potentially altering ecological and community dynamics. This project assesses *L. latifolium*'s impact on food web structure for Suisun song sparrows (*Melospiza melodia maxillaris*) in the brackish tidal marsh of Rush Ranch Open Space Preserve, in the San Francisco Bay-Delta Estuary. Food web structure was assessed through analysis of invertebrate communities (soil infauna and canopy arthropods) and stable isotope analysis of bird blood and feathers. Invertebrate samples were taken in all four seasons within a randomly selected location in the marsh. Suisun song sparrow feather samples were taken in the winter and summer of 2011. Prior to *L. latifolium* bloom and during peak bloom, sparrow blood was sampled to examine tropic shifts associated with *L. latifolium* emergence. The infauna community at the site does not vary with presence of *L. latifolium*, but is structured by phonologic stage of the plant, with habitat zone (ie: fringing marsh, marsh plain, tidal marsh-terrestrial ecotone) significantly impacting abundance in the winter. The canopy-dwelling arthropod community follows a similar pattern of change across season, but this community is also structured by the emergence of *L. latifolium* in the summer. There is an isotopic shift in bird blood between winter (pre-*L. latifolium*) and summer (*L. latifolium* bloom). Mixing models suggest sparrows rely on *L. latifolium*-derived food sources more heavily in the summer months (breeding season) than in the winter months. We predict integration of *L. latifolium* into the food web of Suisun song sparrows, implying *L. latifolium* eradication should be paired with native plant restoration to avoid impacts on sensitive marsh vertebrates.

Keywords: food web, brackish marsh, invasion, *Lepidium latifolium*, Suisun song sparrow
Session Title: Species and Communities II: News from Suisun and the Bay
Session Time: Thursday 3:00PM – 4:40PM Room 306

Variation in Salinity Tolerance among Olympia Oyster Populations: Implications for Restoration in the Face of Climate Change

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Although seldom studied, genetic differences among marine populations may mediate a species' response to climate change. Understanding the extent of local adaptation (when populations become particularly adapted to their local environments through genetic differentiation) in species of special concern is particularly important for conservation and restoration planning in an era of accelerating climate change. We examined whether populations of native Olympia oysters (*Ostrea lurida*) in San Francisco and Tomales Bays are locally adapted to salinity, a factor predicted to shift with climate change. In a first experiment, we spawned oysters from three sites in San Francisco Bay and raised their offspring under common laboratory conditions. These juvenile oysters were then reciprocally transplanted among the three field sites. There was suggestive evidence that oysters of local origin survived better than oysters from other source populations, consistent with local adaptation within a single estuary. In a second experiment, we raised oysters from two sites in San Francisco Bay and one site in Tomales Bay through two generations under common laboratory conditions and then subjected these oysters to different salinity regimes in the laboratory. Oysters from the site with the lowest recorded field salinity had higher survival rates than the other two populations when faced with low salinity in the lab, showing that some populations are more robust against extreme low salinity events. As interest grows in restoring heavily impacted native oyster populations, our results suggest that considering local adaptation may be critical to deciding how and where to conserve and restore native oysters faced with changing ocean conditions. In particular, our results can aid in site selection for restoration, broodstock/source population selection, and prioritizing conservation of stress tolerant genotypes.

Keywords: Olympia oysters, local adaptation, salinity, climate change, restoration
Session Title: Species and Communities II: News from Suisun and the Bay
Session Time: Thursday 3:00PM – 4:40PM Room 306

California Gull Population Growth and Response to South Bay Salt Pond Restoration

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Since 1980, the San Francisco Bay Bird Observatory (SFBBO) has surveyed gull breeding colonies across South San Francisco Bay. This research has documented rapidly increasing numbers of California Gulls, which are the most abundant gull species in the area during the breeding season of many other waterbirds. California Gull populations have increased from only 24 in the early 1980s to over 50,000 in 2014. From 2011 to 2012, the Bay-wide California Gull population increased by nearly 40%, though we observed considerable variability in growth rates from one colony to the next. Simultaneously, we and others have documented declines in populations for many colonially-nesting waterbirds and shorebird species, including the federally-threatened Western Snowy Plover. Scientists at SFBBO, the USFWS and the US Geological Survey have shown that California Gulls consume the eggs and chicks of other waterbird species. Therefore, the rapid growth of California Gulls has been identified as one of the most pressing concerns for management of the San Francisco Bay estuary by SFBBO, by federal and state agencies charged with managing this ecosystem, and by the South Bay Salt Pond Restoration Project. In this talk, we will highlight changes in gull population growth at colonies across the South Bay, and discuss factors likely leading to the rapid growth observed at some colonies and slower growth at others. SFBBO has also monitored gull movements through banding and resight surveys. We present information on the movements of banded gulls, focusing on the responses to restoration of one particular salt pond, which formerly housed the largest California Gull colony in the area. Information on what drives gull population growth, and how gulls respond to restoration activities, helps land managers predict gull response and manage adaptively to the restoration of 15,000 acres of salt ponds in South San Francisco Bay.

Keywords: California Gulls, population growth, South Bay Salt Pond Restoration Project
Session Title: Species and Communities II: News from Suisun and the Bay
Session Time: Thursday 3:00PM – 4:40PM Room 306

Seeds, Space and Time: Assessing Plant Community Dispersal Dynamics in the South Bay Salt Pond Restoration Project

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In many tidal wetland restoration projects, un-assisted dispersal of seeds is expected to drive the development of plant communities. While sites are quickly colonized by pioneer species, the development of diverse plant communities may take much longer. Previous studies in lower salinity marshes in the North SF Bay indicate that un-assisted seed dispersal is likely to support the development of diverse communities, however evidence from higher salinity wetlands in Southern California show that seed availability may be greatly constrained in restoration projects. While un-assisted dispersal is the primary means of plant development in the South Bay Salt Pond Restoration Project, no detailed assessment of dispersal yet exists for newly breached areas. Here, we test two hypotheses related to seed dispersal at 3 restored and 3 reference sites at Eden Landing Ecological Reserve (ELER) in Hayward, CA: H1) Seed communities will exhibit evidence of distance decay of similarity, whereby areas geographically closer will be more similar in composition than those farther away H2) Reference sites will have overall higher densities of salt marsh seeds than restoration sites. To test H1, we examine the transition between a freshwater influenced area and an adjacent salt marsh area. We use Mantel tests to test for evidence of spatial autocorrelation, finding that both vegetation communities and seed communities are significantly influenced by space, supporting H1. Using paired t-tests, we find partial support for H2. Density of salt marsh species is significantly different between restored and reference sites in seed bank samples, but not in seed mat samples. This may be because drought limited seed production during the previous growing season, and points to the importance of seed bank development in restoration. These findings indicate that introducing dispersal-limited species into restoration projects may provide important local sources of propagules for developing sites.

Keywords: Salt Ponds, Restoration, Plant Communities, Dispersal, Diversity
Session Title: Species and Communities II: News from Suisun and the Bay
Session Time: Thursday 3:00PM – 4:40PM Room 306

Abiotic and Biotic Drivers of Native Pondweed (*Stuckenia* spp.) Distribution in Suisun Bay and the West Delta

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Over 1200 acres of native pondweeds (*Stuckenia* spp.) support high abundances of invertebrates along the migratory path for fish species of concern in Suisun Bay and the west Delta, yet patterns and processes in these beds are poorly understood. We explored abiotic and biotic factors that may influence current distribution and abundance patterns through field surveys and mesocosm experiments. We evaluated patterns in water quality parameters over a one-year period in both *Stuckenia*-dominated beds in Suisun Bay and invasive *Egeria densa*-dominated beds in the west Delta, and conducted experiments testing salinity tolerance, turbidity effects, and competition between *Stuckenia* and *Egeria*. Field data suggesting salinity is a major driver of plant distributions were supported by mesocosm results showing *Stuckenia* biomass increased 4-fold over 3 months at salinities of 0 and 5, doubled at 10, and maintained biomass at 15. In contrast, *Egeria* declined 5-fold in biomass at a salinity of 5 relative to the fresh water treatment, and decomposed within 3 weeks at salinities of 10 and 15. Competition may also be important in determining distributions at low salinities, as *Egeria* presence led to a 75% 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. Effects of turbidity tested on the two species showed enhanced growth and flowering for both under simulated future conditions of higher light availability. In addition to aiding in our understanding of current distribution and abundance patterns for 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.

Keywords*:* *Stuckenia*, Egeria, Suisun, salinity, turbidity, Suisun, SAV
Session Title: Species and Communities II: News from Suisun and the Bay
Session Time: Thursday 3:00PM – 4:40PM Room 306

Connecting Process Understanding, Field Observations, and Management Needs to Develop Mercury Cycling Models for the Delta and Yolo Bypass

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A key to creating useful mercury cycling models for the Delta and Yolo Bypass is building connections among modelers, scientists and managers as an integral part of the model development process. In response to recent Delta methylmercury Total Maximum Daily Load (TMDL) requirements, the Department of Water Resources is developing mercury cycling models for both the Delta and the Yolo Bypass. The Delta model will add sediment transport and mercury cycling submodels to an existing flow and water quality model, the Delta Simulation Model 2 (DSM2). The Yolo Bypass model will combine a newly developed TuFlow model of flows in the Bypass with the Dynamic Mercury Cycling Model (D-MCM). During the initial model development phase of these projects, the modelers have fostered connections with scientists and managers in order to create modeling tools that are scientifically sound and support management decision making. This talk explores the critical role that building connections as part of the model development process has in:

· understanding the physical, chemical and biological mercury cycling processes,
· evaluating available field data to support model calibration and validation,
· identifying knowledge and data gaps, and
· anticipating data products useful for addressing regulatory and management objectives.

Keywords: Model development, methylmercury, mercury cycling, sediment transport, TMDL, Yolo Bypass
Session Title: Conundrums in the Delta: Balancing Regulations, Beneficial Uses and Management Objectives
Session Time: Thursday 8:20AM – 10:00AM Room 307

Addressing the Delta Methylmercury Conundrum – Prioritizing Nonpoint Source Management Practices for On-site and Receiving Water Objectives

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Problem Statement: The Sacramento-San Joaquin Delta (Delta) provides multiple beneficial uses for humans and wildlife, some of which are impaired by elevated methylmercury (MeHg) concentrations bioaccumulated in fish. The Delta MeHg total maximum daily load (TMDL) implementation plan obligates dischargers to conduct MeHg control studies to address allocated load reductions.

Approach: Over 150 stakeholders representing MeHg nonpoint sources (NPS) recently collaborated to identify 24 management practices (MPs) for reducing MeHg production on-site and/or discharges off-site. MPs were divided into three categories: biogeochemistry (6), hydrology (14), and soil/vegetation (4). Applicable land uses were divided into six categories: permanently and seasonally flooded wetlands, flooded and irrigated agricultural lands, floodplains, and brackish-fresh tidal marshes. Stakeholders scored each MP-land use option by seven criteria: scientific certainty, costs, load reduction potential, spatial applicability, technical capacity to implement, negative impacts to beneficial uses, and conflicting requirements. Semi-quantitative scoring ("-" discouraging; "0" neutral; "+" encouraging) for applicable MPs (>400 individual scores) led to a consensus-based prioritization by diverse and accomplished NPS stakeholders of the most promising MPs for application or study.

Results: MPs that address hydrology and soil/vegetation were generally prioritized higher because experiences were positive and implementation appeared more feasible. Several other MPs were prioritized lower because they conflicted with other important management objectives.

Conclusions/Relevance: The prioritized suite of most promising MPs for study and application are described for use by all nonpoint source dischargers in the Delta. The management implications of these findings are that current regulations are presenting new obstacles to meeting current land management objectives. The scientific implication of this work is that MeHg control studies need to address the TMDL conundrum that MPs effective at reducing MeHg exports could exacerbate MeHg exposure on-site or conflict with other management objectives.

Keywords: methylmercury, nonpoint sources, TMDL, Delta, management practices, control study
Session Title: Conundrums in the Delta: Balancing Regulations, Beneficial Uses and Management Objectives
Session Time: Thursday 8:20AM – 10:00AM Room 307

Too Much or Too Little? Assessing the Impact of Reduced Nutrient Loading from Wastewater Effluent on Foodweb Dynamics in the Delta

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Prior studies suggest that ammonium in wastewater reduces phytoplankton growth rates and alters phytoplankton species composition in the Sacramento River and San Francisco Estuary, reducing available food stocks for endangered fish. To comply with its new discharge permit, the Sacramento Regional Wastewater Treatment Plant (SRWTP) is building a new tertiary treatment facility that will reduce its loadings of total nitrogen (including both ammonium and nitrate) to the Sacramento River. To better understand how effluent inputs to the Sacramento River affect nutrient and phytoplankton dynamics, we conducted Lagrangian-based sampling campaigns in the presence and absence of wastewater discharges, by coordinating wastewater holds with the SRWTP. Over six-day periods in October 2013 and May 2014 we tracked changes in water quality, nutrient concentration, phytoplankton concentration, and phytoplankton species composition in parcels of water representing normal wastewater discharge conditions (+WW) and no wastewater discharge conditions (-WW) as they traveled 45 miles from the City of Sacramento, past the SRWTP outfall by Freeport, past Isleton, and into the Cache Slough Complex. Results indicate that phytoplankton abundance declined with downstream travel both in the presence and in the absence of wastewater. This finding suggests that declines in phytoplankton concentrations observed as water travels past SRWTP and into the Delta may be attributable to other factors besides wastewater-derived ammonium. Expected reductions in nutrient inputs to the Delta due to changes in wastewater treatment plant operations need to be considered in combination with changes in hydrodynamics and biogeochemical cycling associated with large-scale tidal wetland restoration, as there is potential for there to be complex effects on food-web dynamics and ecosystem function.

Keywords: nutrients, foodweb, wastewater, ammonium, nitrate, phytoplankton, chlorophyll, nitrate
Session Title: Conundrums in the Delta: Balancing Regulations, Beneficial Uses and Management Objectives
Session Time: Thursday 8:20AM – 10:00AM Room 307

No Skeletons in this Closet—Identifying Key Drivers of Methylmercury Reductions in Municipal Wastewater Treatment Facilities in the Delta Region

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The Sacramento-San Joaquin Delta Methylmercury TMDL, effective since October 2011, requires all dischargers of methylmercury to the Delta to evaluate potential control strategies to reduce those loads. The Central Valley Clean Water Association (CVCWA) Methylmercury Special Project Group responded to this requirement with an organized, comprehensive evaluation of historical data from municipal wastewater treatment plants that employ a range of treatment processes. The Special Project Group includes all 14 wastewater treatment plants in the Delta and Yolo Bypass with NPDES permits that have been assigned load allocations under the TMDL, plus six NPDES facilities that discharge to Delta tributary watersheds. Members of the Special Project Group are all currently monitoring influent and effluent methylmercury monthly to supplement previously compiled data, while a subset are also monitoring in-process concentrations. Of particular interest are facilities that have monitored before and after treatment process changes. Consistent with one study hypothesis, effluent monitoring data indicate a strong positive correlation between nitrogen and methylmercury. Specifically, treatment facilities that provide nitrification and denitrification processes consistently show effluent methylmercury levels at or below method detection limits of 0.01 ng/L. These results, from a broad spectrum of municipal wastewater facilities throughout the Delta region, have important scientific and management implications statewide and nationwide: treatment processes that drive nitrogen removal will concomitantly remove methylmercury, and source controls (commonly thought to be an important component of municipal treatment facility mercury control strategies) are not effective at further impacting effluent concentrations.

Keywords: methylmercury, wastewater, treatment, nitrogen, nitrate, delta, TMDL, mercury, CVCWA
Session Title: Conundrums in the Delta: Balancing Regulations, Beneficial Uses and Management Objectives
Session Time: Thursday 8:20AM – 10:00AM Room 307

Using Permanent Wetlands as Polishing Ponds to Remove MeHg: Results of a Large Scale Replicated Field Experiment at the Yolo Bypass Wildlife Area

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Managed seasonal wetlands in the Yolo Wildlife Area (Davis, CA) typically export monomethylmercury (MMHg) during the fall inundation period. In this experiment, we routed tailwater on three separate years from a seasonal wetland through nine 100 m x 25 m constructed permanent ponds to examine the effects that residence time has on MMHg removal . The ponds were kept 1-m deep using an alternate water source from an adjacent ditch prior to receiving the tailwater. We measured unfiltered and filtered total mercury and MMHg as well as nutrients, suspended sediment, and dissolved organic carbon in each of the receiving ponds and tailwater. Pond residence times were estimated, under different flow regimes, using Rhodamine dye as a pulsed tracer and YSI sondes with Rhodamine sensors. Conductivity was used to cross-validate the residence time estimates during the initial pulse of tailwater into the ponds. Residence times ranged from as short as 0.7 days up to 13.0 days in each pond (Q = 0.08 cfs – 1.39 cfs) and was controlled using V-notch risers. Reductions of dissolved MMHg concentrations were 0.024 ng L^{-1} d^{-1}– 0.455 ng L^{-1} d^{-1} and particulate MMHg reductions were 0.028 ng L^{-1} d^{-1} –1.02 ng L^{-1} d^{-1} in the constructed ponds. The constructed ponds were also effective at reducing tailwater total suspended sediments (0.21 mg L^{-1} d^{-1}– 9.13 mg L^{-1} d^{-1}). There was no net additional reductions in MMHg typically >14 days past the initial pulse, which usually occurred mid-November, when tailwater MeHg concentrations are much lower and at equilibrium with the pond water (0.30 ng L^{-1}– 0.40 ng L^{-1}). These results suggests small ponds with short residence times can be efficient at removing MMHg; however, the size of actual ponds will vary depending on the volume of wetland being drained and needs of the wetland manager.

Keywords: Mercury, Methylmercury, Polishing Ponds, Wetland Management
Session Title: Conundrums in the Delta: Balancing Regulations, Beneficial Uses and Management Objectives
Session Time: Thursday 8:20AM – 10:00AM Room 307

Understanding Nitrogen Assimilation and Inhibition in Cultures of *Microcystis aeruginosa*: Implications for Cyanobacterial Bloom Development in the San Francisco Delta

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The magnitude of toxigenic *Microcystis aeruginosa* blooms have increased in the San Francisco Delta (Delta) over the last decade. Although never directly tested in the Delta, the availability of different chemical forms of nitrogen (N) may play a role in promoting *Microcystis* blooms. Our field studies show that *M. aeruginosa*-dominated communities have higher rates of ammonium (NH_4) uptake than nitrate (NO_3), urea or glutamate, suggesting a competitive advantage over phytoplankton such as diatoms, which have high NO_3 uptake rates. NH_4 often inhibits algal NO_3 uptake but it is unknown whether inhibition occurs with *M. aeruginosa*. If *M. aeruginosa* does not experience NH_4 inhibition, this would provide a growth advantage over other algal species since it could equally access both NO_3 and NH_4 pools. The goal of this study was to investigate inhibition phenomena in *M. aeruginosa*. Short-term (0.5 hour) experiments were conducted using non-toxic and toxic strains of *M. aeruginosa* to study whether NH_4 inhibited NO_3 or urea uptake, or if NO_3 inhibited NH_4 uptake. Our results suggest that the non-toxic strain exhibited urea inhibition by NH_4 but no inhibition of NO_3 or NH_4 uptake. Conversely, the toxic strain showed inhibition of uptake by all forms of N; NH_4 inhibited NO_3 and urea uptake, and NO_3 inhibited NH_4 uptake. The strain-specific responses imply that there may be an interaction between toxin production and N uptake. The lack of inhibition of NO_3 and NH_4 uptake with the non-toxic strain may provide a competitive advantage for N uptake over toxic *M. aeruginosa* strains and other algal species. Understanding how *M. aeruginosa* reacts to various N species and concentrations provides insight on its potential for growth and bloom formation in environments with increasing anthropogenic N. These results can inform management in mitigating these cyanobacterial blooms that have negative effects on the Delta.

Keywords: *Microcystis aeruginosa*, nitrogen uptake, ammonium inhibition
Session Title: Food Webs III: When Things Get Toxic
Session Time: Thursday 10:20AM – 12:00PM Room 307

Ecotoxicological Effects of Microplastic and Priority Pollutants in a Bay-Delta Food Chain

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Plastic debris has been documented in the Bay-Delta. To mitigate the problem, storm drain systems are currently undergoing modification to remove larger material, but much of this debris is likely microplastic. Because plastic debris is associated with large concentrations of persistent, bioaccumulative and toxic (PBT) chemicals, the combination of microplastic and PBTs are likely ingested by Bay-Delta organisms. Ingestion of microplastic provides a pathway for PBTs to biomagnify in higher trophic levels, with uncertain health effects. There is no information on the extent to which ingesting microplastics may enhance biomagnification or cause ecological impacts in aquatic foodwebs. To provide a fundamental understanding of how microplastic affects PBT transfer into Bay-Delta food chains and how microplastic affects the health of Bay-Delta organisms we designed an experiment using Asian clams (*Corbicula fluminea*) and white sturgeon (*Acipenser transmontanus*). We aim to quantify the pathway for microplastics to transfer sorbed PCBs to prey, measure the chemical transfer of PCBs from prey to a predator and determine how ingestion of various polymers, with and without PCBs, affects organismal health. Asian clams will be exposed for 30 days to separate treatments of microplastic (polyethylene terephthalate, polyethylene, polyvinyl chloride and polystyrene) with and without sorbed PCBs. Next, diets will be formulated using purified ingredients and clams from the first exposure and will be fed to their predators (sturgeon) for 30 days. Chemical analyses (GC/MS) will track concentrations of PCB congeners from microsplastic in animal tissues, allowing us to measure bioaccumulation and biomagnification. Toxicological assays will provide important understanding about whether ingesting microplastic with and without PCBs affects their health. Our work will provide original understanding of the capacity of different microplastics and PCBs to act as multiple stressors in Bay-Delta foodwebs. Experiments are currently under way, and results to date will be presented.

Keywords: plastic debris, Asian clam, sturgeon, food web, PCBs, bioaccumulation, microplastic
Session Title: Food Webs III: When Things Get Toxic
Session Time: Thursday 10:20AM – 12:00PM Room 307

The Future of *Microcystis* spp. in the San Francisco Estuary Delta: Investigations into the Role of Temperature and Salinity Tolerance on Growth

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Increases in both water temperature and salinity predicted under climate change are hypothesized to promote cyanobacteria blooms in estuaries globally. In the San Francisco Estuary Delta (Delta) such a shift to cyanobacterial dominance may already be occurring. Since 1999 blooms of the toxigenic cyanobacterium *Microcystis aeruginosa* have been observed during the summer, with negative consequences for water quality and the estuarine food web. With the goal of understanding how variations in water temperature and salinity may influence present and future cyanobacteria success in the Delta, a series of small bottle experiments were conducted using field collected phytoplankton, including cyanobacteria-dominant assemblages. The influence of temperature and salinity on phytoplankton community biomass and composition was assessed by phytoplankton size structure, direct microscopy and photosynthetic pigment analysis using high-performance liquid chromatography. Of the phytoplankton groups, cyanobacteria grew at higher temperatures and were tolerant of substantially higher salinities than ambient conditions in the Delta habitats where they were observed. These results linking cyanobacteria to conditions associated with predicted climate change provide insight into potential future habitat expansion and microbial community shifts toward cyanobacterial dominance in the Delta.

Keywords*: Microcystis aeruginosa*, temperature, salinity, climate change, HPLC, cyanobacteria
Session Title: Food Webs III: When Things Get Toxic
Session Time: Thursday 10:20AM – 12:00PM Room 307

The Distribution, Ecology and Genetics of *Microcystis* Blooms Throughout the San Francisco Bay Delta

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Problem statement: The on-going decline of the planktonic food web and several important Bay Delta fishes, collectively termed the pelagic organism decline (POD), temporally coincides with the establishment and persistence of cyanobacterial harmful algal blooms (CyanoHABs) that have occurred annually since the early 2000's. We aimed to assess how these CyanoHABs may be directly or indirectly influencing the food web structure within the Delta.

Approach: One component of this work was to better understand the ecology and physiological potential of these cyanobacterial assemblages. We employed a suite of molecular analyses, including: quantitative PCR to track the distribution of toxic and nontoxic cells over time and space, DNA fingerprinting by 454 pyrosequencing to track the origins and fates of *Microcystis* sub-populations (strains), and shotgun metagenomics and genome assembly to assess their genetic capabilities.

Results: This work identified the presence of at least eight *Microcystis* strains within the Delta, as well as the genetic pathways required to produce a wide variety of secondary metabolites thought to negatively affect the fitness and fecundity of herbivorous zooplankton. Additionally, cyanobacterial blooms were observed to influence microbial community structure within the Delta, resulting in a nearly 50% reduction in total microbial diversity observed during bloom events.

Conclusions/Relevance: Future studies are needed to directly quantify the impacts of cyanobacterial secondary metabolites on keystone zooplankton within the Bay Delta. Additionally, we posit that competitive displacement of more nutritious algae such as diatoms, flagellates and green algae may also confer indirect negative effects on zooplankton fitness, which in turn may influence the POD. Restoration and management strategies should aim to reduce the magnitude of cyanobacterial blooms sustained within the Bay Delta by limiting total nitrogen and phosphorus inputs and by increasing the flow rates through the flooded islands, which appear to be "hot beds" for cyanobacterial blooms.

Keywords: Cyanobacterial blooms, toxicity, genetics, pelagic organism decline, zooplankton, food web
Session Title: Food Webs III: When Things Get Toxic
Session Time: Thursday 10:20AM – 12:00PM Room 307

Pesticide Mixture Toxicity Assessments Differ Between Single Species Tests and Mesocosm Studies

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Water pollution is a major threat to biological diversity worldwide. Increased pesticide use, and their application as mixtures, is one of many drivers affecting habitat health. Most data used in risk assessment of pesticides are based on single species tests using single substances, at concentrations that are usually not environmentally realistic, with few assessments including sublethal endpoints.

In order to bridge the gap between laboratory toxicity tests using individual chemicals, and the effects of mixture toxicity on aquatic ecosystems, we first conducted 10-day toxicity assessments of single and combined exposures of three commonly used insecticides: two pyrethroids; lambda-cyhalothrin and permethrin, and one organophosphate; chlorpyrifos, on lethal and sublethal effects on *Chironomus dilutus* and *Hyalella azteca*, two important ecotoxicological testing organisms. We then evaluated these conditions on community composition within a 6-month multi-species field study using mesocosms, composed of naturally developed invertebrate communities.

In the laboratory-based single-species tests, growth and motility were significantly affected at ecologically relevant concentrations. The effects of mixture exposures, at relative toxic concentrations, were less severe than those observed in the single exposures. In the mesocosms, the effects of a series of applications of tertiary contaminant mixtures resulted in significant decrease of *H. azteca* population, and zooplankton species such as copepods and cladocera. The lethal concentrations determined in single-species tests in the laboratory do not necessarily reflect the effects predicted in the environment. By using lab-based toxicity tests it is possible to determine ecologically relevant sublethal effects under controlled conditions within a very short period of time. Mesocosms on the other hand allow us to evaluate long-term community and food-web effects. Both approaches provide essential information for understanding mixture toxicity and evaluating their effects on aquatic ecosystems, which can be used in risk-assessments of contaminants of concern.
Keywords: aquatic communities, mesocosms, pesticide mixtures, single-species testing, toxicity tests, food-webs
Session Title: Food Webs III: When Things Get Toxic
Session Time: Thursday 10:20AM – 12:00PM Room 307

It's the Economy, Stupid: How the Great Recession May Increase the Risk of Shipping-Mediated Introductions of Nonindigenous Species into the San Francisco Bay-Delta

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Commercial shipping activity is recognized as a major pathway for the introduction of nonindigenous species (NIS) into coastal waters around the globe, including the San Francisco Bay-Delta (SFBD). Ship biofouling (i.e. the attachment or association of aquatic organisms to underwater ship surfaces) has been identified as the most potent coastal vector of species introductions in many parts of the world and, unlike ship ballast water, biofouling is often unregulated.

A major side-effect of the recent Great Recession was a dramatic reduction in shipping activity resulting from fewer goods being purchased and shipped around the globe. Many ships were effectively unemployed, waiting at anchor in long-term layup for a rebounding economy and more goods to deliver. For those vessels that continued to trade during the recession, the fuel saving practice of "slow steaming" (i.e. traveling slower to reduce overall fuel consumption) became more commonplace, and continues for many vessels through the economic recovery today. Unfortunately, the practices of remaining stationary for prolonged periods of time in coastal environments and traveling at slow speeds increase the likelihood of biofouling accumulation and organism survival on ships. The prevalence of these practices was evaluated for ships arriving to ports within the SFBD using ship-reported data submitted annually from 2008-2013. An annual increase in the number and duration of extended residency periods, as well as a year-over-year reduction in the mean traveling speed of vessels that have arrived at ports within the SFBD was observed. These recession-exacerbated risk factors are likely increasing the probability of biofouling colonization on ships and the transportation of NIS into California. These results are being used to inform the development and eventual implementation of biofouling management regulations to reduce the likelihood of biofouling-mediated introductions of NIS into California.

Keywords: Nonindigenous, invasive, species, shipping, biofouling, hull, vector, slow steaming, layup
Session Title: Water Policy: Predicting Outcomes
Session Time: Thursday 1:00PM – 2:40PM Room 307

Projected Impacts of Climate, Urbanization, and Water Management on Waterfowl Habitats and Ecology in California

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

Keywords: waterbirds, WEAP model, Central Valley, habitat, bioenergetics, CVJV, water supplies
Session Title: Water Policy: Predicting Outcomes
Session Time: Thursday 1:00PM – 2:40PM Room 307

Agricultural Losses from Salinity in California's Sacramento-San Joaquin Delta

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Sea level rise, flooding, new exports infrastructure may increase future water salinity for local agricultural production in California's Sacramento-San Joaquin Delta. Increasing salinity in crop root zones often decreases crop yields and crop revenues. Salinity effects are nonlinear and vary with crop choice and other factors including drainage and residence time of irrigation water. We explore changes in agricultural production in the Delta under various combinations of water management, large-scale flooding and future sea level rise. Water export alternatives include through-Delta water exports, dual conveyance (through a peripheral tunnel or canal) and the flooding of five western islands with and without peripheral exports. We employ results from previous hydrodynamic simulations of likely changes in salinity for irrigation water at points in the Delta. We connect these irrigation water salinity values into a detailed agro-economic model of Delta agriculture to estimate local crop yield and farm revenue losses. Previous hydrodynamic modeling work shows that sea level rise is likely to increase salinity from 4% to 130% in this century, depending on the increase in sea level and location. Changes in water management under dual conveyance increase salinity mostly in the western Delta, and to a lesser extent in the north, where current salinity levels are now quite low. Because locations likely to experience the largest salinity increases already have a lower-value crop mix, the worst case losses are less than one percent of total Delta crop revenues. This result also holds for salinity increases from permanent flooding of western islands that serve as a salinity barrier. Salinity increases could have smaller economic effects on Delta farming than other changes in the Delta such as retirement of agricultural lands following large-scale flooding and habitat development. Integrating hydrodynamic, water salinity, and economic models can provide insights into controversial management issues.

Keywords: Salinity, Hydro-Economic Models, Agriculture; Habitat, Climate Change, Sea Level, Flooding
Session Title: Water Policy: Predicting Outcomes
Session Time: Thursday 1:00PM – 2:40PM Room 307

Ensuing Delta Wetland Restoration Heightens Water Quality Concerns for Southern California… or Not?

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Delta carbon quality, cycling dynamics, and bioavailability are key considerations for fisheries restoration and for drinking water management. But what happens when Delta carbon is exported south? Will carbon exported from Delta habitat restoration efforts cause a surge in toxic disinfection byproducts in Southern California's drinking water supply? This is the final study in a series of investigations of organic carbon along California's State Water Project (SWP) aqueduct and associated reservoirs. The study traces an assembly of chemical biomarkers and other water quality parameters, including lignin derived phenols, fatty acids, stable carbon isotopes, bioavailability, disinfection byproduct formation potential, and others as they advect from the Delta through SWP facilities. Taken together, these parameters enable close examination of organic carbon degradation and production trends within the SWP.

Given the weeks-to-months residence time that Delta water spends in the SWP, plus major and minor algae blooms, photoxidation, bacterial degradation and assimilation, the study underscores the potentially significant roles of organic carbon production and degradation in the SWP. Carbon turnover appears to vary seasonally and based on flow rate/residence time within the SWP system. Periods of especially high carbon export from the Delta frequently (though not religiously) coincide with SWP management actions that support longer residence times – for example, routing of Delta water to storage during wet winter months. Key insights regarding Bay-Delta management and ecosystem sustainability include what appears to be at least a partial disconnect between Delta carbon export and the transport of Delta carbon to Southern California. At the same time, organic carbon production within the SWP may offset such losses.

Keywords: Delta, Restoration, Organic Carbon, Disinfection Byproduct, Carbon Export, Wetlands
Session Title: Water Policy: Predicting Outcomes
Session Time: Thursday 1:00PM – 2:40PM Room 307

Operational Ecosystem Modeling to Support Adaptive Management – Lessons from 40 Years of Decision Support for the Great Lakes

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Problem statement: Managing large interconnected systems of water bodies presents complex challenges; model simulations are essential to assessing causes of ecological outcomes, and effects of changes in management and ambient conditions. For many years, the Great Lakes community has used models to support management. Models were used reactively in the 1970s to develop target phosphorus loads to address eutrophication, the adoption of which in the Great Lakes Water Quality Agreement (GLWQA) restored the health of the Lakes. The reemergence of eutrophication in response to the introduction of invasive species has made apparent the limitations of reactive approaches.

Approach: To stay abreast of emerging problems, proactive adaptive management is needed. Scenario-type ecological forecasts can support adaptive management, simulating operational actions using integrated ecosystem models. Models that integrate flows, water chemistry, and ecological outcomes translate data into understanding and support decisions through simulation of management alternatives. An "Operational Ecosystem Modeling" approach has been developed for Saginaw Bay in Lake Huron on behalf of NOAA to help meet the requirements of the GLWQA 2012 Protocol, which calls for adaptive management to deal with harmful algal blooms.

Results: Invasive dreissenids play an important role through their impact on light, plankton production, and phosphorus cycling, but the key is reducing nonpoint source loads of bioavailable phosphorus. The scenario simulations show that phosphorus load reductions on the order of 50 - 75% are needed to reduce harmful algal blooms to acceptable levels.

Conclusions/Relevance: The complexity of the Bay Delta system presents similar challenges. Adaptive management is critical for this system, given climate change and other uncertainties, and can be supported by operational ecosystem modeling to help understand outcomes and recalibrate actions as the system responds. The presentation will provide real-world lessons learned about the potential power of integrated modeling as part of an adaptive management approach.

Keywords: Adaptive Management, Decision Support, Invasive Species, Eutrophication, Operational Ecosystem Modeling
Session Title: Water Policy: Predicting Outcomes
Session Time: Thursday 1:00PM – 2:40PM Room 307

Reconciling Fish, Farms and Fowl on the Yolo Bypass

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Traditional habitat restoration that attempts to recreate pre-development conditions within a protected area is no longer possible at large enough geographic scales in California for the diversity of native species that currently lack sustainable habitats. Reconciliation ecology recognizes this reality and encourages land and water managers to re-engineer human-dominated landscapes to be more inclusive of native species' preferences without eliminating human uses. California's Yolo Bypass, an engineered floodplain on the Sacramento River, is an excellent case study for this new approach to native species management. This talk presents results from a multi-objective analysis of the Yolo Bypass to suggest approaches that balance economic and ecological objectives for a wide array of species. Results suggest that significant habitat improvement is possible with little annual economic losses for farmers, and further that agricultural land uses can prove important and useful in the habitat mosaic for fish and birds on the bypass.

Keywords: floodplain, reconciliation, multiobjective modeling, Yolo Bypass
Session Title: Water Policy: Working Towards Reconciliation
Session Time: Thursday 3:00PM – 4:40PM Room 307

Fish, Farms, and Fowl on the Yolo Bypass: Measuring the Benefits and Impacts of Floodplain Restoration

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The Yolo bypass is a multi-benefit flood management facility intentionally managed to reduce flood risk for Sacramento, provide habitat for migratory birds, and produce agricultural crops. Research demonstrating the value of inundated floodplain for juvenile salmon has led state and federal agencies to consider changes to Fremont Weir that would allow active management of the bypass for fisheries benefits in addition to its other purposes. Fremont Weir is a 1.75 mile-long, seven-foot high concrete structure located at the upstream end of the Yolo Bypass, which passively allows water to flow into the bypass only when the stage of the Sacramento River exceeds 33.5 feet – the elevation of the weir crest. State and federal planners are now evaluating designs that would create an operable, gated-opening in Fremont Weir to allow fish and floodwaters onto the bypass when flows are significantly below the crest of the weir. Farmers and waterfowl managers are concerned that more frequent inundation would reduce benefits for agriculture and waterfowl. We used the estimated annual habitat (EAH) method to evaluate the benefits and impacts of different scenarios on fish, waterfowl, and agriculture. EAH quantifies the area of floodplain inundated for a specified duration, timing, and frequency and is useful in determining the suitability of a floodplain as "habitat" for fish, wildlife, or even agricultural crop species. Operational scenarios that keep the proposed weir gate open later in the spring provide greater benefit for fish but with more impact to agriculture and waterfowl. The total benefits and impacts of later opening is limited, however, because late season inundation already occurs under existing conditions when high flows spill over the weir crest in wet years. Operations of a gated-opening, however, could allow better management of these late season events for fish while minimizing new impacts to agriculture and waterfowl.

Keywords: Yolo Bypass, Floodplain Habitat, Agricultural Impacts, Operable Weir, EAH
Session Title: Water Policy: Working Towards Reconciliation
Session Time: Thursday 3:00PM – 4:40PM Room 307

Measuring the Compatibility of Agricultural Crops with Periodic Floodplain Inundation on the Lower San Joaquin River

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Restoration of inundated floodplain habitat is essential to the restoration of Chinook salmon populations and other fish and wildlife species in California and beyond. Several state and federal plans call for the restoration of thousands of acres of floodplain habitat in the Central Valley of California, but farmers fear that floodplain restoration activities would diminish agricultural production.

We combined coarse economic analysis with a newly developed approach for measuring floodplain habitat suitability to quantify the suitability of periodically inundated floodplains for various agricultural crops. The estimated annual habitat (EAH) method (Matella and Jagt, 2013) generates area-duration-frequency (ADF) curves to quantify the area of floodplain inundated for a specified duration, timing, and frequency and can thus be useful in determining the suitability of a floodplain as "habitat" for a wild species or a cultivated agricultural crop. We plotted the timing, frequency, and duration of inundation on floodplain lands along the lower San Joaquin River and compared it to cropping patterns and inundation tolerances of the agricultural crops planted on the same lands. We then used production value data to estimate how fully removing levees might impact agricultural production values. Due to extreme hydrograph alteration by upstream dams, the impact of levee removal on agricultural production value is surprisingly small. For example, a late May 15,000 cfs flood event (occurring approximately 1 in 7 years) would decrease production value by $4 million.

This analysis demonstrates that it may be possible to advance floodplain restoration for fish and bird habitat during the winter months without significantly impacting agricultural activities during the growing season. More broadly it demonstrates how the EAH method can be used to calculate the benefits that levees provide for agricultural production.

Keywords: agriculture, floodplain restoration, reconciliation, estimated annual habitat (EAH) method
Session Title: Water Policy: Working Towards Reconciliation
Session Time: Thursday 3:00PM – 4:40PM Room 307

Building Capacity for Multi-Benefit Water Management: Governance Arrangements in California's Integrated Regional Water Management Process

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Sustainable management of the Bay-Delta system depends upon building multi-benefit strategies across the state that reduce pressure on the Bay-Delta ecosystem, while also supporting more reliable water supplies. The Integrated Regional Water Management (IRWM) program is intended to help accomplish this by fostering collaborative planning among diverse local interests at regional scales. Supported by $1.5 billion in bond funds, 48 IRWM regions have formed over the past decade, including 17 in the Sacramento and San Joaquin River basins. So far, there has been little study of the functioning and outcomes of these regional collaborations. In particular, the success of the IRWM process depends upon sustained engagement from participants with diverse but interdependent interests. Yet, previous research suggests that collaborations with more diverse participation can be more difficult to manage and sustain. What is the extent of participation in IRWM planning, and what governance arrangements are most effective at sustaining diverse engagement?

I explore these questions through an analysis of participation and governance structures in 19 IRWM regions. Drawing upon a review of governance documents and interviews with over 70 IRWM participants, I find that sustaining partnerships between stakeholders with diverse interests requires a significant, on-going investment in coordination, brokering, and outreach activities. Regional governance structures must support undertaking these activities in a manner that advances the interests of all participants. My research indicates that IRWM regions investing the most in coordination activities are managed by a lead agency with a relatively broad mandate and a scale of operations that matches the IRWM region. Regions without such entities have either formed new organizations or share coordination tasks, but often face challenges in sustaining these arrangements. These findings provide insights into the governance structures needed to help generate multi-benefit approaches that balance water supply and ecosystem needs.

Keywords: collaboration, local partnerships, multiple benefits, watershed management, regional planning
Session Title: Water Policy: Working Towards Reconciliation
Session Time: Thursday 3:00PM – 4:40PM Room 307

The Untapped Potential of California's Water Supply: Efficiency, Reuse, and Stormwater

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For much of the 20th century, California's water supply strategy has meant building reservoirs and conveyance systems to store and divert surface waters, and drilling groundwater wells to tap our aquifers. Hundreds of billions of federal, state, and local dollars have been invested in these supply options, allowing the state to grow to nearly 40 million people with a $2 trillion economy. But traditional supply options are tapped out. Rivers are over-allocated even in wet years. There is a dearth of new options for surface reservoirs, and those that exist are expensive, politically controversial, and offer only modest improvements in water supply for a relatively few users. Groundwater is so severely overdrafted that there are growing tensions among neighbors and damage to public roads, structures, and, ironically, water delivery canals from the land subsiding over depleted aquifers.

But solutions to our water problem exist. They are being implemented to varying degrees around the state with good results, with the potential to do much more. The Natural Resources Defense Council, Pacific Institute, and UC Santa Barbara Professor Robert Wilkinson examined the opportunities for four cost-effective and technically feasible strategies -- urban and agricultural water conservation and efficiency, water reuse, and stormwater capture -- to improve the ability of cities, farmers, homeowners, and businesses to cope with drought and address longstanding water challenges in California. The analysis concludes that these strategies can provide 10.8 million to 13.7 million acre-feet per year of water in new supplies and demand reductions, improving the reliability of our current system and reducing the risks of shortages and water conflicts.

The analysis also examines the extent to which California overdrafts groundwater basins and exceeds sustainable levels of diversion from the Delta watershed on an average basis, and the ability of these strategies to fill that gap.

Keywords: water use efficiency, reuse, recycling, stormwater capture, groundwater overdraft, Delta
Session Title: Water Policy: Working Towards Reconciliation
Session Time: Thursday 3:00PM – 4:40PM Room 307

Severe Storms and California's Fragile Delta—Historical Impacts and a New Monitoring Network

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Problem: Over the past century, California's Sacramento-San Joaquin Delta has been re-engineered to be an important center for water supplies, utilities and transportation, and agriculture. As important and engineered as it is, the Delta is also an increasingly fragile system with aging levees, subsiding land surfaces, declining ecosystems, and many invading species. Severe storms and floods pose great risks to the levees and other infrastructures in the Delta, but have necessary roles in biogeomorphological processes that will need to be restored if ecosystems are to be protected and restored. Of particular concern are severe storms associated with atmospheric rivers (ARs) that, since 1950, have caused 80% of major floods, 76% of inundations of the Yolo Bypass floodplain, and 81% of levee breaks in the Central Valley.

Approach: Because of the critical role of severe storms and especially ARs in the Delta, a new severe-storm monitoring network is being implemented across the Delta catchment and much of California by the Department of Water Resources, NOAA, and Scripps Institution of Oceanography. The network is intended to provide more precise now-casting of critical but previously under-monitored storm characteristics, like rapidly evolving snowlines, barrier jets, and patterns of moisture transport into the State, characteristics that will enable enhanced storm- and flood-forecasts.

Results: The network is now nearly complete, and relies on new radar, sounder, and GPS technologies installed strategically throughout the State. The network has room for additional technological extensions, including some being demonstrated in upcoming field campaigns flying research aircraft offshore into the hearts of approaching ARs.

Conclusions: The network–especially in the context of a new science center at Scripps focusing on extreme weather and water events--constitutes a major step toward enhancing California's ability to anticipate and manage both flood benefits and flood risks in the Delta and its watershed.

Keywords: storms, monitoring, floods, levees, climate
Session Title: Understanding Effects of Climate Change on the Bay-Delta
Session Time: Thursday 8:20AM – 10:00AM Room 308-310

The Next Generation of 21st Century Coastal Flood Maps for San Francisco Bay

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Climate change over the course of the 21st century and beyond will have significant physical and socioeconomic impacts on the low-lying San Francisco Bay margin due to sea level rise (SLR) and the potential variability in storminess and tributary discharge. Most studies of coastal flooding vulnerability in the region consider sea level rise only, typically applying a bath-tub type approach, which omits several key physical-forcing factors that elevate flood levels, such as in-Bay generated waves and fluvial discharge. Here we present a new modeling approach that considers all the relevant factors that contribute to San Francisco Bay flood extents during the 21st century, and highlight areas of the Bay that are highly susceptible to present and future flooding.

The Coastal Storm Modeling System (CoSMoS) is a numerical modeling system developed to predict coastal flooding due to both SLR and plausible 21st century storms. CoSMoS applies a predominantly deterministic framework that encompasses large geographic scales (100s to 1000s of kilometers) yet reduces flood extents to fine-scale local resolution (2 m) so that storm related changes in water levels at the shore can be resolved. Several important processes contribute to total water levels within the Bay. Specifically, efforts were made to incorporate water level fluctuations in response to trapped coastal waves, low pressure systems, ocean swell energy penetrating through the Golden Gate, breaking of locally wind-generated waves, and backflow induced by river discharge. The end product is a web-based tool (www.prbo.org/ocof) where users can assess variations in flood extent, maximum flood depth, maximum current velocities and wave heights in response to a number of potential SLR and storm combinations.

Keywords: climate change, flooding, modeling, San Francisco Bay, waves
Session Title: Understanding Effects of Climate Change on the Bay-Delta
Session Time: Thursday 8:20AM – 10:00AM Room 308-310

The Diminishing Odds of 'Normal' Snow Packs as California Warms

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A substantial portion of the inflow to the San Francisco Bay and Delta derives from mountain snowmelt, but California snow packs vary considerably from year to year. Year-to-year values of spring snow water content has varied, historically, by a factor of nearly 10 (as estimated from VIC hydrological model simulations). This variation has been due mostly to interannual precipitation fluctuations, and only incrementally from temperature fluctuations. However, this mix of precipitation and temperature influences is projected to shift. As climate warms, which is very likely as atmospheric greenhouse gas concentrations increase, the spring and early summer snowpack will decline substantially. The effects of projected climate changes on the odds of various snow pack volumes is being explored using an ensemble of downscaled climate-change projections under two emissions scenarios. With this ensemble, we can address important questions like: *a)* How do the odds of obtaining spring snow-water volumes that meet or exceed the historical median change with time or, as usefully, with level of warming? *b)* And even more pressingly, what are the odds that the snow pack is very small in any given year? Among the projections included in this ensemble, warmings range from +1°C to more than +3°C by 2100. Projected precipitation shows the "normal" high level of year-to-year variability over the region with very modest trend, much like the historical record. Although precipitation fluctuations continue to contribute strongly, the temperature influence in diminishing spring snowpack becomes increasingly strong as the 21st Century unfolds. Notably, the simulated dependence of California-wide spring snow water content on seasonal temperature change is nearly linear over the range of changes represented in the ensemble, and a rule of thumb that emerges is that California loses about 25% of present-day spring snow pack for each 1°C of warming.

Keywords: snow, runoff, climate change
Session Title: Understanding Effects of Climate Change on the Bay-Delta
Session Time: Thursday 8:20AM – 10:00AM Room 308-310

Implications of Water Temperatures from Climate Change Projections for Delta Smelt in the Sacramento-San Joaquin Delta, California

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We assessed the possible effects on Delta Smelt *Hypomesus transpacificus* of water temperatures calculated from four 100-year scenarios of climate change at nine locations in the Sacramento-San Joaquin Delta. Results from two regional climate models at two levels of greenhouse gas emissions were used to calculate water temperatures, using location-specific regression models. We compared modeled daily maximum water temperatures to recently derived laboratory measurements of thermal maxima for four life stages of Delta Smelt: larvae (March-June), juveniles (June-December), adults (December-March), and spawning adults (March-May). We also compared modeled average daily water temperatures to 25°C, a temperature beyond which few Delta Smelt are captured in surveys. The juvenile life stage was the most vulnerable to climate change because of high summer water temperatures particularly in July and August. The upper San Joaquin River upstream of Stockton was the most unfavorable area for juveniles with temperatures exceeding the chronic lethal thermal maximum (CLTmax) for 50 percent mortality (27°C) under even the mildest climate change scenario. The Sacramento River corridor was more favorable but water temperatures still exceeded the threshold at times. The CLTmax for 95 percent mortality (28°C) and the critical thermal maximum (CTM; acute mortality) (29°C) were rarely exceeded except in the upper San Joaquin River. For the most severe scenario, beyond 2060, the CLTmax for 95 percent mortality or critical thermal maximum of juveniles was regularly exceeded for several days per year at all sites, except in Suisun Bay. Exceedances of the 25°C threshold were more common than exceedances of lethal temperatures, suggesting the 25°C threshold may be an indicator of behavioral avoidance of areas likely to become lethal. Our results suggest that climate change is likely to reduce available habitat for Delta Smelt.

Keywords: Delta Smelt, climate change, water temperature, thermal tolerance
Session Title: Understanding Effects of Climate Change on the Bay-Delta
Session Time: Thursday 8:20AM – 10:00AM Room 308-310

Water Temperatures in the North Delta: What Does the Future Hold for Delta Smelt?

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The Northern Sacramento-San Joaquin Delta is a vital confluence for the endangered Delta smelt *Hypomesus transpacificus*, associated habitat restoration proposals, and potential future hydrologic changes related to climate change and water management proposals. Current climate change forecasts indicate potential changes in habitat parameters including sediment, turbidity, and water temperature. These climate change forecasts, coupled with physiological limits for sensitive species such as the Delta smelt, suggest decreasing habitat into the future. The forecasts thus far, however, are spatially limited and do not consider potential thermal refugia. Additionally, water temperature at a particular location is controlled by atmospheric conditions, tidal dispersion, and riverine flows, but current water temperature forecast models do not consider freshwater flow as a variable. Given the climate forecasts for reduced snowmelt and more frequent, longer duration drought conditions, the effects of low freshwater flows on North Delta water temperatures should be considered. This presentation will discuss the water temperature characteristics from multiple continuous monitoring locations in the North Delta specifically from 2011 (a wet year) and 2014 (a critically dry year) while connecting potential implications of future management proposals and comparing water temperature models to observed conditions. Cooler, favorable water temperatures in 2011 were a result of higher flows. In contrast, during 2014, in Miner Slough, water exceeded the favorable temperature threshold for Delta smelt as early as April and exceeded 20^{o}C and pushed 24 ^{o}C as early as May. Daily average water temperature data exceeded the temperature model forecasts for the most extreme climate scenarios in upstream locations such as in Upper Cache Slough and Miner Slough, indicating the importance of low freshwater flows (not considered by the models). Vertical water quality profile data collection efforts from April to September 2014 will also be discussed in regards to potential thermal refugia during spring and summer months.

Keywords: water temperatures, North Delta, Delta smelt habitat
Session Title: Understanding Effects of Climate Change on the Bay-Delta
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Influence of Incomplete Capture on Fish Monitoring and Management: Problems and Solutions

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Natural resource research and decision-making are influenced by the quality of sample data. One factor that influences the quality of fish sample data is incomplete detection. Not all fishes are captured during sampling and the ability to capture fishes varies with sampling method, fish species and size, and the characteristics of the habitats being sampled. Failing to account for differences in capture when comparing locations with different characteristics, species, and through time can introduce a systematic error or bias into the data. The problems are further exacerbated when existing sample designs and methods are changed in response to new program objectives. Several approaches have been developed to minimize the effects of gear bias including calibration, double sampling, and paired gear evaluations, and each differs with respect to relative costs and effectiveness. Another important and often overlooked, consideration when choosing an approach is how the data are integrated with management decision making. There is often profound uncertainty about the system's likely response to management, beyond environmental and other sources of uncontrolled variation. This uncertainty may be reduced through directed research, but management decisions usually cannot wait. Adaptive resource management can be used to reduce uncertainties and improve management through the integration of models and monitoring. Here, I discuss common sources of fish sampling biases and potential consequences of ignoring the biases. I then discuss approaches to minimizing the biases and integrating monitoring data and management decision-making in an adaptive framework using case studies from freshwater systems.

Keywords: capture probability, gear calibration, decision making
Session Title: Accounting for Gear Limitations in Fish Survey Data to Make Inferences about Population Abundances
Session Time: Thursday 10:20AM – 12:00PM Room 308-310

Incorporating Gear Evaluation Studies Data in a Delta Smelt Life Cycle Model (DSLCM)

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A life cycle model characterizing the population dynamics of delta smelt (DSLCM) was fit using catch data from several long-term fish survey monitoring programs in the Bay Delta. To connect the catch data to the underlying unknown population abundances, estimates of gear- and time-specific probabilities of capture were constructed using data from a series of side-by-side gear evaluation studies conducted by California Department of Fish and Wildlife and the US Fish and Wildlife Service. The methods for estimating these probabilities, along with the specific contact selectivity model structure and individual fish growth model, are explained and the resulting estimates are provided. How the estimates are incorporated in the DSLCM is shown along with subsequent DSLCM parameter estimates and output.

Keywords: Delta smelt, population dynamics, state space model, gear selectivity
Session Title: Accounting for Gear Limitations in Fish Survey Data to Make Inferences about Population Abundances
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Constructing Juvenile Chinook Salmon Abundance Indices from Beach Seine Data Collected within the San Francisco Estuary, CA

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Resource managers rely on abundance and distribution metrics derived from long-term fish surveys to make vital decisions that affect fish population dynamics and assemblage structure within the San Francisco Estuary, California. However, population metrics such as abundance indices may be negatively biased by imperfect detection (i.e., false absences) of fishes, which can vary among gear types, species, and environmental conditions. Currently, there is considerable uncertainty about the capture efficiency of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) by beach seines and how efficiency varies with environmental conditions in the San Francisco Estuary. We evaluated the capture efficiency of beach seining conducted by the US Fish and Wildlife Service's Delta Juvenile Fish Monitoring Program within the Estuary and lower Sacramento and San Joaquin rivers. Beach seine capture efficiency was measured using a stratified random sampling design combined with fish enclosures and repeat sampling. A total of 148 samples were collected during the spring, summer, and fall of 2013 and spring and summer of 2014. To assess variability in capture probability and the absolute abundance of juvenile Chinook salmon, beach seine capture efficiency data were fitted using N-mixture models that represented *a priori* hypotheses about factors affecting capture and abundance processes. We observed that the capture efficiency of beach seines and the absolute abundance of juvenile Chinook salmon varied substantially among samples. The best approximating models indicated that capture probability varied among sites and physical habitat characteristics (e.g., water velocity). Our results suggest that beach seining has highly variable capture efficiencies within the San Francisco Estuary and failure to adjust for incomplete detection may bias population metrics. Therefore, capture efficiency sampling should continue to be incorporated into the Delta Juvenile Fish Monitoring Program and other monitoring programs to properly quantify and adjust catch data to develop more robust fish abundance and distribution metrics.

Keywords: beach seine, efficiency, sample design, bias, monitoring, fish, littoral, abundance
Session Title: Accounting for Gear Limitations in Fish Survey Data to Make Inferences about Population Abundances
Session Time: Thursday 10:20AM – 12:00PM Room 308-310

Early Warning of Delta Smelt Movement During an Extreme Drought: Intensive Springtime Kodiak Trawling at Jersey Point

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The Spring Kodiak Trawl Survey (SKTS) is used to determine the relative abundance and spatial distribution of adult Delta Smelt (*Hypomesus transpacificus*). During January 2014 the SKTS had not captured any Delta Smelt in the south Delta, a region in relatively close proximity to the federal and state water pumping stations. The US Fish & Wildlife Service responded to the concern that the monthly sampling intervals of the regular SKTS would miss detection of migration by adult Delta smelt from rearing grounds around Suisun Bay towards the south Delta by conducting multiple tows at near daily intervals at Jersey Point (SKTS station 809) from Feb 6 through April 10, 2014. This talk will present the findings of this survey and discuss factors influencing density changes of Delta Smelt. Two findings will be highlighted: the importance of tow location within the channel for reliably detecting Delta Smelt, and the high probability of zero catch for typical volumes of water sampled per tow at the observed Delta Smelt densities.

Keywords: Delta Smelt, gear selectivity, hidden Markov model, Spring Kodiak Trawl
Session Title: Accounting for Gear Limitations in Fish Survey Data to Make Inferences about Population Abundances
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Compare and Contrast the Midwater and Otter Trawl of the Longfin Smelt San Francisco Bay Study

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Longfin smelt, *Spirinchus thaleichthys*, has been identified as one of the four species that suffered significant population decline since the year 2002 based on fish survey data from the Department of Fish and Wildlife. Fall Midwater Trawl data suggest a sharp decline in longfin smelt abundance during the last decade, though some of that decline might be attributable to a downstream movement in the longfin distribution into regions better covered by the Bay Study fish survey. The Bay Study uses two types of trawls, the Otter trawl and the Midwater Trawl. The Longfin smelt abundance index created from the Fall Midwater trawl is consistent with the trend in the Bay Midwater trawl but not the Bay Otter Trawl. In addition, there have been an increasing proportion of false zeros in the survey data where the Bay Midwater Trawl failed to detect any longfin smelt when they were detected in the Otter Trawl. An examination was initiated to determine what factor(s) were involved in the disparity. The analysis shows that a variety of factors may have affected the distribution and catchability of longfin smelt.

Keywords: Longfin smelt, San Francisco Bay Study, Survey, Bias
Session Title: Accounting for Gear Limitations in Fish Survey Data to Make Inferences about Population Abundances
Session Time: Thursday 10:20AM – 12:00PM Room 308-310

Using Whale Earplugs to Assess Chemical Profiles in Marine Ecosystems: Lifetime Contaminant Exposure and Hormone Profiles

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A technique combining aging with selective pressurized liquid extraction was used to reconstruct chemical profiles from an individual baleen whale earplug. Lifetime profiles for many lipophilic chemicals, including persistent organic pollutants, mercury, and hormones resulted in contaminant exposure and uptake as well as hormone response. Specifically, we quantified, DDTs, PCB's, trans-choradane and trans-nonachlor as a function of time as well as corresponding cortisol levels in a blue whale. We believe this demonstrates that long-lived whales are active marine monitoring systems with the ability record and archive data via earwax. The ecosystems these whales inhabit span the Arctic Ocean to the Southern Ocean and the development of earwax plugs as a new analytical tool for historical trend reconstruction could potentially improve our understanding of the fate and transport of contaminants on global scale as well as provide chronological profile on the health and/or stress of the whale.

Keywords: cetaceans, cerumen, persistent organic pollutants, hormones
Session Title: The Contaminant Connection
Session Time: Thursday 1:00PM – 2:40PM Room 308-310

What do Contaminants Have to do with it? Lessons Learned from the Pelagic Organism Decline Investigations into Contaminant Effects on Fishes and Their Food Web

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Fishes in the Delta have been declining since monitoring began, but in the early 2000s the almost simultaneous sharp abundance declines of four pelagic fishes marked a dramatic tipping point now known as the Pelagic Organism Decline (POD). The diverse life histories of the four fishes suggested that more than one factor was involved and their dependence on the upper estuary for important aspects of life cycle suggested the region of effect. The conceptual model developed to investigate the POD included contaminants among the factors for investigation. Implementation of the POD investigation, started the most recent era of Interagency Ecological Program investment into contaminant effects on fishes. We learned several lessons from this work. First, effective investigations of contaminant effects on fishes takes "a village" of diverse knowledge to organize the approach to sampling and analyses. Second, development of a conceptual model incorporating individual fish species life histories and the when, where and under what conditions effects are likely to take place is invaluable. Model development should be interactive with initial stages of fieldwork and refinement ongoing thereafter. Third, a three-prong approach should be fostered: 1) field sampling near sensitive life stages to document likely contaminant actors, relevant concentrations and associated stressors; 2) laboratory studies using detected contaminants at observed concentrations and their mixtures in combination with associated stressors to determine lethal or more likely sublethal effects on the relevant life stage(s); and 3) development of quantitative models to examine the effects of multiple stressors on individuals and the population. I step through these lessons providing background and pointing out that learning occurred going through the process as well as by reviewing the results.

Keywords: Pelagic Organism Decline, collaboration, contaminants, life cycle model
Session Title: The Contaminant Connection
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Regulatory Challenges of Protecting Aquatic Life and Controlling Contaminants

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The Central Valley Regional Water Quality Control Board has the responsibility and authority to control discharges of contaminants to the Delta and upper watersheds. The goal is to develop effective regulation to protect beneficial uses (e.g., aquatic life) using available toxicity and environmental monitoring data. This presentation will use pesticides as an example to illustrate the regulatory process from an LC_{50} to regulation to environmental results. The Central Valley Water Board is working on a variety of regulatory approaches to control pesticide contamination, including the use of existing regulatory authority and tools (adoption of numeric water quality objectives and total maximum daily loads), as well as outreach to other agencies to request that they take action to prevent water quality degradation (e.g., Department of Pesticide Regulation and U.S. Environmental Protection Agency). Collaborative approaches, such as the Delta Regional Monitoring Program, are also being pursued to improve the quality and quantity of information available to inform decision-making and to fulfill regulatory requirements. There are challenges in all approaches and success can be difficult to measure because the effects of reducing a few contaminants may be masked by the presence of other stressors (e.g., other contaminants, degraded habitats or environmental conditions). Challenges to controlling pesticide discharges include limited toxicity and monitoring data, coordination with agencies that have authority over pesticide registration and application, and the sheer number of pesticides that are applied in the environment. Good science and creative thinking are needed to build and refine regulatory approaches and metrics of successful regulation that accomplish our goals of ecosystem protection and restoration.

Keywords: pesticides, contaminants, aquatic life, water quality, regulation, Central Valley Water Board
Session Title: The Contaminant Connection
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Stormwater Transport of Urban and Agricultural Pesticides into Suisun Marsh

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Suisun Marsh is generally regarded as important foraging and/or nursery habitat for a wide variety of fish species, including delta smelt. The main freshwater inputs to the marsh are five creeks along the northern margin, some of which drain primarily agricultural land, and some receive runoff from urban areas of Fairfield. Pesticide concentrations and aquatic toxicity were assessed in these creeks and in the marsh during a major rain event in February 2014. The creeks with primarily urban lands within their watershed contained several insecticides, any one of which would represent a threat of toxicity to aquatic species. *Hyalella azteca* toxicity was commonly seen, and there were sufficient concentrations of the pyrethroid bifenthrin to explain it. *Chironomus dilutus* toxicity was common, and fipronil concentrations were high enough to expect toxic effects to that species. Imidacloprid was present in most creeks, and present in acutely toxic concentrations in one of them. In contrast to the urban creeks, creeks draining mostly agricultural lands contained the same pesticides, though at considerably lower concentrations. In the sloughs of Suisun Marsh, dilution with waters of the Bay reduced fipronil concentrations to about 10% of those in the creeks, pyrethroids were no longer detectable, and no acute toxicity was seen. These results indicate that several pesticides in runoff are a clear threat to invertebrates of the urban creeks, and fish dependent upon these invertebrates as prey. Upon dilution in the marsh, the threat of acute toxicity to fish or their prey diminishes. Pesticide impacts, if any, to fish populations in the marsh would likely be through any trophic dependency on export of prey from the creeks, or through subtle sublethal routes such as endocrine disruption.

Keywords: Suisun, pyrethroids, fipronil, *Hyalella*, *Chironomus*, pesticides, urban runoff
Session Title: The Contaminant Connection
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Contaminant-Related Thyroid Endocrine Disruption in California Fish

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In selected locations in San Francisco Bay and in other urban coastal aquatic environments in California, indigenous fish species have been observed to exhibit significant disruption of their thyroid endocrine system, which may be associated with impacts that threaten their health. Circulating plasma concentrations of the two thyroid hormones [thyroxine (T4) and and triidothyronine (T3)] can be substantially disrupted, commonly observed in fish residing in environments contaminated by elevated polychlorinated biphenyls (PCBs; mostly non-coplanar, lower-chlorinated congeners), chlordane pesticide compounds, and polybrominated diphenyl ethers (PBDEs). Our studies have traced these impacts to two principal underlying mechanisms. The first is an impact on the enzyme, 5'-monodeiodinase, responsible for conversion of T4 into the more active T3. The second is a direct thyroid gland effect, observed morphologically as evaluated by histological methods, and also observed by a failure of the thyroid gland to normally produce thyroid hormones. These mechanisms of effect are related to distinct classes of contaminants present in the environment. This presentation will discuss results from continuing studies on the relationships between contaminants of emerging concern (CECs) and thyroid endocrine disruption, and the associated impacts on physiological function and potential impacts on health. [Supported by NOAA-USC Sea Grant Program and Pacific Coast Environmental Conservancy]

Keywords: Contamination Thyroid Disruption, Aquatic CEC's, Compounds, Histology
Session Title: The Contaminant Connection
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Predicted Population Decline in Fish Due to Bifenthrin Exposure: Implications for Aquatic Ecosystems in the Bay-Delta

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Bifenthrin, now one of the most commonly used pyrethroid pesticides, is known to interfere with hormonal signaling in fishes at concentrations commonly present in the San Francisco Bay and the Sacramento-San Joaquin Delta. As such, our work with *Menidia beryllina*, an established estuarine model species that frequently encounters pyrethroids in stormwater run-off and effluent, seeks to clarify how low concentrations of bifenthrin interfere with hormonal signaling and reproduction in fish, and how this can be extrapolated to the population level. We conducted 14d exposures with juveniles (60 day old) to three part per trillion concentrations of bifenthrin (0.5, 5, 50 ng/L) and evaluated global gene expression. We also exposed reproductive adult *fish* to 0.5 ng/L bifenthrin for both 7 and 21 days, collecting eggs following the 7d exposure and collecting eggs daily during the 21 day exposure. Exposure to bifenthrin caused significant differential expression of genes related to reproduction and immune function, with indications that bifenthrin could be a carcinogen. Both the 7 and 21 day spawning assays resulted in a 30% reduction (ANOVA, $p < 0.05$) in fertilized egg output from bifenthrin-treated animals. Our population dynamic model predicts that this reduction in fertilized egg abundance would cause a significant decline in a putative population over time, dependent on the degree of masculinization or feminization potentially caused by bifenthrin exposure. Currently work is underway to determine whether *M. beryllina* exposed during the larval period of sex determination have an altered sex ratio upon adulthood. Taken together these experiments quantify the impact of this now ubiquitous pyrethroid on multiple fish life stages, forges links between molecular and reproductive effects, and allows for better assessment of risk to aquatic ecosystems and to human health.

Keywords: pyrethroid, endocrine disruptor, population decline, reproduction, silversides
Session Title: The Contaminant Connection
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Integration of both Exposure and Effect in a Complex Watershed

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Due to the diversity of sources of contaminants and stressors, linking exposure and effects in complex watersheds is difficult. This linkage typically relies upon relatively limited chemical occurrence data loosely coupled with population or community level assessments. Increased discriminatory power may be gained by approaching watershed level assessment in a more holistic manner drawing from a number of disciplines that target endpoints spanning levels of the biological hierarchy. Using the Sacramento River, from the Colusa Basin Drain to Hood station as a case study, the present study aimed to 1) characterize the effects of geographic and temporal variability through the integration of suborganismal, tissue and individual level endpoints, as well as extensive chemical analyses; 2) evaluate the added benefit of non-traditional assays, such as C-start performance, in linking cause and effect in a complex watershed; and 3) provide an experimental design workflow for these types of assessments. Sites were selected to target inputs into the Sacramento River as it transitions from an agricultural to an urban landscape. Chemical analyses were conducted on surface water samples at each site in both the spring and fall for pesticides, hormones, pharmaceutical and personal care products (PPCPs). PPCPs were more often detected across sampling events in the fall; however, at the farthest downstream site more analytes were detected and their concentrations were greater in the spring. The results of gene and protein expression assays targeting endocrine and reproductive effects were inconsistent across seasons. Larval mortality as a response to effluent was seen in both seasons; however, behavioral changes were only observed in the spring. Together results indicate significant influence of seasonality on chemical and biological endpoints, which contributes to a complicated view of the watershed.

Keywords: Contaminants, Sacramento River, Pharmaceutical and Personal Care Products, Endpoints
Session Title: The Contaminant Connection
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Connecting Fish Tissue Selenium Concentrations to Sources and Exposure in a Dynamic Estuary: The Case of Sacramento Splittail

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We identify several key factors controlling the transfer of selenium (Se) from water through an invasive clam *Potamocorbula amurensis* to a migratory native fish Sacramento splittail in the San Francisco Bay and Delta ecosystem. First, Sacramento splittail showed a significant difference in tissue Se concentrations depending on size and time spent foraging in the estuary. Sulfur isotope ratios indicated that these differences were linked to an ontogenetic shift in splittail diets to include the clam *P. amurensis* found in the estuarine portions of the Bay. Second, clam Se concentrations were spatially variable, with the highest concentrations focused in the northern reach of San Francisco Bay, nearest Carquinez Strait and Suisun Bay, resulting in variable dietary exposures depending on where the splittail were feeding. A third factor was the influence of freshwater inflow on seasonal and inter-annual variation in Se bioaccumulation by clams whereby the highest concentrations in clams were observed in the late fall and early winter, just prior to spawning of several native fish species, as well as in years of low freshwater inflow. Collectively, these factors highlight the importance of considering both ecology (foraging location and diet) and hydrology/hydrodynamics (e.g. freshwater inflow) in determining the timing and potential range of aqueous Se concentrations and how that translates into risk to native species.

Keywords: Selenium, bioaccumulation, ecology, food webs, invasive clams
Session Title: The Contaminant Connection
Session Time: Thursday 3:00PM – 4:40PM Room 308-310

Physiological Responses to High Water Temperature in Longfin Smelt and Delta Smelt

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Climate change is one of the most serious issues faced by Bay-Delta managers now and into the future. Most fishes, as ectotherms, are unable to regulate their body temperature and therefore must perform all physiological processes at the temperature of the surrounding environment. Because of the importance of water temperature on physiological function and determining habitat suitability, temperature has been termed the "ecological master factor" in fishes. Predicted future increases in water temperature may greatly influence the ability of some fish species to survive or respond to other environmental stressors in the Bay-Delta system. Two species of concern are the critically endangered delta smelt (*Hypomesus transpacificus*) and the threatened longfin smelt (*Spirinchus thaleichthys*). However, little is known about the mechanistic processes involved in thermal tolerance, and whether these species can cope with increases in water temperature in the Bay-Delta. We determined the critical thermal maximum, a repeatable and standardized method to estimate tolerance to acute temperature changes, for 50 day old fish which was 27.5°C and 25°C for delta smelt and longfin smelt, respectively. We then acutely exposed fish to an environmentally-relevant temperature of 20°C and compared metabolic rate and gene expression responses to a 14°C handling control group. We used a direct RNA-sequencing approach, and compared gene expression with metabolic rates changes, to identify physiological responses associated with temperature in these important Bay-Delta species. Because of the direct and indirect role of temperature on fish, characterizing the physiological responses to changes in water temperature will enable a better understanding of how temperature might interact with other stressors in the Bay-Delta system and impact fish populations. This project uses state-of-the-art approaches to generate molecular tools for understanding the effects of environmentally-relevant high water temperatures on longfin smelt and delta smelt to aid in conservation efforts and management of these species.

Keywords: Longfin Smelt, Delta Smelt, Climate Change, Physiology
Session Title: The Contaminant Connection
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Characteristics of Suspended Solids Affect Bifenthrin Toxicity to Calanoid Copepods of the San Francisco Estuary

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Bifenthrin is a pyrethroid pesticide that is highly toxic to aquatic invertebrates. The dissolved concentration is generally thought to be the best predictor of acute toxicity. However, for the filter feeding calanoid copepods, *Eurytemora affinis* and *Pseudodiaptomus forbesi*, ingestion of pesticide-bound particles could prove to be another route of exposure. This study investigated bifenthrin toxicity to *E. affinis* and *P. forbesi* in the presence of suspended solids from municipal wastewater effluent and surface water of the San Francisco Estuary. Suspended solids mitigated the toxicity of total bifenthrin to *E. affinis* and *P. forbesi* but mortality was higher than what would be predicted from dissolved concentrations alone. Our results indicate toxicity and bioavailability of particle associated bifenthrin was significantly correlated with high counts of particle sizes at 0.5-2µm. Potential explanations could include direct ingestion of bifenthrin bound particles, changes in food consumption and feeding behavior, and physical contact with small particles. The complex interactions between pesticides and particle types and sizes demonstrate a need for future ecotoxicological studies to investigate the role of particle sizes on aquatic organisms in San Francisco Estuary.

Keywords: Copepods, Bifentrhin, Pyrethroid pesticide
Session Title: The Contaminant Connection
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Using Scenarios to Support Climate-Smart Adaptation for the South Bay Salt Ponds Restoration Project

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Managers and decision makers in the San Francisco Estuary are struggling to develop effective conservation and restoration plans because of the large uncertainty surrounding the future effects of sea-level rise and other aspects of climate change on inter-tidal ecosystems. The South Bay Salt Pond Restoration project, the largest wetland restoration project on the west coast of North America, exemplifies the challenges in planning for uncertain futures as the project's adaptive management plan attempts to balance the needs of species that utilize tidal marsh habitats and managed pond habitats. We used predicted future distribution and abundance of marsh bird and shorebird species in response to changes in habitat availability and suitability as a result of projected sea-level rise, salinity, sediment availability and management scenarios in the South Bay. The effectiveness of management scenarios was evaluated by comparing the modeled future abundance of birds to current abundance at the south bay and complex levels. Through our analysis we identified combinations of scenarios in which management targets were not met. We then used scenario planning stakeholder meetings to formulate adaptive management actions that could ensure management targets are met under each scenario. Additionally, the results from our analysis will be used to guide and prioritize future monitoring efforts to help inform ongoing adaptive management. Our project demonstrates how scenario planning can be used to incorporate uncertainty into effective climate smart adaptation planning.

Keywords: Uncertainty, Scenario Planning, Tidal Marsh, Shorebirds, Restoration, Sea-level rise, Conservation
Session Title: Restoration Lessons Learned I
Session Time: Thursday 8:20AM – 10:00AM Room 311-313

Lessons Learned in Large Scale Environmental Restoration Project Management and Scale Dependent Alternatives Assessment

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This paper highlights findings and outcomes of a nationally prominent wetlands restoration program unusual in physical scale (55,000 acres), hydraulic complexity and frame (years in development, decades in implementation) and examines linkages between regional, local and larger-scale processes, and their implications in terms of ecosystem behavior and management. Ecosystems prevailing in the area of the Picayune Strand Restoration Project (PSRP) in southwest Florida had been markedly affected by the installation of canals and drainage features designed to promote various development interests. This shifted flow regimes, altered hydroperiods, and had a massive effect on native populations characteristic of the region. The intent of the current effort was to recover a more natural mix of natural overland flow and amorphous flowways, coupled with positive drainage features necessary to preserve development in and surrounding the restoration area. Constraints associated with neighboring areas, including agriculture, residential, business, transportation and natural systems areas, which were to be explicitly accounted in assessment and intervention. This led to a need to reconcile scale dependent hydraulic requirements spanning roadway clearances and crossings, small and large scale flood conditions, regional levees and protective works, and long term shifts in groundwater regimes, all of which can have an impact on ecosystems in this sensitive and highly valued coastal system. To accomplish this basic scheme, a range of candidate configurations were considered. This paper explores the technical, political, jurisdictional and scientific issues that were at play as the program progressed. The concerns raised by selected rehabilitation practices are discussed and lessons learned for this type of large scale rehabilitation are provided. Suggestions are made regarding preferred practice, and areas meriting further research are identified. Comparisons are made between Bay-Delta systems and processes, and those in this program, with the intent of exchanging experiences that may lead to mutually beneficial insights.

Keywords: large-scale ecosystem management, political jurisdictional constraints, human impact, Florida
Session Title: Restoration Lessons Learned I
Session Time: Thursday 8:20AM – 10:00AM Room 311-313

Evaluation of Restoration Actions in the San Joaquin River using Ecosystem Diagnosis & Treatment

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The San Joaquin River Restoration Program (SJRRP) prescribes flow augmentation and specific restoration projects to restore spring-run Chinook salmon between Friant Dam and the Merced River (150 miles). The Bureau of Reclamation, working with fishery agencies, has used the Ecosystem Diagnosis & Treatment model (EDT) to understand factors controlling success of the restoration actions and to evaluate their potential benefits. To date, actions in reaches 2B and 4B (respectively above and below Mendota Pool) have been analyzed, including expansion of floodplain areas and alternative flow and fish routings. The base condition assumed SJRRP settlement flow and fish passage at existing barriers--substantial modifications from current conditions. Because spring-run Chinook were extirpated from the San Joaquin River, an important task was to evaluate alternative juvenile Chinook life histories and their relative success under restored conditions. Survival rates in the Bay-Delta and ocean were based on recommendations from the fisheries agencies. Under the base condition, habitat supported a small and fragile spring Chinook population that was highly dependent on water year conditions. Scale and location of restoration were key to fish population benefits. The value of actions in reaches 2B and 4B (and likely other actions) was highly dependent on flow and water temperature and the juxtaposition of fish presence. Successful juvenile behavior was to emigrate as fry before water temperatures increased or remain over summer in the cool water below the dam. Benefits of floodplain restoration were limited by the timing of inundation and juvenile emigration. Pre-spawn adults needed to move upstream quickly to cool water below the dam before temperature increased. The analysis showed the close coupling of restoration benefits to the fish life history and the synergy of flow, temperature, and other in-stream conditions. Achieving the SJRRP goals will require a suite of actions across the study area.

Keywords: San Joaquin Habitat Restoration Life Cycle Modeling Salmon habitat
Session Title: Restoration Lessons Learned I
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Immediate Fish Response to Salmonid Rearing Habitat Enhancement in the Spawning Reach of a Highly Altered Central Valley Stream

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Gravel and gold mining, in conjunction with altered flows and decreased coarse sediment transport, has resulted in deterioration of the lower Stanislaus River into a homogenous, incised channel with few functional floodplains or other off-channel rearing areas. Consequently, long-term monitoring of Chinook salmon escapement and subsequent juvenile production indicates an apparent limitation of suitable spawning and juvenile rearing habitat on the Stanislaus River. To alleviate these population constraints, the Oakdale Irrigation District and the Anadromous Fish Restoration Program jointly funded the Honolulu Bar Restoration Project, which was designed with the primary objective of increasing and enhancing juvenile salmonid rearing habitat along a mile-long stretch of the primary spawning and rearing reach. Rearing habitat was enhanced through re-contouring 2.4 acres adjacent to an existing side-channel to function as a small floodplain, and by using harvested material to construct shallow gravel benches along the main channel margin.

Over the past two years, frequent post-construction assessment of habitat use during winter and spring suggests that localized benefits were realized almost immediately in the restored area which was consistently utilized for rearing by juvenile salmonids across a broad range of sizes. These findings illustrate that such restoration projects can provide nearly immediate amelioration of habitat scarcity in Central Valley rivers. In the larger picture, continued long-term monitoring provides the data necessary to evaluate the combined success of multiple restoration efforts in the Stanislaus River. Encouraging and facilitating natural production is crucial to the long-term sustainability of native fish populations, and restoration and management plans for Central Valley salmonids would benefit from the inclusion of rearing habitat enhancement in natal spawning areas where habitat limitations have been identified.

Keywords: floodplain, side channel, salmon, rearing, Stanislaus, habitat, enhancement, production, juvenile
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Session Time: Thursday 8:20AM – 10:00AM Room 311-313

Managing for Changing Tides: Restoring a Tidal Marsh in an Urbanized Area

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Restoring wetland habitats is complex in any environment, but tidal restoration is particularly challenging in urban areas. Ecological needs must be balanced with the concerns of neighboring property owners, and the restoration opportunities are often limited by infrastructure constraints. In 2003, Solvay USA, Inc. launched the Peyton Slough Remediation and Restoration Project in Martinez, California to remedy legacy contamination and restore diked historic tidelands on their property and that belonging to the California State Lands Commission. Construction of a new slough channel was completed in 2007, and a portion of the property, which had been diked and drained over 100 years, was reintroduced to tidal action in 2009. Reintroduction of tidal action required vigilance and adaptation as Solvay and other stakeholders worked to restore wetland without compromising existing infrastructure. Pipelines, subsided roadways, and culvert constrictions adjacent to the restoration presented challenges; the elevation difference between the marsh and the roadways was less than one foot. With daily and seasonal tidal variation greater than the freeboard, water management was a critical and labor intensive element of the plan. Despite these challenges, the site has successfully been restored to a pickleweed marsh now used by numerous fish and wildlife species. This success has been attributed to careful water management, close collaboration with the neighboring stakeholders who now collect upstream data and make recommendations for tide gate operations, and implementation of adaptive management (e.g, re-grading the marsh plain, altering the tide gate structure, changing the tide gate operations). Future tidal restoration projects in urban areas of the Bay-Delta will benefit by incorporating an effective stakeholder working group, tidal data modeling, and regular habitat monitoring to inform adaptive management decisions and lead to better water management.

Keywords: tidal marsh, restoration, stakeholder, adaptive management, infrastructure, pickleweed, wetland
Session Title: Restoration Lessons Learned I
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How Do Restoration Site Characteristics, Plant Caging, and Parental Source Affect Native Pacific Cordgrass (*Spartina foliosa*) Establishment?

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A key programmatic goal of the San Francisco Estuary Invasive Spartina Project's restoration program is to reestablish native Pacific cordgrass (*Spartina foliosa*). This foundation species provides critical habitat for native fauna, including the endangered California clapper rail (*Rallus longirostris obsoletus)*. Five large-scale experiments conducted from 2010-2013 have tested how restoration site characteristics, plant caging, and parental source of *S. foliosa* transplants have influenced establishment rates of native cordgrass. Throughout all experiments, outplanting location (e.g., geographic location, substrate, elevation) and caging were strong predictors of planting success. Establishment rate of native cordgrass was highest on uniform mudflats and wide channel banks (62%) with lower establishment rates occurring in 2nd order channels and bayfront habitat (15%). Cage effects varied by marsh, with the strongest cage effects occurring at sites with nesting Canada goose (7% survivorship in uncaged plots, 78% survivorship in caged plots). In a separate experiment, parental source was a strong predictor of planting establishment. Plants were collected from eight widespread marshes, genetically tested using microsatellites, and grown in identical nursery conditions. After 10 months, source populations differed in terms of culm height and density. Following nursery growth, 300 plants from each donor source were outplanted into two marshes and monitored quarterly. Sources varied significantly in terms of survivorship, flower production, and culm density. Field performance was not predictable from nursery bed performance. Successful restoration of native cordgrass requires understanding site specific conditions including marsh hydrology, elevation, substrate, donor source material, and herbivores.

Keywords: restoration, *spartina foliosa*, cordgrass, clapper rail, caging, adaptive management
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Blacklock Restoration Project in Suisun Marsh - 5 Years of Post-Breach Monitoring

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The Blacklock Restoration Project in Suisun Marsh is a 70 acre site in which tidal flow was restored to managed wetlands by the Department of Water Resources. The objectives of this project are to increase the amount of tidal brackish wetlands to aid in the recovery of listed species and to improve the understanding of tidal marsh restoration through collaborative science. There is a 10 year monitoring period following breaching of the levee in 2006. Data on 15 parameters was collected and analyzed to evaluate progress towards meeting these objectives. Monitoring results for years 1 – 5 include: an average elevation increase of 0.3 ft; total channel length increased by 26%; methyl mercury concentrations in water, sediment, and fish tissue were, overall, higher immediately post-breach and decreased to lower concentrations within 2 years; there were similar concentrations of dissolved oxygen within the restored area and adjacent slough; vegetation cover decreased by less than one acre and the growth rate of *Phragmites australis* is double the rate of native species; there is a diverse range of avian species using the site. Lessons learned from this project will aid future tidal restoration projects by potentially lowering costs while still gaining valuable scientific information. For example, surface elevation tables and cryogenic core sampling were found to be ineffective ways to measure accretion in highly subsided unvegetated areas due to scour. Thousands of acres are planned for tidal restoration in the Delta and Suisun Marsh over the next 10 years. Future tidal restoration projects will benefit from the sharing of these monitoring results.

Keywords: Suisun Marsh, Blacklock, tidal restoration, sedimentation, channel formation, methylmercury, DO
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Lessons Learned from Community-Based Restoration of Transition Zone Habitat

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Transition zones between tidal marsh and upland habitats provide important functions and ecosystem services for marsh-dependent species, such as providing habitat feeding, nesting, and high tide refuge. In addition, these areas provide important functions, such as predator-prey dynamics, habitat connectivity between the tidal marsh and uplands, and genetic diversity, to name just a few. These areas also provide critical wetland migration space as sea level rises and can also provide accommodation space during flood events. Land management has resulted in fragmented t-zones throughout the Bay-Delta system, thereby reducing functionality of these important habitats. For the last 13 years, Save The Bay has focused our work on community-based restoration using over 6,000 volunteers annually to create and restore T-zone habitat on narrow levee slopes in highly urbanized areas. However, while providing important habitat in urbanized areas where similar habitat didn't exist, our initial projects only focused on one type of t-zone. Over time, we have adjusted our methods to focus on broader, wider t-zones and are starting to scale our work up to larger sites and to design our work so that our results can inform other similar projects. We have also adjusted our plant palette to better reflect species that can adapt to rising seas and predicted changes in weather patterns with climate change. Our work suggests that the creation of wider, low-gradient slopes combined with a thoughtfully designed plant palette will result in successful establishment of an initial t-zone plant community that will develop over time to provide important habitat value. This talk will focus Save The Bay's work in narrow transition zones and provide lessons learned that can be applied to the protection, creation and restoration of t-zone habitat throughout the Bay-Delta system.

Keywords: Transition, T-zone, Vegetating, Community, Restoration, Management, Ecosystem, Function(s), Wetland, Migration
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Optimizing Island Nesting Habitat for Waterbirds Breeding in Wetlands of San Francisco Bay

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San Francisco Bay supports approximately 30% of the Pacific Flyway population of breeding Forster's Terns and is among the largest breeding sites for American Avocets in the west. Islands within former salt ponds of South San Francisco Bay provide critical nesting habitat for many waterbirds, especially Forster's Terns and American Avocets. Preserving and enhancing salt pond island nesting habitat is necessary to achieve the South Bay Salt Pond Restoration Project goal of maintaining current populations of breeding waterbirds. In an effort to provide data-driven recommendations for island habitat management, the USGS is evaluating how island density, distribution, morphometry and vegetation cover influences waterbird nesting in South San Francisco Bay. Historic nest monitoring data from over 15,000 nests as well as recent island and nest-site morphometry data were used to examine waterbird nesting patterns. Islands were the main nesting habitat, with more than 90% of Forster's Terns and 70% of American Avocets nesting on salt pond islands. The number of nests increased with island size up to a point and, thereafter, larger islands supported few additional nests. Although Avocets and Forster's Terns often nest on multiple islands within a single pond, a greater number of islands within a pond did not correlate well with more nests per pond, suggesting that a few islands in each of several ponds may be more advantageous than many islands within a single pond. Within islands, Forster's Terns and Avocets were more likely to nest in areas of higher elevation, at an intermediate distance from the water's edge, and in patches containing some vegetation. The results of this study will provide scientific support for adaptive management actions to maintain waterbird populations as restoration projects, which include island construction, are implemented.

Keywords: Forster's Tern, American Avocet, islands, nesting, San Francisco Bay
Session Title: Restoration Lessons Learned II
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Quantifying Greenhouse Gas (CO_2, CH_4, N_2O) Release via Ebullition in Restored Delta Wetlands

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Restoration of wetlands on agricultural land in the Sacramento-San Joaquin Delta has been proposed to slow land subsidence. However, flooding also affects greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Measuring greenhouse gas fluxes in wetlands is difficult due to high spatial and temporal variability, and multiple transport pathways of emission. Transport of biogenic soil gas via highly sporadic ebullition (bubbling) events is often ignored or quantified poorly, but can rapidly release large volumes of gas to the atmosphere. To quantify a robust annual bubble flux we measured ebullition rates continuously for a year (2013-2014) using custom-built chambers deployed in Mayberry Wetland, Sherman Island, CA. We combined bubble flux rates with observations of bubble gas concentrations to estimate ebullition emissions of CO_2, CH_4, and N_2O.

Mean bubble flux rates were 18.3 ± 5.6 L m^{-2} yr^{-1}. Bubble CH_4 concentrations were very high and ranged from 23-76 % with a mean of 47 ± 2.9 %; CO_2 concentrations were lower and ranged from 0.7-6.6 % with a mean of 2.8 ± 0.3 %; N_2O concentrations were below atmospheric concentrations and ranged from 130-389 ppb(v) with a mean of 257 ± 13 ppb(v). We calculated well-constrained annual ebullition fluxes of: 6.2 ± 1.9 g CH_4 m^{-2} yr^{-1}, 1.0 ± 0.3 g CO_2 m^{-2} yr^{-1} and 9.3 ± 2.8 mg N_2O m^{-2} yr^{-1}. Methane emissions via ebullition were very large, representing 15-25 % of total wetland CH_4 emissions measured at this site, whereas ebullition released only small quantities of CO_2 and N_2O. Our results demonstrate that large releases of CH_4 via ebullition can be a significant component of restored wetland greenhouse gas budgets and that the balance of open water and vegetation is important to consider during design and management of restored wetlands.

Keywords: wetlands; greenhouse gas; methane; nitrous oxide; carbon; sequestration; subsidence; restoration
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Conundrum: Understanding Native Fish Functions of Emergent Tidal Marsh Restoration in a Highly Altered Landscape Largely Devoid of Tidal Marsh

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Tidal marsh restoration for years has been as a major strategy for upper estuary native fish recovery (CALFED ROD 2000, Delta Vision 2008, ERP Conservation Strategy 2011, BDCP 2014). Recently, the efficacy of tidal marsh restoration for native fish benefits has been called into question. The severe paucity of tidal marsh study sites in the upper estuary and limited studies of them severely constrain our local knowledge. Two large studies (Integrated Regional Wetland Monitoring Pilot Project, BREACH I-II-III), along with other smaller studies, provide some insight. Impediments to restoration success cannot be ignored, nor should benefits for overestimated. What can we say about tidal marsh functions for native fish? This session presents findings about potential functions. It considers historic and modern landscapes, physical processes, stable isotope-mapped tidal marsh food webs, carbon cycling, prey communities, and fish utilization. It considers landscape potential for restoring tidal marshes, open water, the upland transition, and "novel" landscapes. It concludes with restoration and science approach considerations for Suisun Marsh and the Delta based on current management programs. The limited data show tidal marshes provide native fish functions. Detrital- and invertebrate-based food webs. Trophic relays. Supporting variability in aquatic environmental parameters. Reducing surface water temperatures. Spawning and refuge habitats. Fewer invasive species. Critical interplay between hydrodynamics, biological processes, carbon and nutrient cycling, and associated ecological functions. Position along the estuarine axis and within subregions appears vital and informs limits. "Novel" landscapes may help support ecosystem functions. The time has arrived to "learn by doing" in a well-organized adaptive management framework that supports insight development. Location, variability in restoration types, landscape configurations, restorations as experimental study units, integration with modeling tools, and efficacy assessment are the ingredients to working through our current conundrum.

Keywords: tidal marsh, restoration, conservation, fish habitat, ecosystem function
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 1:00PM – 2:40PM Room 311-313

Value of Wetlands to Aquatic Foodwebs and Fish

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The San Francisco Estuary has undergone extreme urbanization and other anthropogenic changes over the last 170 years that have greatly reduced the quantity, diversity and variability of natural habitats. Future changes include intentional reconnection of shallow areas to aquatic access with the intent of benefiting valued biota, unintentional reconnections due to levee failure and floods, changes in the location of shallow areas, changes in the salinity regime and the tidal prism due to sea level rise, alterations of freshwater flow due to climate change and water management, and continued introduction of organisms suited to the changed environment. What are the limits and opportunities to protect and improve the values of wetland areas in the face of these changes and how do they interact with other human values?

Historical analyses give quantitative and qualitative guidance on the habitats the native fauna evolved in and the extremes of climatic variability they experienced. Large-scale restoration in the lower estuary and elsewhere illuminates the benefits to fish accrue mostly on site. Analyses in remaining wetland areas in Suisun Marsh and in scattered other wetlands in the upper estuary show that salmon and some other fish, including many introduced species, flourish in them. Other species, notably smelts, seldom use wetlands directly and likely benefit only in the immediate vicinity. Hydrodynamic and climatic models depict likely changes to the physical characteristics of the estuary in the next 100 years. Together the results and tools allow us to assess future scenarios and how humans can affect that trajectory. Such integrative work is crucial to formulate reasonable and achievable goals for protecting and restoring the aspects of wetlands that humans value.

Keywords: wetlands, fish smelt, salmon, baylands, marsh, export production, function, location
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
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Direct and Indirect Effects of Large-Scale Restoration and Implications for Science and Management

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Problem statement: Planned large-scale restoration profoundly changes hydrodynamics, shear stresses, and material transport in the channels and bays of the Delta, and the hydroperiod of restored tidal marshes. Tidal range and currents are modified at the Delta scale by each new restoration project, which in turn affects the trajectory of previous restorations. Successful large-scale restoration will require systematic scientific processes for understanding and managing the ecosystem effects of hydrogeomorphic change.

Approach: Hydrodynamics and transport models have been used over the years to plan restoration projects and study the effect of unplanned levee disasters. We draw upon the best of these analyses to propose several rules of thumb for staging, scaling, and judging restoration progress.

Findings: Restorations initiate hydrodynamics and transport process changes that have short, medium, and long-term effects. Wetted area, tidal currents, water levels, temperature regimes and residence times change immediately. Within days to months, sediment erosion and deposition is changing local bathymetry, sediment physiochemistry, primary production and plant and associated invertebrate communities. The adjacency of shallow water or intertidal marsh to more energetic and deeper channels drive scalar fluxes both ways. With years to decades, the energetics of tides, sediment, and vegetation have transitioned the biogeomorphology to a new dynamic state. Each of these processes mediates the other through non-linear feedbacks and thresholds, making predictions about outcomes difficult.

Conclusions: Making restorations relevant to native species resilience is not a matter of accumulating levee bordered restoration projects up to acreage goals. Rather, we should expect restoration of scaled-up functional landscapes to be messy, transitional, and surprising. We need new organization structures that support routine interdisciplinary interaction and use advanced data and modeling tools to manage the complexity of purposeful landscape change.

Keywords: Hydrodynamics, restoration, effects, landscape-scale, native species
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 1:00PM – 2:40PM Room 311-313

Conceptual Model of Fish Benefits of Tidal Marshes, Food Webs, and Linkages to Adjacent Habitats

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Problem. The vegetated intertidal zone with a meandering dendritic channel network is the defining feature of a tidal marsh. Fishes may use tidal marsh for foraging, refuge and spawning and they may access marsh-derived prey resources outside the marsh itself. Its role in supporting native fishes in the San Francisco Estuary remains unclear, however. *Approach.* We developed a conceptual model based on our hypothesis that the physical interaction between tide and geomorphic structure mediates food web production and fish usage in vegetated intertidal zones. The notion is that spring tides, especially those large enough for overbank flooding of the marsh plain, mobilize decaying plant matter and benthic invertebrates, thereby driving benthic food web production; neap tides facilitate in-situ phytoplankton production and advect and accumulate zooplankton, thereby driving pelagic food web production; and these patterns are reflected in behaviors of benthic and pelagic fishes. *Results.* We tested our hypothesis in First Mallard Slough in Suisun Marsh. This slough retains its natural meandering dendritic geomorphology, is subtidal at its mouth and intertidal at its head, and functions as a fish nursery grounds. Early results indicate that the benthic forager Sacramento splittail (*Pogonichthys macrolepidotus*) typically moves into and out of intertidal habitat during peak tides when water inundates stands of emergent vegetation. It is likely that the interaction of tide and channel bank structure provides increased foraging opportunities or predator refuge to benthic fishes. *Conclusions.* There appears to be considerable spatiotemporal variation in resource use within tidal marshes, highlighting the importance of dual food web pathways, heterogeneous channel structure, marsh plain elevation, and connectivity among diverse hydrogeomorphic features within the estuarine landscape.

Keywords: Tidal marshes, native fishes, food webs, invertebrates, zooplankton, hydrology, biogeochemistry
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 1:00PM – 2:40PM Room 311-313

Unraveling Sources of Food Web Support in the Sacramento-San Joaquin Delta's Marsh Ecosystems Using Fatty Acid Biomarkers and Multiple Stable Isotopes

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The current physical, biological, and chemical environment of the Sacramento-San Joaquin Delta little resembles historical conditions. A century of human alterations has dramatically transformed the Delta from a dynamic ecosystem dominated by riverine inflow, high turbidity, and vast marsh landscapes to one characterized by muted hydrodynamic variability, low productivity, and minimal marsh habitat. Adverse effects emanating from this transformation have been well documented for fishes, birds, and terrestrial wildlife reliant on natural ecosystem conditions, but ill-equipped to thrive in the current landscape configuration of the Delta. One major stressor for the Delta's organisms may be food limitation. Phytoplankton has decreased dramatically since the 1987 introduction of *Potamocorbula amurensis* and is thought to be related to the recent pelagic organism decline. Additionally, it is likely that the detrital food web is limited, as areas of internal, non-phytoplankton primary production are extremely limited within the Delta. Food limitation in the detritus-based food web, however, has received little attention in the region.

Given the historical landscape of San Francisco Bay and Delta, we hypothesize that non-phytoplankton detrital material plays an important role in supporting secondary production and that estuarine fish and invertebrates are well adapted to take advantage of this resource. We therefore focus on the detritus-based food web of the Delta, using stable isotope and fatty acid biomarkers to identify origins of food web support for important prey organisms and larval fishes. Preliminary evidence suggests detrital pathways are being utilized in tandem with algal sources. The results of this study may allow restoration planners to more broadly consider the role of vegetated areas, as these areas may not only provide shelter and spawning habitat, but may bolster food web support as well.

Keywords: Food web, Liberty Island, Stable Isotopes, Fatty Acid Biomarkers, Marsh
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 1:00PM – 2:40PM Room 311-313

Ecosystem-Scale Rates of Primary Production Within Wetland Habitats of the Northern San Francisco Estuary

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Large-scale tidal wetland restoration is planned for the northern San Francisco Estuary (SFE) and is thought to provide a variety of ecosystem services including shoreline stabilization, fish habitat, and organic carbon subsidies for estuarine food webs. Organic carbon comes from diverse primary producers that differ in carbon fixation rates and areal extent within wetland systems. This study was designed to obtain some of the first estimates of relative contribution of different primary producers to total organic carbon production within open water and tidally flooded wetlands of the SFE. Carbon fixation rates of phytoplankton, microphytobenthos, and low marsh vegetation were measured in two natural and four restoring wetlands in 2004. Areal (m^2) rates of carbon fixation were greatest for low marsh vegetation, while phytoplankton and microphytobenthos rates were one and two orders of magnitude lower, respectively. However, when areal production rates were scaled to the amount of habitat available for each primary producer group, the relative importance of each group varied by location. Given that each primary producer group supports a different subset of estuarine consumers, the type of food subsidy desired should influence the amount open water channel, mudflat and low marsh area restored. Large-scale wetland restoration activities should consider the types of primary producers likely to occupy restored habitats when estimating future food web impacts.

Keywords: Tidal wetlands, primary production, phytoplankton, microphytobenthos
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 3:00PM – 4:40PM Room 311-313

Nutrient and Organic Carbon Cycling Processes in Tidal Marshes and Shallow Water Habitats

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Tidal wetlands and shallow water habitats can be sites of high aquatic productivity, and they have the potential of exchanging this newly produced organic carbon with adjacent deeper habitats. Indeed, export of organic carbon from wetlands and shallow water habitats to pelagic food webs is one of the primary ecosystem functions contemplated in the Bay Delta Conservation Plan (BDCP). Alternatively, wetlands and shallow water habitats can function as retention areas for nutrients due to the nutrient demand of emergent macrophytes and denitrification in anoxic zones. They can also remove phytoplankton and non-algal particles from the aquatic food webs because the shallower waters can result in higher rates of benthic grazing and higher settling due to lower water velocities.

We conducted studies on Brown's Island, on Liberty Island, in the upper Cache Slough complex, and in the Deep Water Ship Channel to investigate the dynamics of nutrients and phytoplankton production at a variety of temporal scales. We collected continuous time series of nutrients, oxygen, chlorophyll and pH in conjunction with continuous acoustic measurement of water velocity and discharge to provide mass controls and used simple biogeochemical models to assess rates.

We found a high degree of temporal variability in individual systems, corresponding to, for example, changes in nutrient supply, water level, light level, wind, wind direction, and other physical factors. There was also large variability among the different systems, probably due to differences in flows and geomorphic features. We will compare the aquatic productivity of these environments and speculate as to their formative elements. Our findings demonstrate the complex interaction between physical, chemical, and biological factors that determine the type of production and degree of export from tidal wetlands and shallow water habitats, suggesting that a clearer picture of these processes is important for guiding future large scale restoration efforts.

Keywords: Wetlands, nutrients, Cache Slough, aquatic productivity, organic carbon, phytoplankton **Session Title:** Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes **Session Time:** Thursday 3:00PM – 4:40PM Room 311-313

The Utilization of Tidal Marshes by Fishes of the Upper San Francisco Estuary

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There are only about thirty published papers that are explicitly about fishes in tidal marshes and 'shallow water habitats' of the upper San Francisco Estuary. This paucity of publications from a system that generates a lot of scientific literature undoubtedly reflects how few tidal marshes remain or are recently restoring. However, when the estuary was in its pre-1850 configuration, it probably would have been difficult to discern among 'tidal marsh fish' and 'not tidal marsh fish'. Estuarine fish habitat emerges from combinations of relatively stationary landscape features and more dynamic water quality attributes. Different fish species and life stages live and die according to vital rates that emerge from these drivers, but studies that explicitly quantify vital rates inside and outside of nominal habitat types or along habitat gradients are lacking. The primary role of tidal marsh restoration in the estuary is to increase bathymetric variability including emergent marsh plains. This restoration goal is 'co-equal' with re-establishing appropriate dynamic habitat attributes to diversify fish habitat opportunities. To re-establish some of the historical interplay between stationary and dynamic fish habitat features, tidal marsh restoration must be combined with other actions such as an appropriate freshwater flow regime to support native species.

Keywords: Native fish, tidal marsh, fish habitat
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 3:00PM – 4:40PM Room 311-313

Linking Tidal Marshes, Open Water, and Novel Ecosystems for Fish Recovery in the Upper San Francisco Estuary

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Problem: Native fishes of the upper San Francisco Estuary are a subset of the endemic and rapidly declining native fishes of California. Seven species are listed and at least 10 more could be soon. Tidal marsh restoration has been pushed as a key recovery strategy, along with floodplain restoration, improved flow regimes, and reducing effects of other stressors. However, the efficacy of tidal marsh restoration has been questioned, both in terms of its potential for improving conditions for pelagic fishes and in terms of the overall benefits large-scale tidal marsh restoration. *Approach:* I review data and literature from past and ongoing studies for fit with new insights from the conservation literature. These data and literature span the range from very local field studies of focused questions to comparing changes at the landscape and multiyear scale. *Results:* Three major areas, the south-central Delta, the north Delta, and Suisun Marsh differ in their fishes, with natives most abundant in Suisun Marsh and least abundant the south-central Delta. The entire estuary is a novel ecosystem, one irreversibly altered by humans in myriad ways and supporting a mixture of native and alien species. Such systems can be fairly stable and resilient, if environmental change is not too rapid or severe. They presumably can also manipulated to some degree to generate favorable outcomes. *Conclusions:* Actions such as tidal marsh restoration can benefit native species in Suisun Marsh and the Delta, but only if combined with regional actions such as floodplain restoration, improved flow regimes, and resolution of the most critical other stressors. The novel ecosystem context, however, means that surprises can be expected. Reconciliation ecology is recommended as a basic approach to conservation.

Keywords: tidal marsh, novel ecosystems, Suisun Marsh, Delta, reconciliation ecology, fishes
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 3:00PM – 4:40PM Room 311-313

Delta ISB Review of BDCP Documents, Particularly Regarding Reliance on Habitat Restoration

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The Delta Independent Science Board (DISB) completed its review of the draft Environmental Impact Report/Environmental Impact Statement (DEIR/DEIS) for the Bay Delta Conservation Plan (BDCP) in May, 2014. This review was required under the Delta Reform Act of 2009, and it presented a rare opportunity to provide science guidance to a very large, very complex, and (mostly) socially desired capital project. The co-equal goals of water reliability and ecosystem health, together with the "tri-equal goal" of Delta as place, all relying on "best available science", presents the regional science community with a challenge as well as opportunity.

The DISB recognized the many strengths embedded within the BDCP and its associated DEIR/DEIS, but also identified several substantive shortcomings in the technical underpinning of the analyses of project impacts and mitigation or remediation. These are summarized in our review document, but pertinent to this session is the heavy reliance on habitat restoration as an offsetting measure of project impacts. The DISB specifically stated "Many of the impact assessments hinge on overly optimistic expectations about the feasibility, effectiveness, or timing of the proposed conservation actions, especially habitat restoration". The interplay between habitat restoration and resulting ecosystem outcomes, as a mitigation for project impacts, particularly with looming alterations to the biophysical system resulting from climate change, requires more explicit attention.

Keywords: BDCP; habitat restoration; mitigation; Delta Independent Science Board; climate change
Session Title: Exploring Emergent Tidal Marsh Restoration in Suisun and the Delta for Fishes
Session Time: Thursday 3:00PM – 4:40PM Room 311-313

Using Process-Level Science on Peat Formation to Inform Wetland Restoration

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Wetland restoration in the Delta and Suisun Marsh is of key interest to increase and improve habitat for flora and fauna, particularly sensitive species. In these slightly brackish and freshwater parts of the San Francisco Estuary, both inorganic sedimentation and organic accumulation are important peat-forming processes required for marsh sustainability under sea-level rise. Several recent studies have shed light on marsh formation processes that could inform restoration decisions. In the Rates and Evolution of Peat through Time project (REPEAT), the peat column from four Delta marshes was analyzed for bulk density, organic carbon content, sediment content, and major/trace metals. Results showed that peat formation relied more on organic accumulation in marshes along low energy tributaries and more on inorganic sedimentation in marshes situated along the main channels. As part of the Computational Assessments of Scenarios of Change for the Delta Ecosystem project (CASCaDE II), modeling using the Wetland Accretion Model of Ecosystem Resilience (WARMER) showed that the rates of sea-level rise and inorganic sedimentation are key factors determining the future sustainability of marshes in the Delta. In the Waccamaw National Wildife Refuge (NWR) project, carbon sequestration rates were compared over a 40-year period in moist-soil managed (impounded) and naturally tidal marshes in South Carolina. The moist-soil managed marshes had ¼ the vertical accretion rate and less than half the carbon storage of the naturally tidal sites. A study similar to that carried out in the Waccamaw NWR is needed in Suisun Marsh to determine how naturally tidal vs. impounded marshes will fare under sea-level rise. All of these studies demonstrate that a strong understanding of soil formation processes is critical for choosing wetland restoration sites with a high likelihood of long-term sustainability.

Keywords: marsh, marsh sustainability, peat formation, sea-level rise, wetland restoration
Session Title: Estuarine Geomorphology
Session Time: Thursday 8:20AM – 10:00AM Room 314

Evaluating the Influence of Suspended Sediment Concentrations on Marsh Resiliency for Three Marsh Accretion Models in San Francisco Bay

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Planning for effective conservation and management of tidal marshes necessitates the use of predictive models to evaluate the effects of increased sea-level rise rates, sediment availability, and plant productivity on marsh resiliency. A variety of marsh accretion models have been used to develop predictions of tidal marsh response to these factors; however, current management and planning options using these models remain restricted by uncertainty of model inputs, particularly for sediment concentrations. We evaluated the influence of suspended sediment concentrations on marsh resiliency at two tidal wetlands, China Camp and Rush Ranch, using three published accretion models calibrated for San Francisco Bay: Marsh98, Wetland Accretion Rate Model of Ecosystem Resilience (WARMER), and the Marsh Equilibrium Model (MEM). We aligned as many model inputs as possible and varied century sea-level rise rates, suspended sediment concentrations, and initial elevations to examine predicted changes in marsh elevation and habitat type. As sea-level rise rates increase and suspended sediment concentrations decrease, marsh resiliency decreased and elevations shifted to low marsh or mudflat habitat across all models. Elevation trajectories were comparable between WARMER and Marsh98, while MEM projected markedly slower rates of elevation loss over time. Our results highlight the importance of collecting field-based data (e.g., suspended sediment) to improve the calibration of marsh accretion models. Differences across models highlight the need to better understand the relative roles of mineral and organic matter accumulation for marsh resiliency and to identify the particular factors that are driving these processes within each model. However, the similarities in the general trends in predictions across models demonstrates the agreement from previous studies that tidal marshes are vulnerable to sea level rise and that current suspended sediment concentrations may not be sufficient to prevent future marsh drowning. .

Keywords: tidal wetlands, marsh accretion models, sea-level rise
Session Title: Estuarine Geomorphology
Session Time: Thursday 8:20AM – 10:00AM Room 314

Sediment Flux between San Francisco Bay Shallows and Marshes

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As sea level rises, marshes accrete a combination of plant-derived material and mineral sediment imported from adjacent waters, and their ability to maintain elevation depends largely on the magnitude of sediment supply. We conducted a study for ten weeks in the winter of 2013/2014 spanning the large spring ('king') tides of December and January to investigate factors governing sediment delivery to the China Camp marsh in southwestern San Pablo Bay. We measured time series of suspended-sediment concentration (SSC), water level, and tidal currents in the subtidal shallows, on the intertidal mudflats, and in two channels within the marsh. Discrete samples for SSC were collected over the marsh plain during each king flood tide in transects perpendicular to the channels, and in cross-shore transects between channels extending landward from the Bay's edge. We observed significant sediment export during king tides in the marsh channels. Cumulative suspended sediment flux (SSF) over four days during the January king tides was approximately 10 tons/m of channel width, towards the bay. During neap tides SSF in the channels was directed landward, but was lower in magnitude. Elevated velocities in the channels during ebb king tides suggest that resuspension within the channels, rather than erosion of the marsh, accounts for much of the bayward SSF. On the marsh plain, SSC was highest at the bayward end of the cross-shore transects, indicating landward sediment flux. Taken together, our results suggest that sediment is primarily supplied to the marsh across the marsh-Bay interface, and exported from the marsh through tidal channels. These findings are relevant to the design and monitoring of restored marshes, which frequently rely on transport through breaches for sediment supply. They also indicate the importance of accounting for sediment export as well as import in modeling the response of marshes to sea level rise.

Keywords: marsh sustainability, sediment flux, suspended sediment concentration, marsh restoration
Session Title: Estuarine Geomorphology
Session Time: Thursday 8:20AM – 10:00AM Room 314

Mitigating Wave-induced Erosion with Vegetation on Breached Delta Wetlands Levees

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The breaching of Delta levees to initiate tidal wetlands restoration may expose the remaining levees to wave-induced erosion. The levees surrounding the restored area can prevent wave impacts from the restored open water from negatively impacting levees on adjacent property. Hence, restoration designs often need to consider the levee vulnerability to erosion and management actions to protect against erosion.

Based on wave modeling and vegetation monitoring on breached Liberty Island, we assessed levee vulnerability to wind-wave erosion and the capacity of vegetation to mitigate this vulnerability. The two-dimensional SWAN wave model was used to hindcast six and half years of wave conditions at tidally-inundated Liberty Island. The resulting seasonal and extreme wave climate is compared with levee erosion rates and observations of vegetation evolution quantified from ground surveys and aerial photographs.

These results characterize the relative contribution of typical and extreme wind events to wave power. Fetch and water depth are both key factors in levee vulnerability, such that levees exposed to long fetches are less vulnerable if they are fronted by intertidal mudflats that dissipate wave energy. Even at Liberty Island, where breaching was unplanned and minimal management actions have been taken, vegetation has been able to colonize and expand in areas exposed to relatively high wave power. Other studies demonstrate that similar vegetation significantly attenuates wave power, and presumably, reduces levee erosion vulnerability.

Although more information is needed, these findings suggest that the design of Delta tidal wetlands restoration could be guided by assessing levee vulnerability. Where indicated, levee vulnerability can be mitigated by grading to create dissipative bed elevations and to provide improved conditions for vegetation. By using vegetation, rather than traditional rock armoring, wave-induced erosion can be managed to minimize impacts to neighboring properties while also providing tidal marsh vegetation habitat.

Keywords: levee vulnerability, wave modeling, vegetation
Session Title: Estuarine Geomorphology
Session Time: Thursday 8:20AM – 10:00AM Room 314

Sea-Level Rise Impacts on Salt Marsh Vegetation in the San Francisco Bay Estuary

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Salt marsh plants mediate many important estuarine functions including food web support, sediment accretion and habitat provision for wildlife. While it is generally understood that species abundance, composition and productivity vary along tidal gradients, species and site-specific responses of vegetation to future sea-level rise must be quantified to assess future changes in wetland function and climate resilience. Since 2008 our team has investigated potential vegetation responses to sea-level rise (SLR) in San Francisco Bay using observational surveys, SLR modeling, and manipulative experimentation of flooding effects on plant growth. Vegetation and elevation surveys conducted at sites throughout San Francisco and San Pablo Bays showed that most marshes in the region are dominated by pickleweed (*Sarcocornia pacifica*), with additional areas dominated by *Spartina* spp. (low-elevation, high-salinity marshes) or sedges (low-elevation, low-salinity marshes). SLR modeling results using digital elevation models and estimates of long-term accretion rates from sediment cores suggests that many existing San Francisco Bay marshes will drown over the next century. Greater inundation may lead to shifts in vegetation composition or conversion to mudflat habitat. To test flooding effects on plant productivity, we are conducting an on-going manipulative SLR experiment in Petaluma marsh with *Sarcocornia*, *Spartina* and *Bolboschoenus*, three common species in the region. Preliminary results suggest that all three species show relatively high growth rates between mean high water (MHW) and mean tide level (MTL). *Sarcocornia* growth (the dominant marsh plain species throughout much of California) tended to have reduced growth at depths about 40 cm below MTL, but otherwise grew relatively well across a range of flooding levels. Our results provide species and site-specific information about coastal wetland vulnerability to SLR, information that resource managers can use to plan for restoration and management of coastal resources in changing landscapes.

Keywords: climate change, primary productivity, *Sarcocornia*, sea-level rise, *Spartina*
Session Title: Estuarine Geomorphology
Session Time: Thursday 8:20AM – 10:00AM Room 314

Estuarine Tidal Flat Evolution at Decadal and Seasonal Time Scales

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Estuarine tidal flats are rich habitats that change at seasonal and decadal time scales. Their shape and width is determined by the interplay of wind waves, tides and sediment availability. To explore the processes governing tidal flat evolution, we use a combination of observations and 1D process based modeling (Delft3D) of the tidal flat-channel system at Dumbarton Bridge in South San Francisco Bay. At the seasonal time scale, 8 interferometric sidescan sonar swath bathymetry surveys collected from December 2008 to January 2011 reveal subtle changes in tidal flat morphology. Tidal flats tended to accrete during the winter and early spring when sediment supply from tributaries is high and erode during the late spring, summer, and fall when stronger winds generate larger waves. At the decadal time scale, a series of bathymetric surveys collected approximately every 30 years from 1858 to 2005 shows that tidal flat width varied from 550 to 900 m. Width is correlated with net deposition/erosion of the entire South Bay. Tidal flats widen during periods of net sediment import and narrow during net sediment export from South Bay. Model runs with constant sediment supply and wave and tide forcing show bayward progradation of the channel margin and slow development from a flat bed towards a concave-up equilibrium within 5 years. Equilibrium consists of similar erosion and deposition rates, maintaining locally high sediment concentrations above the tidal flat. Sensitivity analysis is carried out with respect to forcing conditions and sediment characteristics. Important research questions are to what extent rare, extreme events (large wave heights) determine the bathymetric profile compared to typical conditions and whether forcing and sediment availability change to rapidly for the system to ever reach equilibrium. This study will improve assessment of possible impacts of restoration and sea level rise on tidal flats and their ecosystems.

Keywords: intertidal flats tidal modeling sediment supply equilibrium
Session Title: Estuarine Geomorphology II
Session Time: Thursday 10:20AM – 12:00PM Room 314

Hydraulic and Geomorphic Processes in an Overbank Flood Along a Gravel-Bed, Meandering, River: Implications for Chute Formation

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The hydraulic interactions between meandering rivers and floodplains produce off-channel chutes, whose presence can increase the ecological value of the valley floor. Detailed studies of the hydrologic exchanges between channels and floodplains are usually conducted in laboratory facilities, and studies documenting chute development are generally limited to qualitative observations. Here we use a reconstructed, meandering reach of the Merced River as a field laboratory for studying these ecologically significant mechanisms at a realistic scale. Using an integrated field and modeling approach, we quantified the flow exchanges between the river channel and its floodplain during an overbank flood, and identified locations where flow had the capacity to erode floodplain chutes. Hydraulic measurements and modeling indicated high rates of flow exchange between the channel and floodplain, with flow rapidly decelerating as water was decanted from the channel onto the floodplain due to the frictional drag provided by substrate and vegetation. Peak shear stresses were greatest downstream of the maxima in bend curvature, along the concave bank, where terrestrial LiDAR scans indicate initial floodplain chute formation. A second chute is developing across the convex bank of a meander bend, in a location where sediment accretion, point bar development and plant colonization have created divergent flow paths between the main channel and floodplain. In both cases, the off-channel chutes are evolving slowly during infrequent floods due to the coarse nature of the floodplain, though rapid chute formation would be more likely in finer-grained floodplains. The controls on chute formation at these locations include the river curvature, cross-stream position of the high velocity core, floodplain gradient and the density of riparian vegetation. This study illuminates the mechanisms that promote chute formation in a meandering river, with a thinly vegetated floodplain, and provides a predictive modeling framework that can be transferred to other Central Valley rivers.

Keywords: meandering, river, floodplain, chute cutoff, vegetation, modeling, restoration
Session Title: Estuarine Geomorphology II
Session Time: Thursday 10:20AM – 12:00PM Room 314

Subsurface Flow through a Gravel River Bar: Physical Controls to Suitable Spawning Habitat for Chinook Salmon (*O. tshawytscha*) in the San Joaquin River Basin

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Shallow alluvial aquifers beneath river channels have distinct hydrologic and geomorphic characteristics whose variability determines the extent of suitable spawning habitat for Chinook salmon (*O. tshawytscha*). We investigate how bedform morphology and heterogeneity of hydraulic conductivity affect patterns of subsurface flow through gravel bars, the magnitude and extent of infiltration and seepage, and the residence time distribution when surface water stage varies with flow releases in select gravel bed reaches of the San Joaquin River Basin, CA. We measured *in situ* hydraulic conductivity, interstitial pore water temperature in Artificial Redds, and near-bed temperature. We then quantify bedform-flux interactions using high-resolution derived terrain, discharge information measured at multiple gauging sites, and climate information in distinct bar-bend reaches to inform and evaluate a two-dimensional subsurface hydrologic model in channel bedforms where the spatial distribution of hydraulic conductivity is measured *in situ*. Field and modeling results show that (1) riffle-pool asymmetry is a key control to the extent and magnitude of infiltration, (2) riffle-pool channels may be recharge-limited, constituting as little as 15-20 percent of the length of the riffle during low flows, and (3) the magnitude of infiltration fluxes is greatest during low flows rather than high flows. The areas of most active recharge exhibit the lowest hydraulic conductivities, impregnated with sand after a flood. Intragravel temperature patterns are controlled by infiltrating surface water temperatures where streambed water fluxes are high. Where recharge is limited, the role of bed conduction may be significant. These results suggest that management through flow modification can alter flow and thermal conditions in the hyporheic zone, however, streambed morphology, the presence of sand, and the systematic downstream coarsening of the surface layer due to the genesis of gravel bars are primary controls to the variability of intragravel flow and temperature critical to *O. tshawytscha* early life stages.

Keywords: subsurface flow, river, gravel bars, physical, habitat, hyporheic flow, salmon
Session Title: Estuarine Geomorphology II
Session Time: Thursday 10:20AM – 12:00PM Room 314

Effects of Human Alterations on the Hydrodynamics and Sediment Transport in the Sacramento-San Joaquin Delta, California

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The Sacramento-San Joaquin Delta, California, (Delta) has been significantly altered since the mid-nineteenth century. Many existing channels have been widened or deepened and new channels have been created for navigation and water conveyance. Tidal marshes have been drained and leveed to form islands that have subsided. All of these islands have flooded temporarily due to levee breeches; however, the levees of a few islands have never been repaired and are considered to be permanently flooded. To understand how these alterations have affected hydrodynamics and sediment transport in the Delta, we analyzed measurements from 27 sites, along with other spatial data, and previous literature. Results show that (a) the permanent flooding of islands results in an increase in the shear velocity in channels downstream, (b) artificial widening and deepening of channels generally results in a decrease in shear velocity except when the channel is also located downstream of a flooded island, (c) 1.5 Mt/yr of sediment was deposited in the Delta (1997-2010), and of this deposited sediment, 0.31 Mt/yr (20%) was removed through dredging.

Keywords: sediment transport, dredging, tidal prism, sediment budget, shear velocity
Session Title: Estuarine Geomorphology II
Session Time: Thursday 10:20AM – 12:00PM Room 314

Exploring the Complex Couplings between Environmental Drivers and Greenhouse Gas Exchange in Restored Delta Wetlands

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Restoring agricultural areas to wetlands in the Sacramento-San Joaquin River Delta of California can help reverse subsidence and reduce greenhouse gas (GHG) emissions. Some or all of the costs of wetland restoration can be recouped by selling the generated carbon credits on emerging markets. Determining financial feasibility and developing best management practices of wetland restoration in this regard therefore requires a robust understanding of the sensitivity of GHG exchange in these ecosystems to factors such as management and meteorology. However, developing this understanding is no small feat. Wetlands can exhibit complex, overlapping, and asynchronous couplings between site characteristics, environmental drivers and GHG exchange. Sophisticated tools are needed to disentangle and characterize these couplings so that they can be effectively modeled. In this research we use the combination of wavelets and information theory to explore interactions between environmental drivers and GHG exchange (CO_2 and CH_4 exchange measured by eddy covariance) from hourly to monthly time scales in two restored Delta wetlands. Despite differences in age and architecture, CO_2 exchange at both wetlands was similarly sensitive to meteorological conditions up to a time scale of several days. At the monthly timescale, however, the effects of a more variable water table management at one wetland became apparent. Relatively large and prolonged drops in water table resulted in a reduction in net CO_2 uptake. The same analysis applied to CH_4 exchange revealed a more sensitive and complex coupling with water table management. CH_4 exchange was sensitive to even small, multi-day shifts in water table and displayed a lagged response to larger shifts. With these methods we were able to disentangle the effects of management from meteorology, and better understand how site age and architecture influence the sensitivities of GHG exchange. Our results provide important insights for modeling efforts and management practices.

Keywords: carbon sequestration, wetland management, gas flux, restoration, methane, carbon dioxide
Session Title: Estuarine Geomorphology II
Session Time: Thursday 10:20AM – 12:00PM Room 314

Yolo Bypass Widening into the Elkhorn Basin: A Multi-Benefit Opportunity for Flood Control, Floodplain Habitat and Fish Passage

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Large scale projects addressing flood control, seasonal floodplain habitat and fish passage needs are critical for the survival of threatened salmonids in the face of climate change and a growing California population. Local agencies in the Sacramento region and the State of California are collaborating on a feasibility study of widening the Yolo Bypass into the Elkhorn Basin. The Elkhorn Basin is bordered by the Sacramento River to its north and east, the Yolo Bypass to its west, and the Sacramento Weir bypass to its south. Given its location and existing topography, the Elkhorn Basin presents a significant opportunity for flood relief, increasing floodplain habitat and enhancing fish passage. Initial hydraulic analyses demonstrate that degrading and setting back existing levees in the Elkhorn Basin could generate as much as 1,830 acres of floodplain habitat inundated for at least 2 weeks every 2 of 3 years between December 1st and May 15th. In addition to providing habitat for juvenile salmonids in winter and spring months, this additional floodplain area could provide a seasonal habitat for waterfowl and a net primary production export to the Delta via the Yolo Bypass. A preliminary 2-D hydrodynamic modeling of a coupled Elkhorn Basin and Yolo Bypass system has been developed to assess floodplain inundation and habitat conditions, flood attenuation, and agricultural impacts. Finding a solution that maximizes ecological benefits while also meeting flood relief goals, agricultural needs, and economic constraints will require creative collaboration among agency staff, landowners, non-profits and engineering firms to determine specific project objectives, site design, an operation regime, and compensation schemes for farmers creating fish habitat.

While it is shown that the ecological benefits are clearly substantial, gaining stakeholder buy-in is critical given the agricultural, economic and flood protection consequences of the considered project and this process is outlined.

Keywords: Yolo Bypass, Flood Control, Fish Passage, Fish Habitat, Ecology, Hydraulics
Session Title: Flood Management
Session Time: Thursday 1:00PM – 2:40PM Room 314

An Integrative Approach to Modeling Effects of Reactivation of River Migration on Aquatic and Floodplain Habitats

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As part of implementing the Central Valley Flood Protection Plan, the Department of Water Resources seeks to enhance natural dynamic geomorphic processes in the flood management system to increase flood conveyance, thereby reducing downstream flood risks. One possible strategy is expansion of floodway corridors, which would ideally have ancillary benefits to aquatic and terrestrial habitats of listed species, particularly rearing habitat for juvenile salmonids. We modeled the potential effects of reactivated river migration associated with hypothetical revetment removal and levee setbacks along the middle Sacramento River on habitat suitability of Chinook salmon and Central Valley steelhead. For the sites considered (each approximately 3 river-miles in length), meander migration processes were initially modeled to forecast likely future channel positions following the hypothetical management action. We then employed the Standard Assessment Methodology (SAM) to assess potential changes in near-shore and floodplain aquatic habitat for the special-status fish species resulting from the forecasted river migration. The SAM, originally developed by Stillwater Sciences for the U.S. Army Corps of Engineers, evaluates habitat suitability based on the fish species' understood sensitivities to six habitat parameters: bank slope, floodplain availability, bank substrate size, instream wood, aquatic vegetation, and riparian shade. The analysis required enhanced approaches in order to incorporate the one-dimensional meander-migration results and interpret associated riverine processes, including change in channel position and profile, point-bar development, riparian forest succession, and woody material recruitment. Our results generally reflect large increases in habitat value due to more suitable bank-cover conditions (i.e., habitat quality) and greater channel dimensions (i.e., habitat quantity) associated with the predicted reactivated channel migration. The analysis thus demonstrates the use of a new framework within which future SAM analyses of a dynamic channel state may reasonably follow, and provides initial confirmation that expansion of the river floodway will potentially improve aquatic habitat conditions.

Keywords: Sacramento River, aquatic habitats, ecosystem restoration, flood management, modeling
Session Title: Flood Management
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Background Quality of Delta Island Soil and Ground Water and the Implications for Reusing Dredged Sediments

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Annual maintenance dredging of the deep water ship channels produces 100+ thousand cubic yards of sediment each year, the proposed deepening of the Sacramento and Stockton channels could produce 50+ million cubic yards, and the twin tunnel project is likely to produce several 10s of millions of cubic yards. Dredged sediments are a public asset, yet, there are several regulatory and administrative impediments to beneficially and cost effectively reuse these sediments and the potential impacts of placing dredged sediments on the Delta Islands are poorly understand. Furthermore, the Water Board considers dredged sediment to be a waste and incorrect assumptions about the quality and impact of dredged sediments persist. We have performed several studies that characterize the quality of dredged sediment and provide a reasonable understanding of the background geochemical quality of three Delta Islands - Sherman, Twitchell, and Brannan Andrus. This information allows the potential effects of reusing dredged sediments to be put into proper perspective with the background quality of these three Delta Islands. In short, the data show that, overall, dredged sediments reused in an upland environment pose little to no risk to the quality of soil and ground water, and are more likely to improve the overall quality. In addition, this talk will identify some important regulatory, permit, administrative, and bureaucratic inefficiencies to reusing dredged sediment along with potential solutions.

Keywords: Sediment Groundwater Reuse Dredge
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Post-Cyclic Behavior of Sherman Island Peat

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Seismic risk is a significant issue for the Sacramento / San Joaquin Delta because levees are composed of saturated, often liquefiable soils that rest atop soft compressible peaty organic soil. A moderate earthquake on one of the faults in or near the Delta is anticipated to cause multiple simultaneous levee breaches, resulting in inundation of multiple islands and intrusion of saline water. Liquefaction of levee fill soil is a well understood problem and a significant driver of seismic risk in the Delta. Much less is currently understood about the engineering properties of the peat soils that underlie many levees. Our hypothesis is that peat soils may contribute to levee settlement, and we have performed a laboratory investigation of the peat soils to study this behavior. A direct simple shear device at UCLA has imposed cyclic straining on peat samples gathered from the subsurface at Sherman Island, and development of excess water pressure in the peat and the post-cyclic settlement of the peat has been measured. Test results reveal that excess pore water pressure builds up and post-cyclic volume change develops when shear strain amplitude is greater than 1%. This is important since shear strains higher than this level would be anticipated for a moderate magnitude earthquake in the Delta. In addition to settlement associated with expulsion of excess water pressure, peat exhibits continued settlement over time called secondary compression. Our study has identified that the secondary compression clock is partially or even completely reset by cyclic straining, which would translate to an increase in the rate of settlement of levees that survive strong shaking during an earthquake, potentially resulting in loss of freeboard. We anticipate that our results will provide more realistic seismic risk assessments in the future, and will help guide policy decisions in the Delta.

Keywords: Levees, Sherman Island Peat, Earthquake, Settlement
Session Title: Flood Management
Session Time: Thursday 1:00PM – 2:40PM Room 314

Subsidence and Levee Movement in the Sacramento-San Joaquin Delta: Application of Radar Imaging to a Region-Wide Levee Assessment

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Land subsidence in the Sacramento-San Joaquin Delta poses a serious challenge to maintaining the local ecosystem and the integrity of the state's water supply. Subsidence in and near the levees reduces levee freeboard, increases hydrostatic load on the levees, and can induce various problems that could cause levee failure. In the Delta, a complex host of causes drive sub-island-scale subsidence, including aerobic oxidation, consolidation, shrinkage, anaerobic decomposition, wind erosion, resource withdrawal, and dissolution of soil organic matter. The variety of subsidence mechanisms and the hetereogenity of Delta soils make it difficult to uniquely characterize levee-scale deformation across this dynamic landscape. Here we report on an ongoing study to determine current-day subsidence rates across the Sacramento-San Joaquin Delta using data from NASA's UAVSAR L-band radar platform acquired at ~6 week intervals during 2009-2014. In this presentation, we focus specifically on the levees, using high resolution (~7 m ground resolution) radar remote sensing to resolve the levees from the surrounding area. We report preliminary analyses that suggest various specific spatial patterns of subsidence can be identified and quantified: We found that there is increased land subsidence and surface deformation on and near levee segments subsequent to repairs; general differential levee subsidence that affects sections of levees and island interiors that have not undergone recent repair; and specific other land-side and water-side slope instabilities. We observe that consolidation from material addition causes compaction to be the main contributor following levee repair in some, but not all, areas. We also found that general subsidence can induce changes to the levees and, conversely, levee repair can induce subsidence a substantial distance inland from the directly loaded section. This information is of value to both risk management associated with levee maintenance and to long-term plans for providing a more reliable water supply for California.

Keywords: Sacramento-San Joaquin Delta, levees, subsidence, radar remote sensing, UAVSAR
Session Title: Flood Management
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Predation in the North Delta: Tales from the Digestive Goo

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Predation in the Sacramento-San Joaquin Delta has been identified as a major stressor to declining native fish populations. While predation is a universal process for biota of nearly all trophic levels, a primary concern for native fishes in the Delta is that predation pressure from introduced, highly effective predators such as Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*), and Smallmouth Bass (*Micropterus dolomeiu)* may limit population recovery or even exacerbate species declines. We investigated predation patterns in the North Delta, a region that is heavily used by many native species for rearing and migration. To elucidate predation patterns, we sampled predator populations in 2012-2014 via gill netting in different habitats and migration corridors in the North Delta commonly used by native fish. Targeted non-native predator species, as well as the native Sacramento Pikeminnow (*Ptychocheilus grandis*), had their digesta removed and screened for the presence of 14 prey species of interest using genetic assays. A single target prey species was found in 17-50% of predators, depending on the predator species, and multiple prey species were detected in 15% of predators. Striped Bass were the most commonly sampled predator (~54% of catch), with common prey being Threadfin Shad (*Dorosoma petenense*), Sacramento Pikeminnow, and Mississippi Silverside (*Menidia beryllina*). Among non-Striped Bass predators, Striped Bass was the most commonly detected prey item, comprising 22% of detections. Understanding patterns of predation on native fish populations, and the environmental parameters correlated with increased predation, is critical for being able to manage and restore the Delta for native fish species.

Keywords: Predation, Invasive Species, North Delta, Genetics
Session Title: Innovative Approaches in Assessing Non-Native Predators and Predation in a Modified System
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Predator Densities and Associated Salmonid Smolt Mortality around Water Diversions

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State-of-the-art fish screens on large water diversions effectively prevent juvenile salmon from being entrained by the diversion, but the physical structure and their prey-concentrating effect may attract predators and create a local predation problem. We are assessing the impact of predation near two large diversions on juvenile Central Valley Chinook salmon (*Oncorhynchus tshawytscha*) using a combination of acoustic telemetry, a DIDSON camera, and tethering. We expect to answer these questions:

(1) Is predator density higher near water diversions relative to nearby areas?
(2) Do predators express site fidelity to the diversions?
(3) Is the relative smolt predation rate near the diversions higher than nearby areas? What about seasonal and diel predation rate dynamics?
(4) What proportion of the predators' diets consists of smolts near the diversions?
(5) All factors combined, does this result in higher than average smolt mortality rates near the diversions?

During a pilot season in 2011 on one diversion on the Sacramento River, we gained limited insight into these questions. Predator densities were lowest near the diversion, and highest near the riverbank. Striped bass (*Morone saxatilis*) did not seem to express site fidelity while Sacramento pikeminnow (*Ptychocheilus grandis*) did. Finally, relative predation rates around the diversion were near average, with the highest relative predation rates near the riverbank.

In the 2012 and 2013 seasons, we added a second diversion representing a different design model, allowing the comparison of predator-prey dynamics between different commonly-used diversion designs. We will present data from the more intensive second and third seasons.

This project was conceived in response to the knowledge gap regarding how large water diversions influence predator-smolt dynamics; the majority of research on the impacts of diversions on salmonids concentrate on dewatering and lethal entrainment into pumps.

Keywords: water diversion, predation, salmon, smolt, striped bass, Sacramento, pikeminnow
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Making the Connection between Fish Predation Hot Spots and Regional Hydrodynamics

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Based on the literature review and presentations at the 2013 State of the science workshop on fish predation on Central Valley salmonids in the Bay-Delta Watershed (July 2013; www.dfg.ca.gov/erp/predation.asp), we identified predation hot spot locations throughout the Delta. We superimposed these hot spots on a map with additional knowledge of circulation patterns of the Delta, transport timescales, and the connection between channels to identify six distinct regions of the Delta. We then hypothesized predation risk from low to moderate to high for each region. In this regional assessment, it is clear that anthropogenic structures (e.g. gates, bridge piers), bathymetry, channel connections, hydrodynamics, both tides and freshwater input, and operations are all key controlling physical factors for the locations of predation hot spots. In this talk, we will discuss the physical factors contributing to predation hot spots in each of the six regions and discuss some engineering design criteria that should be considered when modifying existing facilities, such as Clifton Court Forebay.

Keywords: fish predation, hydrodynamics, predation hot spots, operating structures, bathymetry
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Interactive Effects of Habitat Alterations and a Non-Native Predator, Striped Bass, on Native Juvenile Salmon Mortality

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Human stressors are leading causes of declines in species and biodiversity driving wide scale ecosystem changes. Additionally, multiple human stressors, including non-native species and habitat alterations, can interact with complex consequences on native species. Human-modified habitats can change non-native predator functional and aggregative responses with additive impacts on native prey species. We assessed how the non-native predator, striped bass (*Morone saxatilis*), and habitat alterations (small diversion dam and other altered habitats) interact to influence mortality on native juvenile Chinook salmon (*Oncorhynchus tshawytscha*) migrating to sea on the lower Mokelumne River, CA (USA). Striped bass relative abundance and diet surveys across natural and human-altered habitats assessed functional and aggregative responses of striped bass. Striped bass showed elevated per capita consumption of juvenile salmon and behavioral aggregation (estimated as catch per unit effort – CPUE) at a small diversion dam site (Woodbridge Irrigation District Dam: per capita consumption= 3.54 juvenile salmon and CPUE= 0.189) over other altered (0 juvenile salmon; CPUE= 0.0024) and natural habitats (N/A; CPUE= 0.0003) creating a localized area of heightened predation. At this predation hotspot, experimental predator removals, diet energetic analysis, and before-after impact assessment estimated striped bass consumption of the population of out-migrating juvenile salmon to be between 10-29%. Striped bass per capita consumption rates among the three approaches were 0.92%, 1.03-1.55%, and 0.96-1.11% respectively. This study highlights how interactions between multiple stressors can exacerbate consequences for native species and are important to examine when predicting ecological impacts from stressors and planning local management strategies.

Keywords: predation, striped bass, juvenile salmon, predator removal, diversion dam, interactions
Session Title: Innovative Approaches in Assessing Non-Native Predators and Predation in a Modified System
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Using a Predator Density Manipulation Study to Quantify Salmon Smolt Predation in the San Joaquin River

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Telemetry studies that track downstream migration and mortality of salmonids in the Central Valley have demonstrated high mortality rates (80-99%) during emigration through the freshwater and estuarine portions of the watershed. In recent years, estimated survival rates for juvenile Chinook salmon in the lower San Joaquin River declined to approximately 5%, despite increased river flows and reduced spring water exports. The hypothesized cause of these low survival rates is a combination of factors that includes piscine predation by non-native species. Although predation has been suggested as a major cause of salmon smolt mortality, there is insufficient research in the San Joaquin Delta to rigorously evaluate this hypothesis. For a relatively-defensible consideration of potential management actions, more studies are needed to quantify predator density, movement, and predation rates, as well as examine how environmental and anthropogenic factors interact to influence predation of salmon smolts. To address this research need, a predation study is underway in the San Joaquin River in collaboration with the DWR, DFW, USFWS, USGS and USBR. This study revolved around a predator density manipulation in nine 1-km river reaches (3 control; 3 predator removal; 3 predator addition). Effects were assessed before/after manipulations with 1) release of >3000 acoustically tagged Chinook salmon and steelhead smolts, 2) capture/release of acoustically tagged piscine predators (striped bass, largemouth bass, channel catfish, and white catfish), 3) quantification of relative salmon smolt predation using drifting tethered smolts in each of the study reaches, 4) quantification of predator density and fish habitat using hydroacoustic imaging, 5) determination of prey items using genetic analysis of predator stomach contents, and 6) species diversity and abundance surveys. A total of 1,531 predators were captured and removed/relocated from 37hr of electrofishing. Preliminary results for each of the study components will be presented and future work will be outlined.

Keywords: Predator, salmon, smolt, San Joaquin River
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